

GROUNDWATER GOVERNANCE IN THE MIDDLE EAST AND NORTH AFRICA

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Groundwater governance in the Arab World

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Table of contents

Foreword.....	9
Section 1. Groundwater governance in the MENA region	
Part 1. Groundwater resources, use, and governance in the MENA region	
1 Morocco.....	13
1.1 Groundwater resources and abstraction in Morocco	13
1.2 Legislation to regulate groundwater abstraction in Morocco.....	16
1.3 Enforcement difficulties and perverse incentives	18
1.4 The 'Aquifer contract' as a groundwater regulatory tool in Morocco	20
1.5 Groundwater abstraction in the Souss Region, Morocco	21
1.5.1 Groundwater management and the 'contrat the nappe' in the Souss	21
1.5.2 Groundwater development in the Upper Souss Basin	23
1.6 Traditional irrigation and groundwater abstraction systems in Morocco	25
1.7 Groundwater user strategies in Morocco	29
2 Algeria.....	30
2.1 Groundwater resources and abstraction in Algeria	30
2.2 Groundwater regulations	31
2.3 Groundwater abstraction in the Mitidja plain, Algeria	32
2.4 Traditional groundwater abstraction systems in Algeria	33
2.5 Land, inequality and groundwater abstraction in Ouarizane	33
3 Tunisia.....	34
3.1 Groundwater resources in Tunisia.....	34
3.2 Groundwater management and regulation in Tunisia	36
3.3 Groundwater overexploitation in Tunisia.....	38
3.4 Measures to curb groundwater use in Tunisia	40
3.5 Tunisia's model of decentralized groundwater management	42
3.6 Authorizations and enforcement	44
3.7 Groundwater in the Merguellil basin, Tunisia.....	45
3.8 Groundwater management in Tunisia's oases	48
4 Libya	49
4.1 Groundwater resources in Libya.....	49
4.2 Groundwater abstraction in Libya	49
5 Egypt.....	50
5.1 Groundwater resources in Egypt.....	50
5.2 Groundwater regulation in Egypt.....	51
5.3 Groundwater abstraction in the Nile delta	52
5.4 Groundwater abstraction in the Western Desert, Egypt.....	53
5.5 Egypt's new reclamation plans for the Western Desert.....	56
6 Sudan.....	57
6.1 Groundwater in Sudan.....	57
6.2 Groundwater-fed irrigation in Northern Sudan	58
7 Lebanon	59

7.1	Groundwater resources and abstraction in Lebanon.....	59
7.2	Groundwater use in the Bekaa Valley	60
7.3	Groundwater regulation and development in Lebanon.....	61
8	Syria.....	63
8.1	Groundwater resources and abstraction in Syria.....	63
8.2	Regulation of groundwater abstraction and wells in Syria	64
8.3	Perverse incentives for agriculture leading to groundwater over-abstraction.....	65
8.4	Traditional groundwater management systems in Syria.....	66
9	Jordan	66
9.1	Groundwater resources and abstraction in Jordan.....	66
9.2	Groundwater abstraction in Azraq	69
9.3	Groundwater regulation in Jordan	71
9.4	Traditional groundwater management in Jordan	75
10	Yemen.....	76
10.1	Groundwater resources and abstraction in Yemen	76
10.2	The development of groundwater abstraction in Yemen	76
10.3	Groundwater management policy and regulation in Yemen	78
10.4	Traditional groundwater management systems and their recent evolution in Yemen.	80
10.5	Community management of groundwater resources in Yemen.....	81
11	Saudi Arabia	82
11.1	Groundwater resources in Saudi Arabia.....	82
11.2	Groundwater regulation in Saudi Arabia.....	83
11.3	Expansion of groundwater abstraction in Saudi Arabia	84
12	Bahrain.....	85
12.1	Groundwater resources and abstraction in Bahrain	85
12.2	Groundwater regulation in Bahrain.....	86
13	Oman	88
13.1	Groundwater resources and abstraction in Oman.....	88
13.2	Groundwater regulation in Oman	88
13.3	Traditional methods for collecting groundwater in Oman.....	89
14	Iran	91
14.1	Trends in groundwater development.....	91
14.2	Regulation of groundwater use	92
15	Turkey.....	93
15.1	Current groundwater use and general management framework.....	93
15.2	Groundwater Irrigation Cooperatives	95

Part 2. Analysis

1	Groundwater development in the Middle East and North Africa.....	100
2	The role of the state in groundwater management.....	100
2.1	The state and groundwater development in the Arab world	100
2.2	State legislation and regulation of groundwater abstraction: a panoply of policy tools	102
2.2.1	Controlling well expansion.....	103
2.2.2	Controlling and reducing abstraction in existing wells	107

2.2.3	Supply-side measures	110
2.2.4	Government-led participation and attempted groundwater management decentralisation.....	114
2.3	Effectiveness of state action in groundwater regulation	118
2.3.1	Enforcement weaknesses	118
2.3.2	Administrative and organizational regulation of groundwater abstraction.....	120
2.3.3	The role of international donors in water management: the example of Yemen	122
2.3.4	Perverse incentives for agriculture and irrigation	123
2.3.5	The state, vested interests, and groundwater management	124
2.4	Public policy outcomes and user responses to groundwater depletion	129
2.4.1	Expansion, coping with groundwater depletion, or exiting the system	129
2.4.2	Cooperation and conflicts between users and with the state.....	131
3	Community groundwater management in the Arab World	134
3.1	Traditional groundwater management structures in the Arab world.....	135
3.2	Community management of wells in Moroccan and Tunisian oases.....	135
3.3	Community management in Yemen and its limits	136
4	A typology of wells in the Arab World	138
5	Trajectories of conjunctive surface and groundwater interaction.....	142
6	References	145
7	Annex 1.....	162
7.1	Groundwater resources in Yemen.....	162
7.2	Groundwater politics and policies in Yemen.....	164
7.2.1	Groundwater development in Yemen before unification in 1990	164
7.2.2	Groundwater policy and management after 1990	165
7.2.3	Groundwater management and Yemeni politics after the 2011 revolution	169
7.2.4	Legal pluralism and water management	171
7.2.5	Failed decentralisation through local councils and water basin committees	172
7.2.6	The role of the international community in water management in Yemen.....	175
7.3	Groundwater, power, and vested interests in Yemen	176
7.3.1	Corruption, political power networks, and vested interests in Yemen	177
7.3.2	Qat, politics, and groundwater in Yemen	181
7.4	Community and groundwater management in Yemen.....	185
7.4.1	Community management rules	185
7.4.2	Conflict resolution mechanisms.....	185
7.4.3	Dismembering local traditions.....	187
8	Annex 2.....	189
8.1	The state and political systems in the Arab world	189
8.2	Characterizing the Arab State.....	190

Figures

Figure 1. Project case studies and cases reviewed for the project.....	10
Figure 2. Groundwater over-abstraction in Morocco (a) and water table declines in the Haouz and Saiss Plains, Morocco (b).....	14
Figure 3. Main aquifers in Morocco.....	15
Figure 4. The Souss aquifer in Morocco.....	22
Figure 5. Diagram of a khattara/qanat	24
Figure 6. Effects of modern groundwater abstraction technology on traditionally irrigated areas in Ouled-Berrhil between 1970 and 2005.....	25
Figure 7. Schematic of a typical irrigation system in Figuig.....	27
Figure 8. The Figuig Oasis, Morocco	28
Figure 9. The Mitidja plain, sub-basins and the aquifer	32
Figure 10. Shallow and deep aquifers in Tunisia	35
Figure 11. Water resources and infrastructure in Tunisia	36
Figure 12. Evolution of density of wells in Dar Chichou, Cap Bon in 1951-1989.....	39
Figure 13. Evolution of four piezometers in Haouaria, Cap Bon (1972-2007).....	40
Figure 14. The Merguellil Basin and groundwater over-abstraction in the Kairouan plain	47
Figure 15. Depth to water level in Misratah (northern coast) and in Kufra (South-eastern desert), Libya	49
Figure 16. Main aquifers in Libya	50
Figure 17. Major aquifer systems in Egypt	51
Figure 18. Groundwater withdrawals in the Kharga area, West Desert, Egypt.....	55
Figure 19. Centre pivots in East Oweinat, Egypt, near the border with Sudan (Western Desert) 55	
Figure 20. Egypt’s land reclamation plans and desert oases.....	57
Figure 21. Changes in groundwater levels in the Central Beqaa (1970-2010).	61
Figure 22. Total irrigated area, groundwater irrigated area, and number of wells in Syria (1981-2009).....	64
Figure 23. Groundwater basins in Jordan	67
Figure 24. Groundwater production volumes in Jordan (2003)	68
Figure 25. Groundwater abstraction per sector in Jordan	69
Figure 26. Year of well installation in Azraq	70
Figure 27. Spring discharge and groundwater pumping levels for drinking water supply in Azraq	70
Figure 28. Piezometric levels in Azraq (1985-2013) and increase in salinity in one sample well..	71
Figure 29. Yemen’s main aquifers.....	78

Figure 30. Principal aquifers in Saudi Arabia	83
Figure 31. Wheat production and imports in Saudi Arabia	84
Figure 32. Historical groundwater abstraction from the Saq-Ram Aquifer by Saudi Arabia between 1975 and 2007.....	85
Figure 33. Groundwater level decline in the Ram Aquifer in the South Wadi Araba Basin	85
Figure 34. Bahrain’s groundwater abstraction	86
Figure 35. Annual production of desalinated water and groundwater abstraction in Bahrain	87
Figure 36. Growth of tubewells, irrigated cereal yields, and cultivated area in Iran	92
Figure 37. Use of surface and groundwater in Iran	93
Figure 38. Main aquifers in Turkey	94
Figure 39. Groundwater use by sector in Turkey.....	95
Figure 40. Evolution of groundwater-irrigated land area.....	96
Figure 41. Evolution of salinity in a recharge site in Korba, Cap Bon, Tunisia, before and after 3 years of recharge.....	112
Figure 42. Seawater desalination capacity installed in the Arabian peninsula (in 2008)	114
Figure 43. Timeline of events in Syria	133
Figure 44. Processes of community groundwater management.....	135
Figure 45. A simplified groundwater well typology for the Arab World	138
Figure 46. General evolution of well use for groundwater abstraction	139
Figure 47. Cumulative disbursement for Yemen’s water sector support project committed amount (original and actual amounts).....	176
Figure 48. Power circles and nepotism structure in Yemen during Saleh’s rule	180
Figure 49. Share of qat cultivation in agriculture areas in Yemen.....	184
Figure 50. Conflict resolution in the Ya’fa tribes	187

Tables

Table 1. Main legislation enacted in Morocco to regulate groundwater	18
Table 2. Water pricing according to groundwater abstraction levels for private agricultural wells in Jordan	72
Table 3. Legislation regulating groundwater in Jordan	74
Table 4. Number and discharge of groundwater resources (Year 2006-2007)	91
Table 5. Groundwater use in Arab countries.....	100
Table 6. Groundwater management and policy instruments, tools, and areas of implementation in the Arab world.....	103
Table 7. Groundwater regulation tools for agriculture in selected Arab countries	119
Table 8. Incentives for irrigation in Arab countries	124
Table 9. A general typology of wells in the Arab World	141
Table 10. Surface and groundwater trajectories	143
Table 11. Comparative of groundwater recharge estimates.....	163
Table 12. Comparative of basin recharge estimates	163
Table 13. Yemen's 2002 Water Law selected articles on water and groundwater	167

Boxes

Box 1. The oasis of Figuig in Morocco.....	26
Box 2. The <i>Marqum</i> , a consensus-building document for groundwater management in the Northern Highlands, Yemen	82
Box 3. Decentralization in the Arab World	117
Box 4. Local institutions and communities in Jordan	127

Foreword

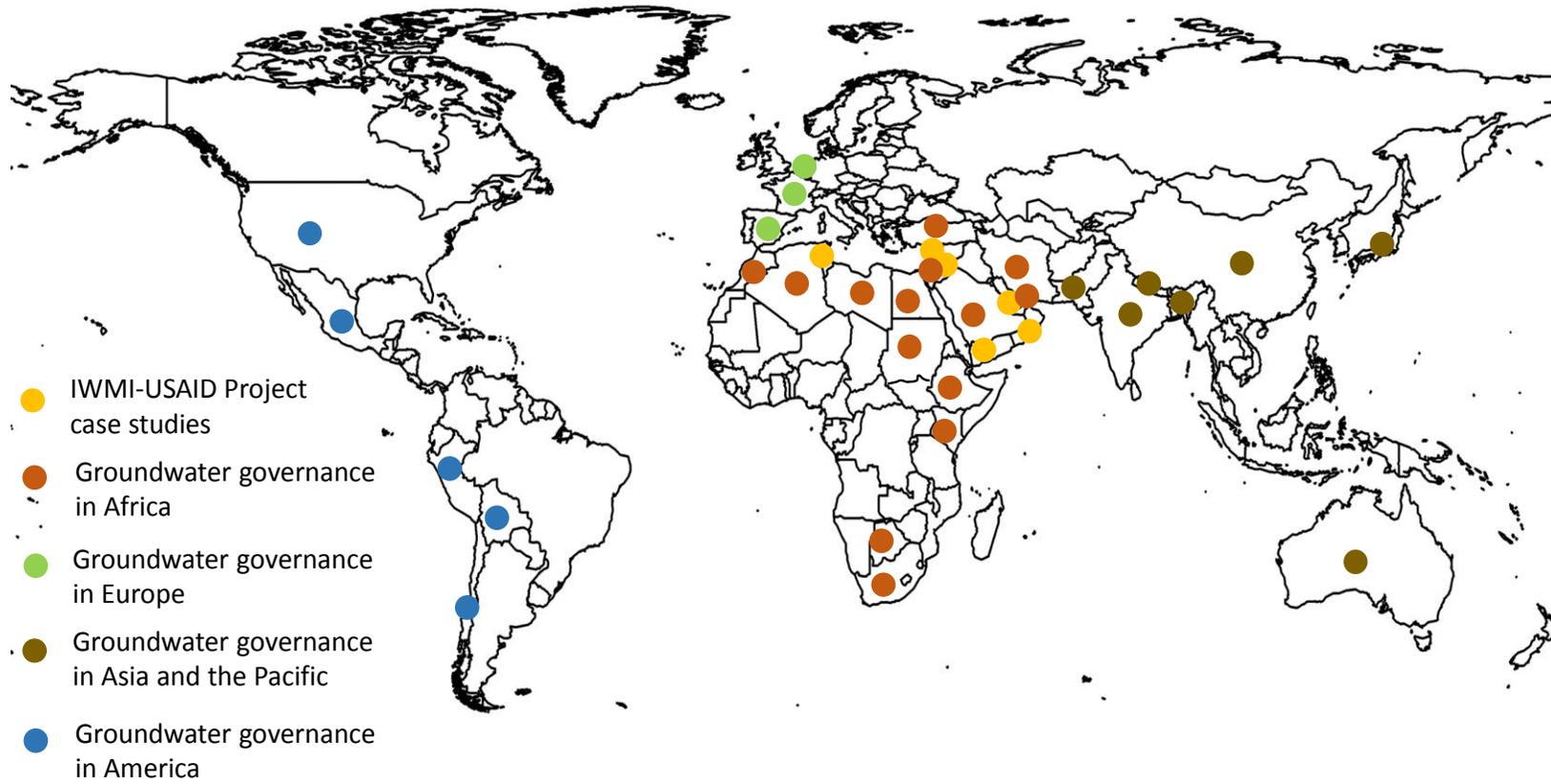
This report on groundwater governance in the Middle East and North Africa is part of a series of four regional reports arising from a research initiative undertaken by the International Water Management Institute (IWMI) and funded by USAID aiming to address the challenges posed by the unsustainable use of groundwater in the Middle East and North Africa (MENA) region (Figure 1). Groundwater over-abstraction is a phenomenon threatening the sustainable economic and social development of the countries on the southern side of the Mediterranean and the control and management of over-abstraction has become a clear challenge for policy-makers, managers and academics in the region. This broader research exercise is aimed at presenting different governance problems and challenges that exist around the world regarding groundwater and inform potential future management and policy pathways in the MENA region.

The reason for this report on groundwater governance in the MENA region arises out of the necessity to examine, at various scales, existing cases of groundwater regulation and management so that policy discussions, effective solutions, and mitigation measures to the groundwater crisis may be found. The countries reviewed in this section are Morocco, Tunisia, Algeria, Libya, Egypt, Sudan, Jordan, Lebanon, Syria, Bahrain, Saudi Arabia, Yemen, Oman, Turkey, and Iran. The report analyses, through a political, regulatory, and historical lens, the different groundwater regulatory tools, reflecting on the different laws, regulations, community actions, and institutional structures found in the different countries in order to curb groundwater over-abstraction.

Although this report does not attempt to be exhaustive as it is based on existing and accessible literature, it offers a number of analytical and factual elements on groundwater governance presented in an original way. Semi-arid and arid countries are understandably more likely to (over)exploit their groundwater resources and the lessons drawn from the situation in other arid areas with different political economies, can potentially be very relevant for the MENA region as they may indicate potential solutions or -more often than not- flag the dangers or irrelevance of certain standardized, or seemingly desirable, policies. Thus, the examples studied here can provide a deeper understanding of the challenges countries in the MENA region face when it comes to reducing groundwater abstraction, echoing some of the attempts to regulate groundwater abstraction made by other states in the region.

The results and failures faced by governments and communities can also represent relevant insights when it comes to enforcing regulation or understanding legal barriers to policy implementation, all relevant and important lessons for other countries. Reflecting on a wealth of background stories and experiences will also provide a richer understanding and diversity of insights to these problems, what worked and did not work. The gravity and complexity of the situation require a systematic and wide-ranging approach building on existing knowledge and practices in and beyond the region, so that innovations in groundwater regulation and legislation can be found and the groundwater depletion trend averted.

Figure 1. Project case studies and cases reviewed for the project



Groundwater governance in the MENA region

Part 1. Groundwater resources, use, and governance in the MENA region

1 Morocco

1.1 Groundwater resources and abstraction in Morocco

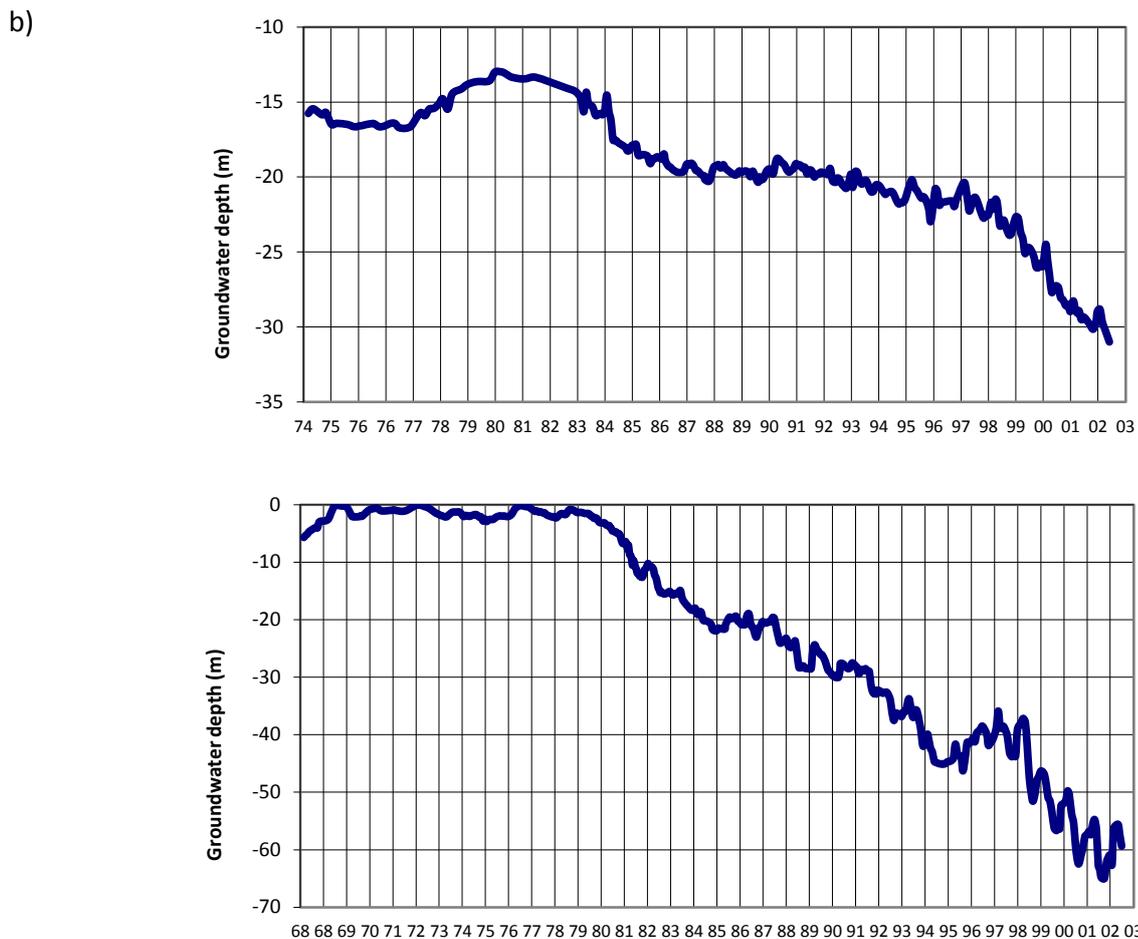
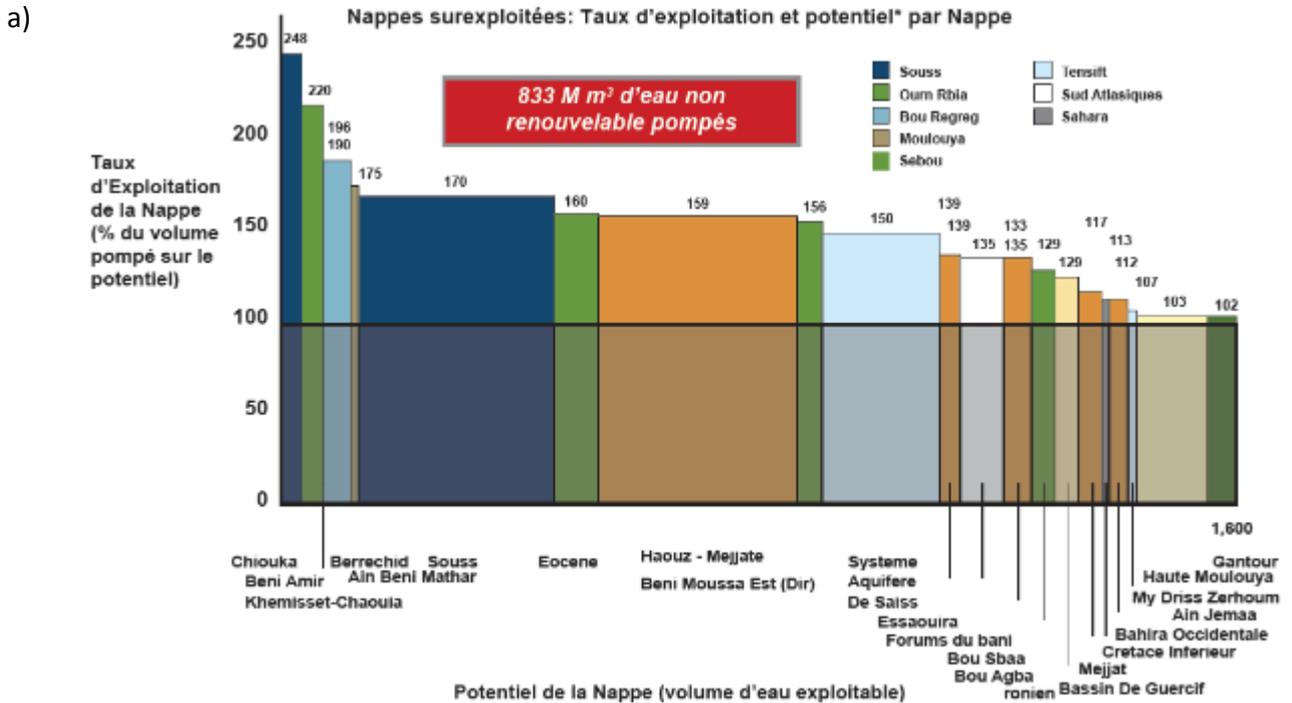
Morocco is characterized by a large geological and hydrological diversity. Groundwater resources in Morocco are found in 126 aquifer units (FAO 2008a). The Atlantic geological area (consisting mainly of sedimentary deposits) is the richest in groundwater, with an estimated 60 percent of the country's groundwater potential and with large regional aquifers including those of Tadla, Haouz, and Saiss (ibid.). Groundwater is also found in the Eastern part of Morocco, an arid region except for its northern boundary on the Mediterranean coast, where 15 deep aquifer units can be found. The third major geological unit in Morocco is the South Atlas area, also a sedimentary basin where some of the most-exploited aquifers in the country such as the Souss and Chtouka are found (ibid.). Groundwater contributes around 40 percent of the water used for irrigation in Morocco. Private irrigation with groundwater outside of the state-sponsored irrigated areas (of which 28,930 hectares are irrigated with groundwater) represents around 65 percent of the total private irrigated area in Morocco (although if conjunctive use, springs, and khattaras are included, groundwater represents around 90 percent of water use in private irrigation in Morocco) (ibid.).

In Morocco, the expansion of private irrigation, especially in the absence of effective regulatory arrangements, has resulted in aquifer depletion and the decline of spring flows supporting medium and small-scale irrigation perimeters, with a decline in area estimated between 150,000 to 200,000 hectares (Van Steenberg and El Naouari 2010). Overall groundwater over-abstraction has been estimated at 862 Mm³ by Benabdelfadel (2012) and at "over 1 billion m³" by the FAO (2008a). The Ministry of Water recently rounded up the number at 1 billion m³ annually (Maroc.ma, 2014). Water tables are declining and so are well depths, reaching up to 300 meters in the Tadla region (Hammani and Kuper 2008) or averages of 100 meters in the Guerdane perimeter in the Souss region, with a water table having dropped 24 metres in 34 years, or in the Saiss Plain with a drop of 64 metres in 25 years (Figure 2) (Benabdelfadel 2012). The exact number of wells in Morocco is not known nor estimated, which shows the high uncertainty due to a high number of illegal wells. In the Tadla scheme, some surveys estimated the total number of wells at 8,300, with more than 2,500 boreholes (Hammani and Kuper 2008).

Groundwater is used for agriculture in a number of distinct situations (FAO 2008a):

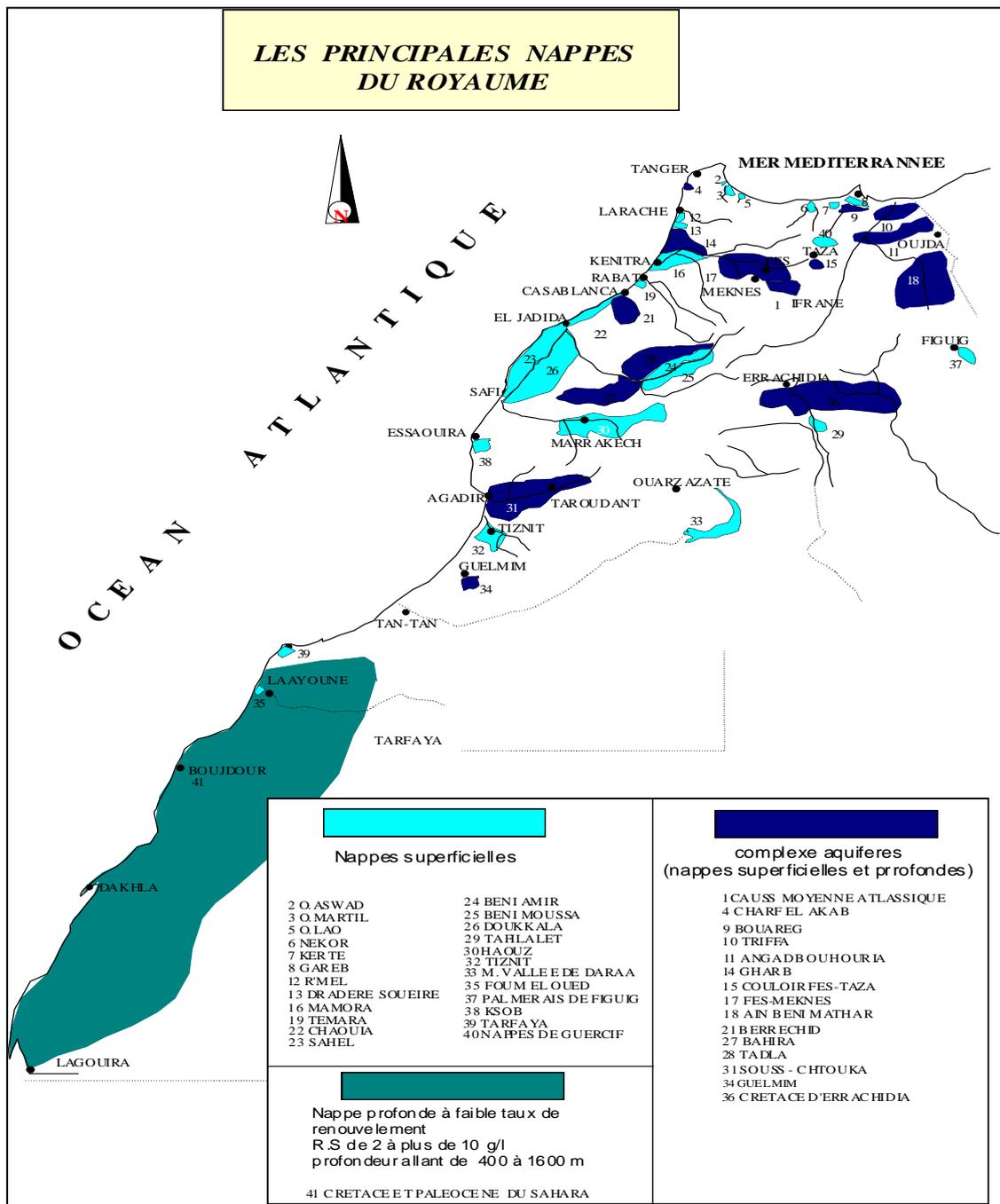
- 1) *Large-scale public irrigation schemes* abstracting water from the aquifer and distributing it through piped networks. This is the case of the Souss Amont scheme in the Souss basin for example, which irrigates an area of 6,300 hectares;
- 2) *Smaller communal schemes* around one well that distribute water through a collective piped network, totalling 28,930 hectares in 1995;
- 3) *Conjunctive use in large-scale public gravity irrigation schemes*, where canal water is supplemented with water that farmers individually source from their wells; a situation that prevails in the Tadla, Haouz, Souss Massa, Moulouya, Tafilalet and Ouarzazate public schemes (ORMVA). According to the 2002 survey on private irrigation, the number of hectares irrigated by individual wells and boreholes inside the publicly designated irrigation areas (supplied with surface water) was estimated at nearly 185,000. Additionally, the survey also estimated that around 105,000 hectares were irrigated with surface and groundwater conjunctively. Actual numbers are of course expected to be substantially higher;
- 4) *Individual wells* drilled by local farmers or investors. This private irrigation has been a major trend of irrigation development in the last 30 years.

Figure 2. Groundwater over-abstraction in Morocco (a) and water table declines in the Haouz and Saiss Plains, Morocco (b)



Source: a) SNE in FAO 2015; b) Benabdelfadel 2012.

Figure 3. Main aquifers in Morocco



Source: FAO 2008a.

1.2 Legislation to regulate groundwater abstraction in Morocco

The current regime of groundwater abstraction in Morocco was established in 1925 when a 'dahir' (decree) was approved reaffirming the public nature of water¹ and establishing the need for abstraction permits and concessions (with the exception of shallow wells for drinking water in rural areas and for livestock use). Alongside the introduction of authorizations for the use of water, the 'dahir' also legislated about the creation of a 'water police', in charge of controlling and enforcing regulations and sanctions (Adnane 1989).

In 1995, the government of Morocco, immersed within a historical context of legislative and constitutional reforms, issued a new Water Law (Del Vecchio 2013). The law maintained the public domain of water, put forward the notion of integrated water resource management, the creation of river basin organizations, and encapsulated the need for users to obtain an authorization and/or a concession in order to access, use, and dispose of water (BRLI and Agro-concept 2012; FAO 2008a). The difference between the two is that concessions are contracts introducing a volumetric cap and issued by the governmental authority in charge of water resources, whereas the well (drilling) authorization is subject to the River Basin Agency's rule and does not refer to volumetric limitations (BRLI and Agro-Concept 2012).

Decree 2-97-487 (4th of February 1998) established the procedure for granting authorizations and concessions relative to the state's public water domain ('*domaine public hydraulique*'). Abstraction permits (from a well or from any other water source) stipulate the volume of groundwater to be abstracted, the maximum discharge per hour, the depth of the well, the intended use of the water, and the area to be irrigated in the case of agriculture. The person requesting the permit must also present a map of the land plot with the position of the well, as well as the ownership titles.² The decree also mentions that water withdrawals for irrigation must be accompanied by a study showing the impact of the project on water resources, cultivable lands and aquatic ecosystems (but in practice this requirement does not even feature in the official form provided for permits requests). Groundwater abstraction permits are required only for wells deeper than 40 metres. When a request is made, a public inquiry ('*enquête d'utilité publique*') is conducted by a commission with representatives from the local commune (*qaid*), the ABH (*Agence de Bassin* or River basin organization), the Office *de mise en valeur* (ORMVA) (if the land is part of a large scale public irrigation scheme), and a representative of the provincial or regional services of the ministry of agriculture. This inquiry is to be carried out within 30 days after the proposed abstraction is announced in the official Journal (*Bulletin officiel*) and displayed at the local administration and at the ABH.

If the commission issues a positive recommendation, the director of the ABH can decide whether a concession can be granted, requiring the approval of the management board (*Conseil d'Administration*) of the ABH. In the case of the drilling of a well, the authorization must also specify the technology to be used, the characteristics of the casing, and the minimum distance to other wells or water sources to be respected. This distance is supposed to vary depending on local conditions but the standard distance to other wells is often taken as 100 m (although most hydrogeological studies point to preferred distances of 400 to 500 m). At the end of the work, the grantee is in theory given 60 days to submit a report indicating the results of the pumping tests (to be conducted in presence of a representative of the ABH), the level of the static level of

¹ The definition of 'public domain' in Morocco was established through a dahir under the Protectorate in 1914. In 1919 a new dahir introduced water (including groundwater) into that public domain, in order to ensure the 'methodological utilization of the resource' (Adnane 1989).

² In the case of land distributed by the agrarian reform (and not yet owned by the farmer), the document is produced by the cooperative; in the case of 'guich' land a certificate is issued by the local representative of the ministry of interior.

groundwater, the results of chemical and bacteriological analyses (requirement later dropped in 2009), soil samples taken at each meter excavated. This quite demanding procedure is complex and costly for farmers who, expectedly, prefer to continue drilling wells illegally.

The decree establishes a special case for authorizations requested within the area of responsibility of the regional land reclamation districts (ORMVA: Office de Mise en Valeur Agricole), in charge of the large-scale public irrigation schemes. Withdrawal authorizations are delivered (modified or cancelled) by the Offices, and a notification must be sent to both the ABH and the ministry in charge of public works. This created tension in terms of responsibilities and prerogatives between the Offices and the Agences.

Decree 2-97-487 of 1997 indicated that water withdrawals points established before the enactment of the 1995 Law should be declared to the director of the ABH within a timeframe of three years after the publication of the decree, and also that permits and withdrawals allowed based on the earlier 1925 law were cancelled by the new dispositions.

In 2000, Decree 2-00-474 of November 14th, determined the procedure for the recognition of rights acquired on the public domain. A public inquiry is to be conducted within 60 days by a commission consisting of representatives of the governor, the ministry of public works, ministry of agriculture the chamber of agriculture, the communal Council and the ABH, and is to be announced by posters displayed in public places.

On January the 16th, 2009, Decree 2-07-96 established the procedure for granting authorizations and concessions relative to the state water domain, replacing Decree 2-97-487 from February 1998. It provided clarifications and more details on the procedures to be followed (for example announcements of public inquiries must be shown in the River basin agencies, the Offices and the local commune concerned; requests for a drilling authorization and for withdrawal are combined in one procedure). The Ministry of public works became the ministry in charge of water and more importantly the new decree gave another period of three years for the regularization of wells drilled prior to the date of this decree (i.e. January 2009), opening the way for the regularization of the wells dug in the past 15 years.

The law also empowers the administration to establish protections or prohibition zones (Decree 2-97-657 of February 1998), based on an evaluation report of the quantitative and qualitative status of the resource, and its vulnerability to pollution or degradation, prepared by the governmental authority in charge of public works (*Equipement*), with advice and input from the ministry in charge of the environment. Zones of protection, exclusion or prohibition are to be delineated by a commission formed with various representatives of the local administration, ministry in charge of public works, ministry of agriculture, ministry of the environment, the ABH and the commune concerned during an inquiry which cannot exceed 30 days and announced in the official State Bulletin. Different types of activities affecting water quantity or quality can be constrained or prohibited in 'périmètres de sauvegarde', such as the drilling of wells. In Prohibition zones no new authorization or concession can be granted unless it is to be fully utilized for human or livestock consumption.

Table 1. Main legislation enacted in Morocco to regulate groundwater

Year	Legislation	Contents
1995	Water Law	<ul style="list-style-type: none"> - Public domain of water - Integrated water resource management through river basin organizations - Users to obtain an authorization and/or a concession in order to access, use, and dispose of water
1998	Decree 2-97-487	<ul style="list-style-type: none"> - Established the procedure for granting authorizations and concessions relative to the state's public water domain (including groundwater abstraction)
2000	Decree 2-00-474	<ul style="list-style-type: none"> - Determines the procedure for the recognition of rights acquired on the public domain - Establishment of a commission to grant groundwater abstraction rights - Registration timeframe of 3 years to register wells dug before 1995
2009	Decree 2-07-96	<ul style="list-style-type: none"> - Replacing Decree 2-97-487 from February 1998. It provided clarifications and more details on the procedures to be followed - Extension of well registration for another 3 years

Source: Compiled by authors.

1.3 Enforcement difficulties and perverse incentives

Today, no specific area in Morocco has been declared as a groundwater prohibition zone. The Souss Massa basin organization, in the South, prepared the necessary files and made such a request in 2009 but the central administration has so far failed to take a decision or action on that request. The Tensift basin organization has not followed such a path but chose to issue an internal note in 2008 that gave instructions to ban the drilling of new wells. But these instructions have not been adhered to and many investors have obtained authorization for new wells, especially when they are needed for projects proposed in the framework of the Plan Maroc Vert (a major public investment programme in the agricultural sector). As reported by some officials, some individuals are able to obtain permits 'by telephone', using their personal connection with powerful officials.

Several ways are used to circumvent this (semi-official) reluctance to deliver new permits. Some people apply for wells to be used for domestic proposes or to water cattle, and later on use them for irrigation. Other apply for permits to deepen their wells (which in most cases have run dry); although this is treated as a new authorization it is more difficult to turn down such a request, especially when it comes within the process of regularisation by the farmer. Some people are keen to rent or buy land with old wells in order to obtain deepening permits more easily. Other make use of the well regularization process (that has been extended twice - farmers now have until October 2015 to regularize 'old' wells) to declare recently drilled wells as 'old' (that is, drilled earlier than 2009) and turn them legal.

But the most popular way out is to register for a project within the high priority *Plan Maroc Vert* (PMV), which seeks to increase agricultural productivity in the country and has adopted an aggressive policy of subsidizing drip irrigation projects (at the level of 80 percent for farms over five hectares, and 100 percent for farms under this limit).³ With just a certificate that their file is being processed (for either a request for deepening the well or the regularization of an 'old'

³ In the early 2000s subsidies for drip irrigation were already at the level of 40 percent and were raised in 2007 to 60 percent.

well) by the ABH or the Office, farmers can obtain a green light to invest in drip irrigation (and even well drilling) and at the same time, implicitly, secure the recognition of their well. The state itself has rented out public land through so called public-private partnerships which "have often been the opportunity to intensify cultivation and consequently increase groundwater withdrawals" (BRL and Agro-Concept 2012) and, more disturbingly, is even renting land that is not cultivated (as can be seen for example with some land from agrarian reform cooperatives in the Haouz, or 'forestry land' in the Souss), on which investors are subsidized to develop (new) intensive agriculture.

The PMV even subsidizes well drilling, which helps small farmers that are out-pumped by bigger farms, but at the same time clearly fuels the expansion of groundwater use. Subsidies as high as 100 percent of course also prompt perverse incentives, with irrigation companies approaching small and medium-size farmers to propose them projects where they take care of the administrative procedure, the implementation of the project, and even of the bribing sometimes necessary to push it through the pipeline. For those with a farm larger than 5 hectares and 'only' 80 percent subsidies, these companies have also learned to slightly overrate project costs in order to make it effectively free (despite limits in per ha costs fixed in the Plan), or to decrease the quality of the equipment effectively installed, for the same purpose.

The regularization of 'old' wells has also been bedevilled by deviant behaviours. Because of the limited success of the first three-year campaign following the February 1998 decree, a subsequent second three-year period was offered starting with the publication of the 2009 Decree. When this new period for legalization elapsed in February 2012, few users and well owners had shown up and many of those who did came in during the final days and saturated the system. As a result it was decided to extend the time frame until October 2015. These successive steps convey the message to farmers that registering is not so important and that more time will eventually be given to them to legalize their wells. The cost and the burden of the administrative procedure also work against farmers willing to regularize their wells.

Enforcement of the law on the ground is also very limited. Currently, the 'water police' is the responsibility of the River Basin Agencies in conjunction with the police and technically the agencies have the legal means to control the development of illegal abstractions. In areas managed by the Office, one or several officials from the Offices are also sworn in. The 1995 Water Law also grants access to water abstraction facilities, wells, and boreholes, to the members of the 'water police' and offences by users can be reported, according to the law, and passed on to the competent judicial authorities to be sanctioned. In the case of a flagrant offence, they can stop the works and confiscate the equipment found on the premises (drilling or boring equipment) (BRLI and Agro-Concept 2012). In most cases the water police, or a visit from officials to the field, is only activated when there is a conflict or a denunciation by some neighbour.

This legislation aiming to rationalize water resource use, planning, and allocation through the management of abstractions lost its legitimacy in the eyes of Moroccan farmers as it was used by the colonial administration to dispossess traditional agriculture of its water rights due to the lack of knowledge about the regulation and procedures by traditional farmers. When the officials of the protectorate tried to impose groundwater abstraction limits, they also encountered the power of colonial agricultural lobbies (BRLI and Agro-Concept 2012). A similar situation prevails now, with investors having the power to insulate themselves from the application of the law. Nor are small farmers a target, either because officials are sympathetic to their situation or because the socio-political situation does not allow them to use 'sticks' with such dire consequences.

The lack of political will to enforce difficult regulatory measures can be seen from the non-effectiveness of the water police, the unchecked perverse incentives of the PMV (where and when they promote more abstraction of groundwater in critical areas), or the failure by the Agencies to act on people who have openly violated the law (e.g. irrigating crops with the well authorization for domestic use or cattle). It is also reflected in the fact that authorized wells must theoretically be equipped with a meter (at the cost of the user), which are nowhere to be seen on the ground; that water fees (also made compulsory by the 1995 law) are maintained at an extremely low level; and that the 'Aquifer convention' signed in the Souss basin in 2009 has so far largely remained a dead letter (BRLI and Agro-Concept, 2012; see next section).

In Morocco, in view of the challenges associated with groundwater over-abstraction, King Mohammed V declared in May 2008 that groundwater protection would be a national priority and instructed the government to prepare a National Water Strategy (Van Steenberg and El Naouari 2010). The principle of paying for water use is part of the 1995 Water Law and farmers have to cover the full cost of development, operation and maintenance of wells. Its implementation is not effective and groundwater users do not pay for groundwater abstracted (Tanouti and Molle 2014). Moreover, groundwater meters have started to be introduced with the new Plan Green Morocco for agriculture in 2008, and it is a prerequisite to access state subsidies for agriculture. A special commission verifies that the equipment is installed in order for the farmers to obtain the subsidy. However after this has been verified, there is no further monitoring and many farmers may remove it or tamper with it after it has been verified by officials (Tanouti 2014, pers. com.).

1.4 The 'Aquifer contract' as a groundwater regulatory tool in Morocco

Morocco has been trying for the past several years to implement an aquifer management model loosely based on France's '*contrats de nappes*' (aquifer contracts). These 'contracts' are presented by the Ministry of Water as a groundwater management tool based on a collective process of dialogue on the problems shared within an aquifer, and ultimately signed between the different public administrations and user associations, incorporating all the measures to be implemented in order to protect water resources, sustain groundwater demand. The aim of the government through these contracts is also to prioritize the different measures to be taken in order to protect the resource and establish an action plan, while defining sustainable water management policies involving all concerned users (AGIRE 2011).

The experience in Morocco with the '*contrats de nappes*' started in the region of the Souss Massa, when in 2006 a 'contrat' was established, leading to a Framework convention for the preservation and development of water resources in the Souss Massa in September 2007. Authorizations issued by the River Basin Agency in the Souss region include groundwater abstraction, well and borehole drilling, and other infrastructure using water from the public domain.⁴

⁴ As studied by BRLI and Agro-Concept, the system of authorizations in the Souss River Basin in Morocco remains also unclear as to what can be done once the authorization expires or if the River Basin Agency decides to reduce the abstraction volume authorized annually for users (in case of groundwater zoning due to over-abstraction or drought). According to their study, BRLI and Agro-Concept purport that due to the fact that this authorization creates a de facto right over the resource, the law does not clarify whether any compensations would need to be made by the River Basin Agency to the users in case the agency had to reduce the amount of groundwater it authorizes the users to abstract. Given the potential harm caused by these decisions, it is not clear either whether the users could appeal these decisions. Moreover, the renewal of authorizations can be restrictive for users. This is why abandoned land plots with wells are attractive for farmers and investors (particularly greenhouse owners in the Massa area) and represent a potential for irrigation expansion as the land purchase or lease allows for the renewal of the abstraction authorization and the access to additional groundwater (BRLI and Agro-Concept 2012, in French in the original).

1.5 Groundwater abstraction in the Souss Region, Morocco

1.5.1 Groundwater management and the 'contrat the nappe' in the Souss⁵

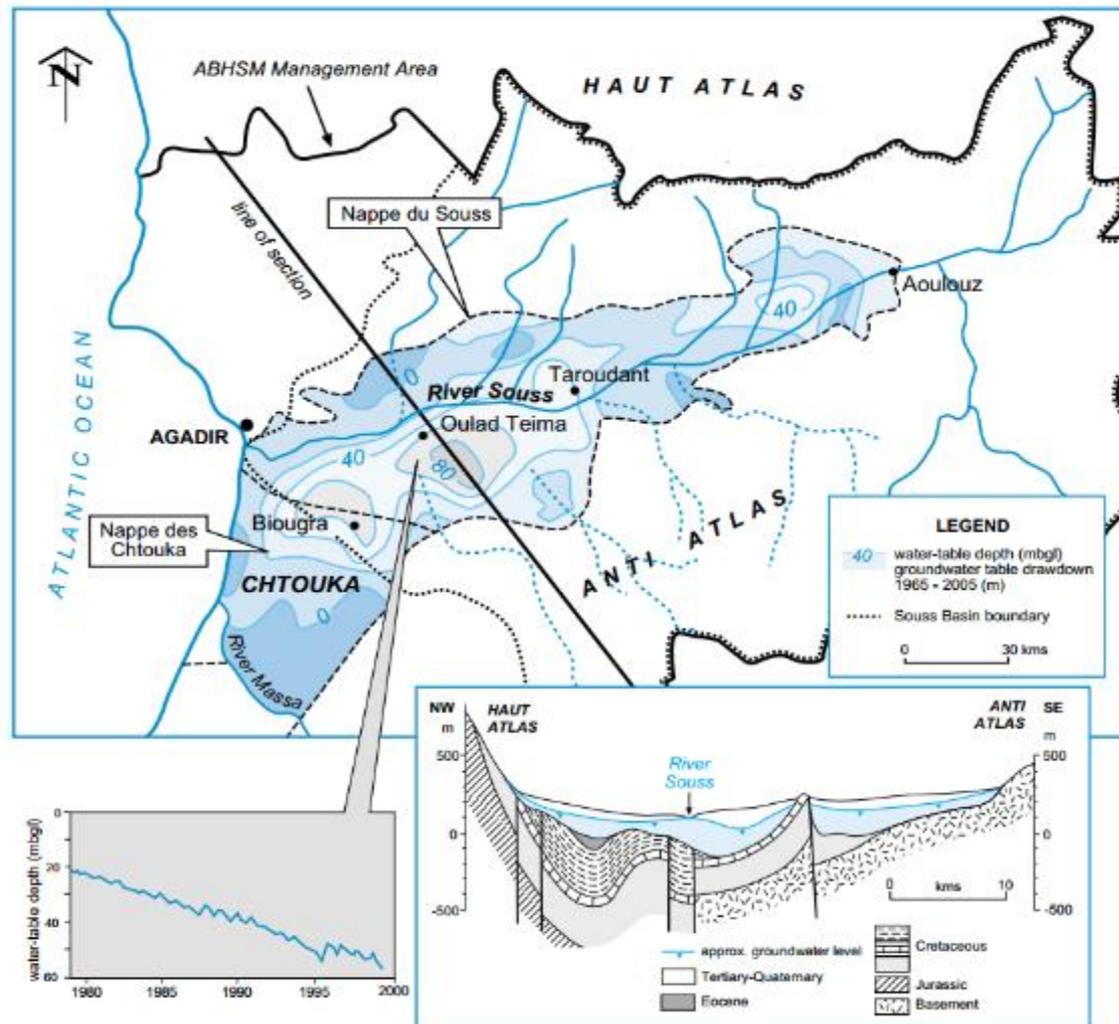
The Souss region produces around 60 percent of the country's citrus fruits and accounts for half of the country's agricultural exports (Houdret 2012). Groundwater represents 95 percent of the total water use, amounting to around 646 Mm³ per year (2003 data). The Souss-Massa River Basin has a surface of 25,000 km² and three main aquifers: the Souss aquifer with around 323 Mm³ of renewable annual recharge, the Chtouka aquifer with 35 Mm³ and the Tiznit aquifer with 17 Mm³ (Benchokroun 2008). In Agadir, on the coast, tourism represents 30 percent of the sector's activity in the country (Houdret 2012) although the estimated water demand is low (0.72 Mm³ per year) (BRLI and Agro-Concept 2012). As a result of agricultural activities and intensive groundwater abstraction for irrigation, the Souss Massa aquifer experiences a structural average deficit of 270 Mm³ per year.

The development of agriculture in the Souss region since the 1940s followed the first hydrogeological studies which showed that there was an 'important aquifer' underneath. This brought about the increase in groundwater abstraction for irrigation from 6,700 hectares in 1950 to 28,000 in 1956, mainly for citrus, tomatoes and vegetables. The decrease of the water table in the 1980s affected traditional agriculture in the first place, dependent on shallow wells and khetaras. During that same decade, the increase in private wells and a series of dry years brought a reduction in surface water affecting 90 percent of traditional farms. The state intervened in the 1990s by providing pumps for wells in some of the traditionally, and in some cases collectively, irrigated areas (around 10,000 hectares) in order to supply groundwater for irrigation, while establishing user associations to manage the systems, levy fees, and cover the operational costs of running the system (the fee of 0.5 dirham per cubic meter only covers part of the costs, estimated at 1.20 dirham).

In 2004, the Souss Massa River Basin Agency carried out an awareness campaign about the new water law aimed at farmers, while at the same time decided to close two wells drilled without authorization. Different agricultural unions saw this event as a potential precedent and a risk for many wells without authorization. After they staged different protests the wali of the region suspended the decision and decided to approach the problem by creating a commission and integrating the representative members of agricultural unions in order to find a solution. The commission was then established with 20 institutional partners (including the governorate of the region; the River Basin Organization; local authorities; agricultural chambers; a federation of water users for agriculture; research institutes; and water suppliers).

⁵ When not stated otherwise, this section is based on the report by BRLI and Agro-Concept (2012).

Figure 4. The Souss aquifer in Morocco



Source: Garduño and Foster 2010.

According to government documents, an agreement was then made encapsulating the discussions that took place during the commission's sessions and included: freezing the expansion of irrigated areas for citrus and vegetables; the transformation of gravity irrigation to drip irrigation funded by the region and also by a fund replenished by the fees levied on farmers' groundwater abstraction; the increase of fees for groundwater users; the completion of several surface water infrastructure projects by the state (22 small dams and 5 large dams); carrying out studies about the feasibility to irrigate with desalinated water the region of the Chtoukas; and regularize 'illegal' wells. The agreement also included enforcing rules and allowing the 'water police' to fulfil its mission, closing down wells (40 were envisaged in the convention), confiscating boring and drilling equipment (100 were aimed to be confiscated according to the convention), asking for drilling permits to drilling companies, as well as purchasing 3 cars for surveillance patrols.

The issue about limiting the expansion of irrigated areas became one of the most controversial points, with groundwater users arguing that groundwater could be saved with drip irrigation and augmented by the supply of surface water with the new infrastructure projects. After further discussions, an agreement was made on the areas to be included, with a commitment by the regional Office to follow through a GIS system these cultivated areas, as well as a

commitment by the River Basin Agency to regularize wells and authorize new ones in the areas declared to be irrigated in the convention if groundwater flow becomes insufficient. In order to implement this agreement, a monitoring committee was also created, with regional elected authorities and farmer representatives.

The agreement was signed in 2007 by the parties involved in the '*contrat de nappe*', and by three large agricultural unions (vegetables and fruit exporters, as the largest producers in the Souss Massa region). Once signed, partial agreements would be also signed in order to implement the various dispositions and plans. Thus, the terms of the regularization of wells or the installation of meters would be negotiated between the River Basin Agency and the farmer associations under the supervision of the Monitoring committee. User participation and consultation for these contracts was going to be based on the concept of 'participative planning' whereby representative groups constituted of various actors and users would be informed of a series of preliminary studies and introduced to the concept of a '*contrat de nappe*'. The contract would then be drawn, identifying the common problems and potential measures to be adopted based on the feedback from working groups with users. An institutional, monitoring, and supervision structure was supposed to be created as well as indicators regarding the completion of the '*contrat*'.

Eight years after the signing of the Contrat de Nappe, the situation has not really changed, as the contract has been undermined by a general *laissez-faire* attitude, the failure of the government to deliver on the supply augmentation projects, and the event of a few good hydrologic years that have displaced the prevailing sense of urgency. In 2014, however, the government has put the '*contrat de nappe*' in the limelight again, declaring a policy to have such contracts established in all major aquifers in Morocco by 2016 (L'Economiste 2014).

1.5.2 Groundwater development in the Upper Souss Basin⁶

Boujnikh (2008) has studied the evolution of technology and agriculture in the Upper Souss basin (upstream from Taroudant). Traditional water technologies such as the *khettaras*, predominant during centuries became marginalized and then abandoned after the 1960s and 1970s with the surge of modern groundwater abstraction technology. Boujnikh (2008) counted more than 100 ancient *khettaras*, in some case 300 years old, in the Upper Souss basin, with water flows up to 300 litres per second in winter and irrigating around 5,000 hectares of land. Even though modern technology came from the lower parts of the basin further south-west in the 1960s and 1970s, it was preceded by the development of private irrigation well before the arrival of modern pumps. Due to unforeseeable climate conditions, farmers benefiting from communal water management supplied by *khettaras* complemented their water supply from shallow wells equipped with water lifting devices (*arghrour* and *naaora*)⁷ (especially upstream of the *khettara*, for those farmers not connected to the canals carrying the water from the *khettara*) (ibid.). Boujnikh (2008) wrote that by the 1950s there were around 3,907 water lifting devices in the Upper Souss valley irrigating around 3,000 hectares.

In the 1950s however, the first European investors arrived with the first wave of agricultural colonization, buying land alongside traditionally irrigated plots, and drilled wells. The traditional water lifting devices could not compete with modern technology nor could the wells be deepened below 25-30 metres, even though farmers' water wheels changed to the *arghrour*

⁶ Section based on Boujnikh (2008).

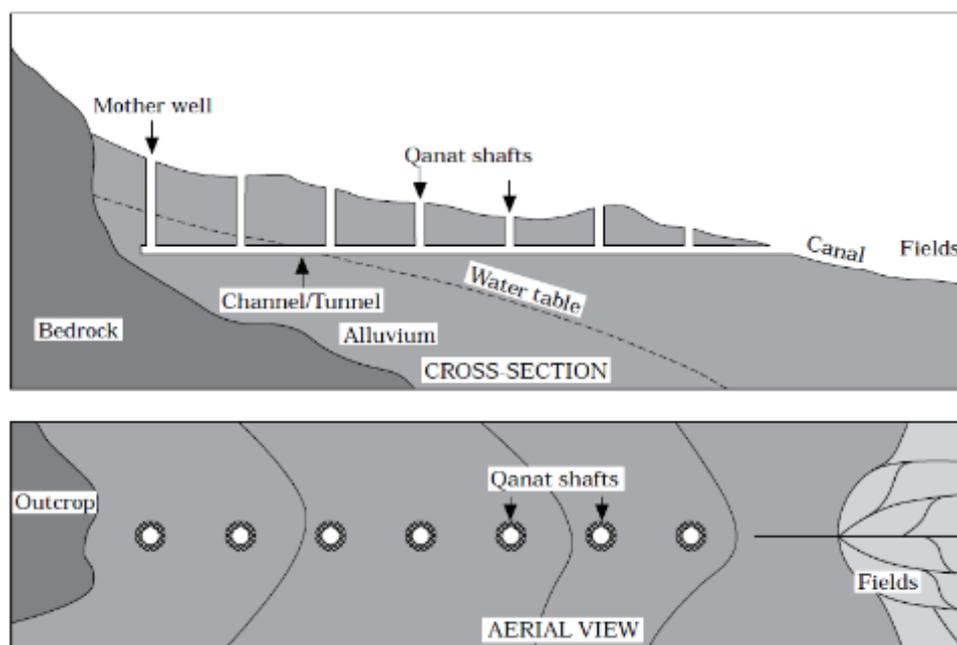
⁷ The '*arghrour*' is a water lifting device which uses animal power to lift, via a system of pulleys, a container (usually made of animal skin) full of water from down a well. The '*naaora*' is the equivalent of the Persian water wheel. The depth of the wells for these devices would be limited to 25 metres maximum (Boujnikh 2008).

(which could reach depths of 30 metres as opposed to the shallower water wheels) in order to reach further for groundwater. In the 1980s however, according to Boujnikh (2008) the transformation of traditional water lifting technology became prevalent as farmers first started to fit engines to the traditional lifting devices, then use deep pumps (having deepened their wells down to 70 metres in some cases). This transformation, following Boujnikh (2008) brought out social and economic differences between farmers, as the deepening of wells following the dropping water table excluded poorer farmers without the means to install modern equipment. New farmers from the lower Souss able to cover the costs of the new technology also appeared in the area, sometimes buying land upstream from the khattaras and, as in the case of Tamast, started investing in intensive fruit farms with sophisticated groundwater abstraction technology. Over the 1980s and 1990s, boreholes took over the traditional water lifting devices, amounting to over 2,500 and irrigating 25,000 hectares of land (Boujnikh 2008). Khettaras stopped flowing in the Upper Souss basin in 2000, with a then average then water table depth between 70 and 110 metres.

In the 1970s, the state initiated a programme to rehabilitate and preserve some of the communally irrigated areas with khettaras (ibid.). The state drilled wells in the Upper Souss basin in Ouled-Berrhil and improved over 2,300 hectares of land for irrigation (mostly olive trees), rebuilding and lining of water canals, construction of reservoirs (ibid.). Many old seguias (water canals) were improved, and a well was drilled upstream feeding the system with groundwater. Two user associations were put in charge of the system, managing the allocation of water amongst its members.

These measures aimed at mitigating the impact of the drawdown of the aquifer on small farmers, together with diffuse private investments in the Valley, eventually compounded over abstraction. Figure 5 provides a graphic illustration of how Khettaras have been undermined and eventually displaced by boreholes, a story commonplace across the MENA region.

Figure 5. Diagram of a khettara/qanat



Source: Lightfoot 1996.

Figure 6. Effects of modern groundwater abstraction technology on traditionally irrigated areas in Ouled-Berrhil between 1970 and 2005



Note: the first large modern farm appeared in 1970 with 900 hectares of citrus fruits. Light green designates areas irrigated by khettara and dark green designates the areas irrigated via private wells. Source: Boujnikh 2008.

1.6 Traditional irrigation and groundwater abstraction systems in Morocco

In Morocco, community rules for groundwater abstraction and management still exist, mainly found in oases and small traditional irrigation communities. In oases, norms limiting borehole drilling exist in traditional systems stemming from the historical rights of these communities to harvest and manage groundwater (Faysse et al. 2011). In these communities, norms have banned borehole drilling in the catchment areas of the *khettaras* (underground drainage galleries) (ibid.). Outside these areas however, farmers consider that the prerogative for borehole control falls within the role of the state (Bekkar et al. 2009).

Oases are thus in tension between community-managed irrigation systems and private development and the case of the Figuig oasis in Morocco illustrates how these can coexist in some instances (El Jamali 2013). New agricultural dynamics have appeared, driving substantial agricultural development based on market profitability rather than economic subsistence and household consumption. The Al Arja area was developed in the 1990s by private investors as an extension of the irrigated area outside the traditional boundaries of the oasis. The availability of

water and good soil pushed some community members to exit the communal system of water management and drill wells (El Jamali 2013). Some oasis dwellers in pre-Saharan Morocco have also used migrant remittances as capital to experiment with new crops and produce for the market (Rignall 2015). This caused a strengthening and diversification of agricultural practices and in some cases led to the rejection of agricultural traditions and the development of mechanization, labor organization, and other capital-intensive investments (ibid.).

Box 1. The oasis of Figuig in Morocco⁸

The oasis of Figuig in eastern Morocco has approximately 20 springs, 90 percent of which are located in the upper areas of the oasis. Traditional 'khetaras' systems were used to collect water before the arrival of pumps in 1965. Nowadays the oasis relies on groundwater via wells (collective and private as well), in addition to khetaras). The community operates 7 motor pumps and stores water communally in a reservoir. Irrigation in the oasis consumes 90 percent of the water resources available.

The system of irrigation in the Figuig Oasis has adopted both modern and traditional technology to abstract groundwater (with collective diesel pumps and khetaras conveying artesian groundwater) and traditional techniques of water allocation. The traditional system of water rights in the oasis was established as a private system and farmers can inherit, sell, buy and transfer water rights. Through the traditional allocation system, each farmer has access to 45 minutes-worth of water ('kharrouba'). Each spring has a fixed number of kharroubas, with the day divided into 32 kharrouba of 45 minutes each. Water rights for users are therefore defined by time (X-amount of kharroubas) and not by quantity of water. The volume of water is then established through the variation in time of the level of water stored in the storage reservoir (via a stick used to measure the height of the water, which is then divided by the number of water rights in that reservoir). At night, water is however allocated via volume through the use of a small storage basin between the spring and the garden.

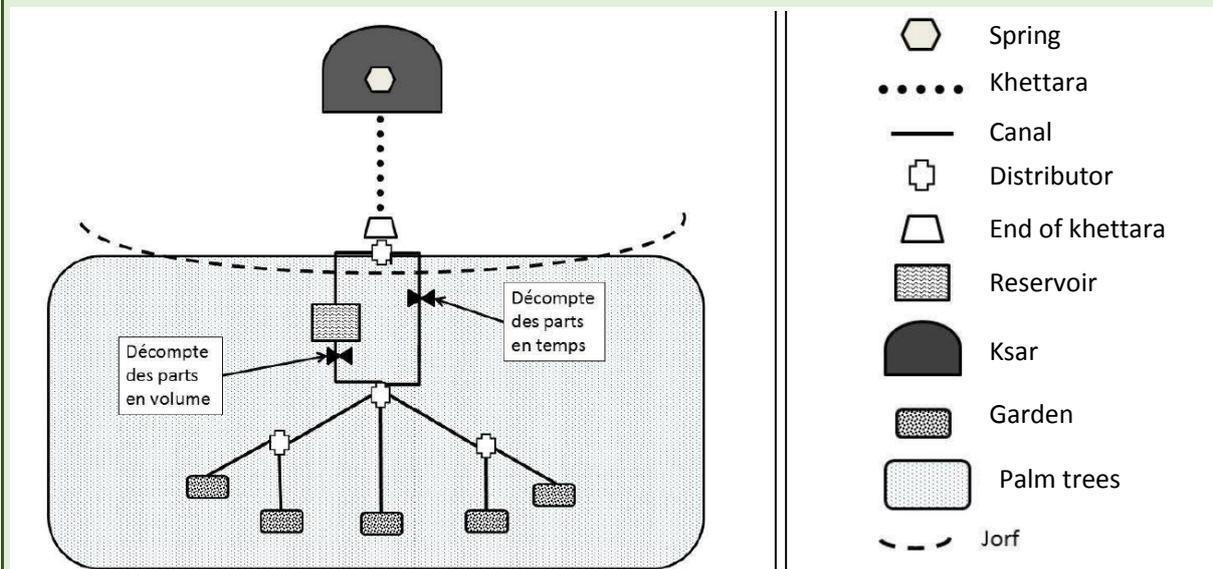
Irrigation turn allocates the frequency of access to the user water rights (currently set at 14 to 16 days). Water is also not linked to the amount of land owned by a user. Additional days in the irrigation turn (called 'tantawat') were established during colonial times in order to pay taxes to the French authorities. Water would not be allocated to its rightful users in the oasis and sold to other uses and the money raised would serve to pay for the taxes. Nowadays the money is raised to do maintenance and repairs in the system. The system of water allocation is also characterized by water markets or exchanges, where farmers with less private water rights, can rent or buy from other users. The price established for sale is between 40,000 and 45,000 Dh and 350 Dh to rent for 6 months. Water rights are managed by the 'Sarayfi', a well-respected man designated by the community.

The oasis is governed by an autonomous central authority which appoints local people from the oasis to govern on the basis of community management rules headed by elders. The system of government in the oasis is characterized by family lineage and roots and not by wealth. The elders form the 'Jma'ah', a local community system that has been the main actor in the management of water. Access to water is also restricted to farmers having both land and water rights or people owning water rights. Traditional unwritten rules are used to manage and settle irrigation disputes and grant sanctions. The 'Urf', an oral code known to all members of the community, allows farmers to use water from the common canals under the following

⁸ Source: El Jamali 2013; Janty 2014; Jilali 2014.

circumstances: if the farmer is doing any construction on his plot or if the farmer has planted new palm trees, as they need to be irrigated every three days.

Figure 7. Schematic of a typical irrigation system in Figuig

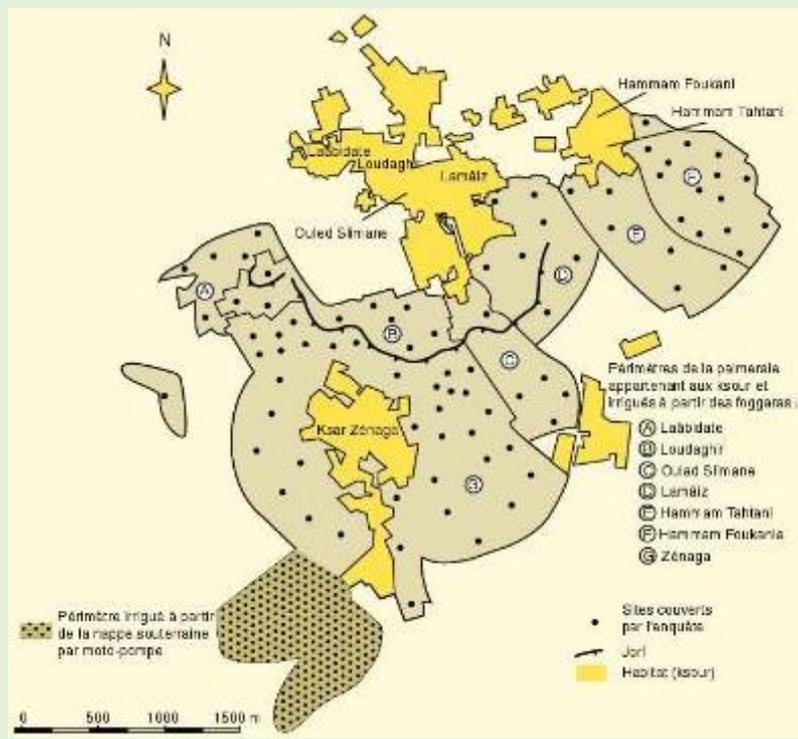


Source: Janty 2014.

The system of water management is however also based on official documents stating the number of water rights and irrigation time assigned to each member of the community. The traditional rules of 'Urf' considering water a private good, and the existing legal code of Islamic law which states that water is a public good coexist and customary law has been tolerated by Muslims for political reasons with the purpose to ensure stability in the country between Berbers and Arabs. Disparities in land ownership and water shares have caused that a small minority of farmers own most of the water rights. Strong competition over water rights has caused an increase in the price of water rights before and after the adoption of pumps. Therefore, most farmers rent additional water rights although prices have also increased during the last 50 years.

These difficulties faced by communities in the shared allocation of water for irrigation coupled with limitations of land expansion (due to strict inheritance rules have caused the expansion of the irrigated area outside the historically farmed area (Figure 8). The newly developed area of Al Arja appeared in the 1990s, using groundwater through 60 private wells. Farmers in this new area have invested in drip irrigation and sprinklers. In some instances farmers have up to 3 wells per land plot and most of them did not obtain permits for their new private wells. The lack of water due to increasing groundwater abstraction and drought pushed the government to plan a dam to store 4 Mm³ in order to provide additional water to the community and revive the foggara system. The impact on the natural stream system in the oasis has also noticed, with a decrease of the average flow rate of springs in the oasis of 4 litres per second between 1994 and 2011 (Jilali 2014). In general however, Janty (2014) found that over 40 percent of the traditionally cultivated oasis is stable, with around 20 percent of the traditionally cultivated land in regression. The regression of cultivated land is mainly due to factors linked access to an irrigation system (the lack of access to water is an important factor explaining such regression) and also changes in spring discharge, soil salinity, and demographic changes due to emigration.

Figure 8. The Figuig Oasis, Morocco



Source: Bencherifa and Popp 1992 (obtained from: www.figuig-genealogie.com/plans/figuigjle.htm, Accessed 10th April 2014).

In the palm groves of Ait Aissa OuBrahim in the Toghga valley in south-eastern Morocco, the abstraction of groundwater via several khettara by the Ait Atta tribe was essential for irrigation (Rondier 2012). However, over various generations, water access rights and land property in the oasis have become fragmented, contributing to a lack of interest in agriculture by the new generations who think there is no point in working hard for only a few minutes of water rights for irrigation for a narrow patch of land (ibid.). Although these water rights are governed by social relations and decisions dating back several centuries, the lack of definition of rights between old and new assignees has provoked conflicts between users, and additional pumping in the oasis by means of individual pumps has eroded traditional relationships between users (ibid.).

Wolf's (2000) research on the Berbers of the High Atlas Mountains in Morocco examined the different approaches and mechanisms for water allocation and conflict resolution. As in most communal systems water is quantified in units of time rather than in units of volume, a procedure also observed by Boujnikh (2008) in the khettaras of the Upper Souss River Basin, where farmers use a 'tanast', a specially made copper bowl with a small hole at the bottom in a bucket full of water. When the bowl reaches the bottom of the bucket, this constitutes one unit of water or one unit of irrigation right (ibid). For Wolf (2000), this method allows to adapt local management of water to a fluctuating supply from wells, springs or khettaras, and provides the means for a water exchanges without storage structures. Demand for different sectors is prioritized according to a hierarchy of importance. This allows for less important water uses to be discontinued during low flow regimes rather than cutting off entire downstream villages and protect the investments in essential infrastructure. Berbers also protect downstream and minority rights and only allow traditional diversion structures to be used in their irrigation

systems. Despite their 'inefficiency', they allow for the flow to continue downstream. Bedouins also use concepts of equity, honour and pride as well as distinctions between right and wrong. Bedouin and Berber groups also have distinctive dispute resolution mechanisms and follow Islamic practices of ritual ceremonies of forgiveness, whereby after the ceremony is performed the dispute may not be discussed again.

Decisions about the sharing of a well between neighbours or family members are established in order to preserve peace and honour in a family or a community. The solution of disputes in Berber and Bedouin communities requires though a clearly defined water authority and specific members of the community assist in the process of conflict resolution. Despite that the role of 'marabout' as social mediator in Berber communities has disappeared, each village chooses an individual 'a'alam' to manage the irrigation schedule and resolve internal disputes. This role in some communities also rotates from family lineage to family lineage. If a dispute between villages arises, the 'a'alam' of the villages attempt to solve the issue with, if necessary, the help of the villages heads. If the resolution is unfruitful, villages recognize the authority of the regional 'hak'm' (a traditional judge who adjudicates using a combination of Islamic law and Berber tradition). If neither party is happy then an appeal can be made to the regional court system according to Morocco's formal legal structure (Wolf 2000).

1.7 Groundwater user strategies in Morocco

In Morocco, the development of public irrigation in the 1960s and 1970s came with a series of obligations for farmers participating in these schemes in terms of enforced cropping patterns, mortgages, and investment repayments to the state. As studied and characterized by Kuper et al. (2012), the drilling of boreholes came to be seen as an 'exit' strategy for these farmers not willing to be subdued by more government regulation and additional fees and, more importantly, seeking to increase supply to compensate the decline of irrigation (canal) water delivered to them. Through these strategies, the development and access to groundwater allowed 36 percent of medium and large size farms to overcome reductions in surface water (ibid.). Well water makes for a quantitative decline in supply but also frees farmers from the constraints of surface water irrigation, its turns and priority crops so that they can access water at will (Errahj et al. 2009). Even if the cost of groundwater is higher than that of surface water (between 0.35 and 0.60 Dirham/m³ compared to 0.22 Dirham/m³), this practice is common especially amongst large farmers (with farmers bigger than 2.5 hectares) (Van Steenbergen and El Naouari 2010).

The decline of centralized irrigation coordination in Morocco also favoured the emergence of several processes of inter-structuring of individuals and institutions (so called 'local coordination modes') (Errahj et al. 2009). These authors have shown how local coordination modes (informal or even illegal) help farmers in the Tadla scheme go beyond survival strategies by providing access to land and water resources as well as more formal development spheres and policy making (ibid.). Despite being seen sometimes as a taboo according to cultural perceptions, these exchanges occur however based on informal arrangements based on reciprocity mechanisms in the case of drought and mainly between family members or neighbours (Kuper et al. 2012). Informal arrangements regarding groundwater abstraction are also mostly 'illicit'. According to Errahj et al. (2009), two thirds of tubewells in the Tadla region are managed under unofficial arrangements. These can vary from a joint investment by a group of farmers to collective use of a tubewell inherited from relatives, or one-off water transactions.

In the Tadla, these coordination modes were integrated via collective action, e.g. ‘mutualistic arrangements’⁹ for sharing equipment, boreholes, or tubewells, or ‘capitalistic arrangements’ whereby landowners would provide the land and the tubewell and the land lessee the agricultural inputs and the running costs (fuel) for the well (ibid.). Hammani et al. (2009) and Bekkar et al. (2009) found that around 20 percent of farmers generally benefit from informal arrangements with neighbours or family members. According to Errahj et al. (2009), purely capitalistic arrangements (such as buying and selling water via monetary transactions) represented only 14 percent of the total informal arrangements.

The development of private groundwater abstraction in the Tadla scheme was also linked to groundwater access and to informal land markets as well as off-farm revenues for micro-farms (representing 50 percent of their total revenues) (Kuper et al. 2012). Off-farm revenues can be generated from trading, agricultural services, and agricultural labour. These pervasive and informal land markets and land exchanges are extremely dynamic and 40 percent of the farms studied by the authors are actually subdivided into smaller plots for family members and 30 percent of small farms engage in some form of informal arrangement to access groundwater in order to obtain higher cereal and alfalfa yields (ibid.). These arrangements however only involve small size farms and typically include indirect cropping (renting and sharecropping) happening 30 percent of the medium size farms.

In the Souss, the use of ‘defensive strategies’ by farmers is very much contextualized by the fact that small-scale family farms have collective access to groundwater (via public tubewells) (Bekkar et al. 2009). Because of its depth (around 300 metres), which results in high installation and pumping costs, groundwater users do not have individual access to the resources (36 percent of farmers have access to groundwater via arrangements with other users). With decreasing groundwater levels, users in the public irrigation schemes with access to groundwater (via collective wells managed either by the administration or by a user association) have been forced to reduce their irrigated area or to invest collectively in water-saving irrigation technology (drip irrigation) in order to maintain their irrigated area (ibid.).

2 Algeria

2.1 Groundwater resources and abstraction in Algeria

In Algeria, groundwater was historically abstracted in the North near the coast via shallow wells and in the South, in the Sahara desert fringes, through the traditional system of *foggaras* (underground galleries collecting groundwater) with 700 accounted for according to the FAO (2008b). Geologically, there is a major difference too between the north of the country where groundwater resources are renewable and mostly found in alluvial plains such as the Mitidja and Hodna plains, and the Saharan regions in the south where groundwater is quasi non-renewable (ibid.).

Groundwater is abstracted in Algeria through over 100,000 shallow wells and 13,600 deep wells according to estimates by FAO (2008b), supplying, in total, 96 percent of total water demand in the Saharan regions and 75 percent of the country’s total water needs (ibid.). According to the same FAO report, most aquifers in the north of the country are over-exploited, with important drops in water table levels (reaching up to 1 metre per year), a pervasive proliferation of illegal

⁹ Mutualistic arrangements happen where two or more brothers or neighbors share the tubewell investment or running costs, while solidarity arrangements are based on one-off arrangements regarding neighbors in dire straits with crops requiring water (Errahj et al. 2009).

wells and a decrease in water quality in coastal areas due to sea water intrusion. A series of droughts between the 1970s and 2000s influenced the use of groundwater, driving groundwater abstraction further (ibid.). The explosion of groundwater abstraction was backed in the 1970s and 1980s by bank loans for farmers to develop agriculture, irrigation improvement, and tractors. Access to easy credit increased the irrigated surface between 1981 and 1985 with 650,000 new hectares (Imache et al. 2010).

In the desert, the development of commercial oasis agriculture in Algeria was fuelled by the Law 83-18 about access and property of agricultural land. This law enabled farmers to acquire agricultural land at a symbolic price (one symbolic Dinar) provided that the buyer will put them into productive use (Ben Hounet et al. 2011). The National Development Programme in the 2000s accompanied and amplified this dynamic as it provided state support to commercial date palm cultivation by investing in cooling warehouses (Amichi et al. 2015). This drove the change in the El Ghrouss community in the Zeban oases, for example, from a multi-level traditional oasis agriculture (dates, fruit trees, and vegetables) to extensive, commercial greenhouses, and monoculture agriculture.

2.2 Groundwater regulations

Water management in Algeria is centralized through the Ministry of Water Resources (Benblidia 2011). At the local level, water resources are controlled by the hydrological department of the *wilaya* (ibid.). The control of groundwater abstractions in Algeria is done theoretically through permits and it is the Wali who, since the new Water Law 05-12 in 2005, signs the positive recommendations for a well permit. Before that it was the local administration in charge of water works (Imache 2014). Meters are only installed on state-owned wells for drinking water supply. Abstraction limits in especially designated areas can be put in place to protect drinking water supply (ibid.). The 2005 Water Law also contemplates the establishment of *quantitative* protection areas (*périmètres de protection quantitative*), where new wells are banned, and where the actual abstraction of wells can be limited or discontinued (Algérie, 2005); and also of *qualitative* protection areas (*périmètres de protection qualitative*), where activities generating pollution or contamination can be prohibited. Algeria has also established 5 river basin agencies since 1996 after the 1983 Water Law was amended (El-Gohary 2010).

The request for an authorization of use of (public) waters includes information on the purpose, duration and amount of use, technical documents on the works, and is subject to a technical visit of the Wilaya (provincial) technical services, to the advice of the National Hydraulic Resources Agency and the river basin agencies. The authorization specifies the conditions of water use, the obligation to install a meter and pay fees, and the duration of its validity (Decree 08-148, 2008). But an authorization for drilling a well is also subject to the subsequent Decree 10-318, 2010, which additionally requires a map showing the location of the well, a note on local hydro-geology, the intended drilling operations and pumping tests. The well owner must inform the administration if he stops its exploitation, and must allow and facilitates control technical visits by officials at any time, who are entitled to cancel the authorization if a lack of conformity is evidenced.

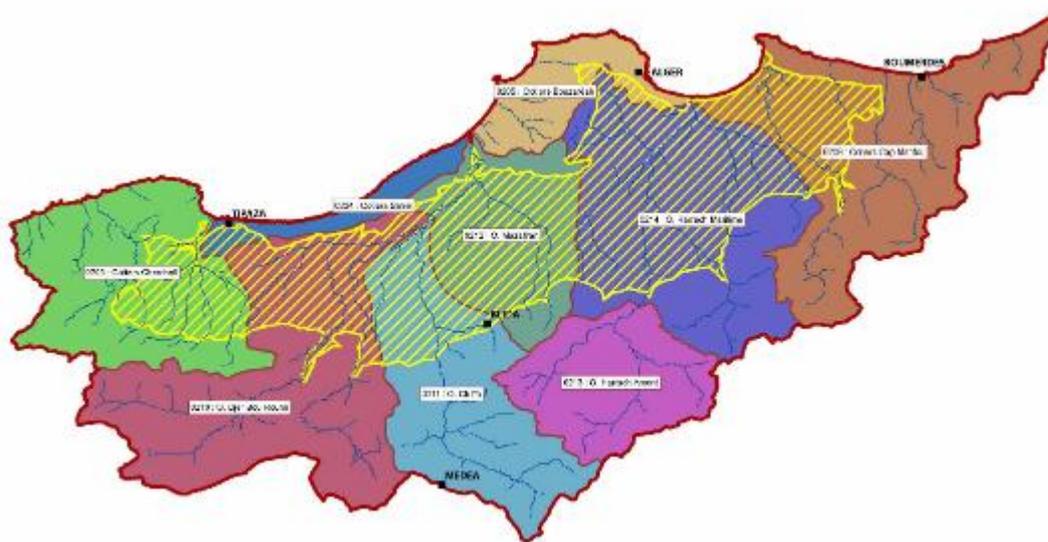
However, in contrast with these legal requirements, surveys by Bellal et al. (2015) in the Wilaya of Oran have evidenced the proliferation of illegal wells, despite the 2006 Wilaya's decision to inventory and destroy illegal wells. This decision was followed by some action on the ground that however largely remained symbolic. Water use in agriculture remains a blind spot to which authorities have turned a blind eye, ignoring existing laws. Since the "overwhelming majority" of farmers wells are not registered, controlling or rationalizing water is an elusive goal (Bellal et al 2015). Likewise the Mitidja Plain Management Plan (2013) observes the "easy and uncontrolled"

access to groundwater, the race to the bottom despite drilling prohibition, the inefficacy of the 'water police', and observes that for the Wilaya of Blida 2000 illegal wells can be found alongside the 1,200 legal wells.

2.3 Groundwater abstraction in the Mitidja plain, Algeria

The Mitidja plain covers around 1,400 km² located south of Algiers. It overlies two aquifers, a shallow one which is from where most wells abstract groundwater for irrigation (the water table is on average at 40 meters) and a deeper aquifer used mainly for drinking water supply (Imache 2008). On average every year, 40 percent of water resources come from surface water and 44 percent come from groundwater (the rest, 16 percent, from desalination) (MRE 2013).

Figure 9. The Mitidja plain, sub-basins and the aquifer



Source: MRE 2013.

Estimates for the Mitidja plain point to around 3,100 wells found in the plain, abstracting around 126 Mm³ per year (not including abstractions for drinking water supply, another 146 Mm³) (Imache 2008). In the West Mitidja plain, south of Algiers, farmers facing reduced water supply from the collective irrigation canals as well as the degradation of the water supply infrastructure have turned to groundwater (ibid.). Also, given the fact that top priority is given to drinking water supply and an increasing lack of security in supply, water reserves stored in dams in the basin initially allocated to irrigation have increasingly been used to supply urban areas on the coast (MRE 2013). This has reduced the availability of surface water in the large public irrigation schemes and users have started to rely more and more on groundwater to compensate for the lack of surface water (ibid.). The increase in groundwater abstraction in the Mitidja caused a drop of the groundwater static level between 20 and 50 metres between 1985 and 2010 (FAO 2008b; Saidi 2012). According to the Water Resources Plan for the Mitidja, the aquifer is exploited at 110 percent of its capacity (MRE 2013). The plain concentrates 51.5 percent of the national production of citrus in the country and 20 percent of the country's vegetable production (Imache et al. 2010).

With the land reforms in the country, which dismantled state-owned farms, users have also faced water access problems. Water supply points for irrigation (*'bornes d'irrigation'*) in the old state-run system were not designed for this change and many users have suffered from a lack of

water. Some of the new land plots had access to more than one water supply point whilst others had only access to one. Surface water users have however, additional costs (e.g. maintenance of the infrastructure) factored into their bills that groundwater users do not have (Imache 2008). This has prompted the making of informal arrangements in West Mitidja, allowing 90 percent of farmers to access groundwater (despite a low tubewell density). This is due to the fact that users with private wells only have to count as running costs their energy bill. The authors put forward the idea that farmers became used to jointly manage tubewells in the era of collective farms and to the relative insecure land status which generated further agreements between owning farmers, leasing farmers and assignees cultivating the land (Hammani et al. 2009).

In the Mitidja, Amichi et al. (2012) studied the informal arrangements used to allocate and exchange groundwater, often intertwined with access to land as the economic history of public farm dismemberment by the state unfolded. Their research found that in spite of the breaking up of large farms into smaller groups or individual farms, water pumped from collectively owned wells was still shared and that informal arrangements have appeared over the last 20 years based on land and water markets. Small landholders occupying about 7 percent of the land have also found cooperative ways to access land and water. Due to their limited investment capacity, they have joined forces in order to rent a few more acres of land to have enough capital to farm it. But, arrangements amongst users are limited to fellow tubewell shareholders and thus fail to ensure regular access to groundwater for other farmers.

2.4 Traditional groundwater abstraction systems in Algeria

The development of traditional groundwater abstraction systems in Algeria, called the *foggaras*, was based on the existence of slavery and servitude as well as the natural hydrogeological conditions of particular arid and semi-arid areas in south-western Algeria (FAO 2008b). Just like for khetaras in Morocco, these traditional systems are based on a system of water rights based on the idea that each individual is the owner of a share of water proportional to the contribution made to build the *foggara*. Water allocation was made possible by constructing a series of regular openings in one of the sides of a storage tank leading to secondary canals conveying water to the different irrigated areas (ibid.).

2.5 Land, inequality and groundwater abstraction in Ouarizane

In Ouarizane, in the Bas Chélif region, a dynamic of differentiation has also occurred amongst the farmers after the dismantling of state-owned agricultural estates as assignees to new lands received various types of agricultural assets, thus influencing the conditions of access to surface and groundwater (Amichi et al. 2012; 2015). These authors observed a strong relationship between access to groundwater and the current process of land concentration. Marked inequalities in access to groundwater were driven first by the inherited agricultural goods and structures that allowed some assignees to obtain access to collective tubewells as well as to surface water. Orchards inherited from these public estates received priority surface water. These assignees also owned tubewells inherited from the former estates or that had been drilled during the period before the collective farms were divided up. Second, access to financial capital allowed big tenants to buy tractors and other heavy equipment, drill individual wells and thus secure their access to groundwater. And thirdly, farmers with both social and financial capital have benefitted from the leniency of the authorities and discretion of neighbours with regards to instances of illegal drilling (ibid.).

In a context of scarcity of surface water, these differences and access to groundwater have excluded an increasing proportion of small assignee from agricultural activities. In Ouarizane, 62

percent of the farms are seeing their livelihoods being reduced as they cannot satisfy their basic economic needs nor find jobs in other sectors due to structural unemployment in the country's economy (ibid.). The continuing unequal access to groundwater has consolidated the established balance of power and supports the hypothesis that the on-going formalization/de facto privatization of land rights might lead to the maintenance of, or even increase, inequality as the liberalization of production factors is subject to power struggles and competition that can result in the accumulation of land and other production inputs by larger and wealthier farmers (Amichi et al. 2015).

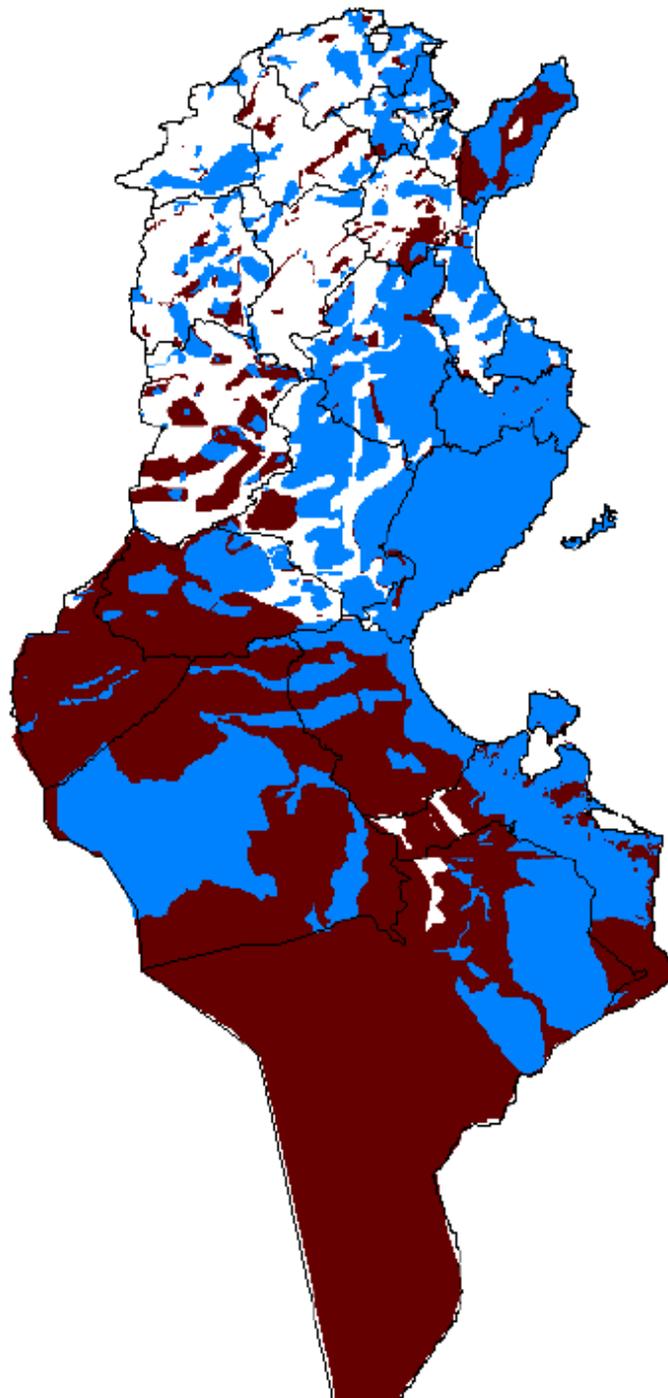
3 Tunisia

3.1 Groundwater resources in Tunisia

Aquifers in the north are found in sandstone deposits and sometimes alluvial and calcareous. The alluvial formations can be part of large sedimentary plains sometimes quite large and up to 100 metres in thickness (Gaubi 2008). Groundwater abstraction in these areas combines hand-dug shallow wells with a large diameter (3 to 5 meters) with deeper boreholes down to 100-200 meters (ibid.).

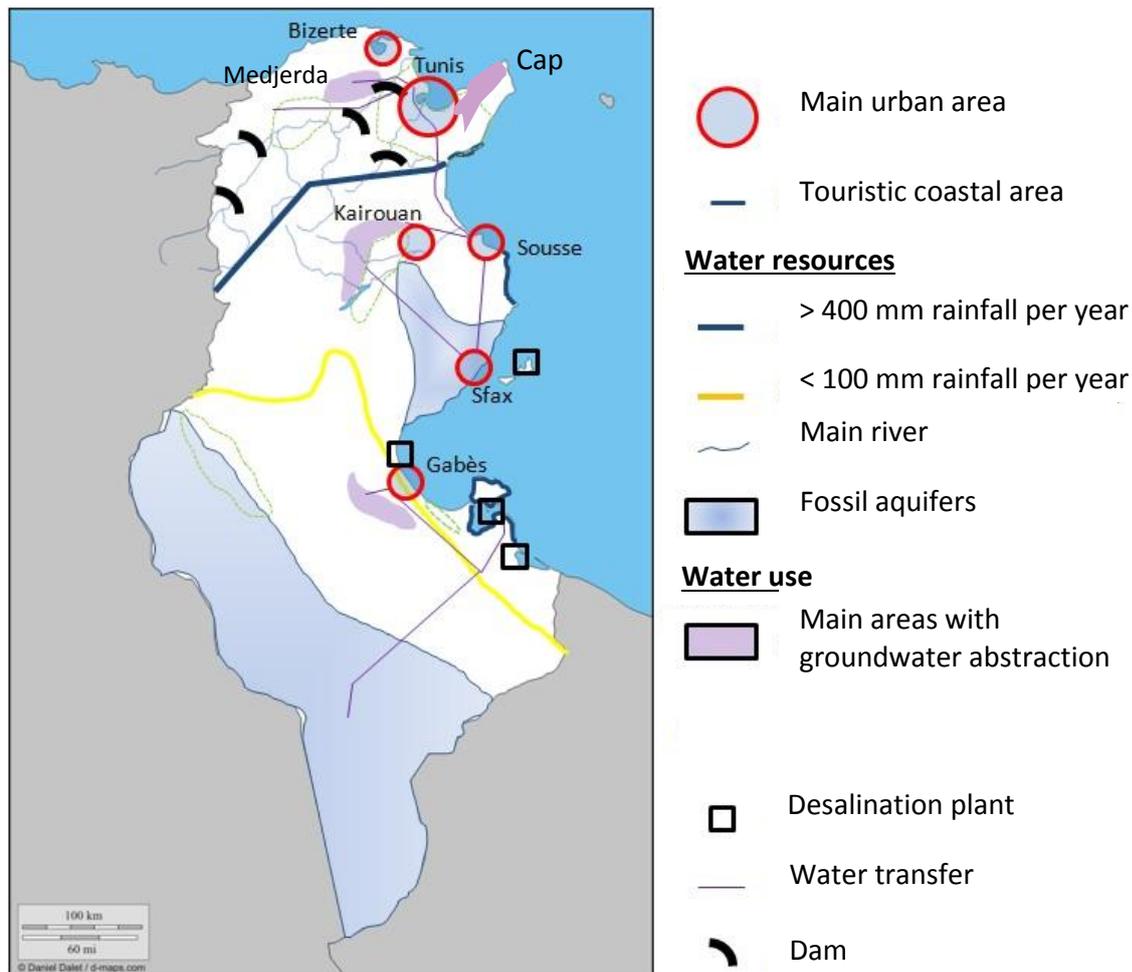
Groundwater in Central Tunisia is found in multi-layered detrital aquifer formations reaching up to 600 meters in thickness, and is abstracted mostly via boreholes (200 to 500 meters) (ibid.). Some of these formations are partially confined and give rise to hydraulic heads causing the overflow of the aquifer into wadis (ibid.). Most shallow groundwater resources (there are more than 210 shallow aquifers where groundwater is found at a maximum depth of 50 metres) are found in the north (50 percent) and the centre of the country (34 percent of shallow groundwater) (Figure 10) (ibid.). Deep groundwater in Tunisia is mostly found in the south (56 percent of all deep groundwater) where large aquifer reserves including the Jeffara aquifer in Gabes, and two large fossil aquifers in the Sahara region, the calcareous and sandstone Complex Terminal Aquifer with an area of 350,000 Km² in Tunisia, and the calcareous Continental Intercalaire aquifer, with an area of around 600,000 Km² in Tunisia (ibid.). These two aquifers are part of the North-Western Sahara Aquifer system shared between Algeria, Tunisia, and Libya.

Figure 10. Shallow and deep aquifers in Tunisia



Note: in blue are the shallow aquifers and brown the deep aquifers. Source: Hamdane 2014a.

Figure 11. Water resources and infrastructure in Tunisia



Source: adapted from www.d-maps.com and <http://k-classroom.blogspot.com/2012/04/pour-les-5e-tozeur-et-la-gestion-de-la.html> (Accessed 4th September 2014).

3.2 Groundwater management and regulation in Tunisia

Groundwater use for irrigation in Tunisia represents 86 percent of the total use of this resource in the country (Gaubí 2008). Shallow groundwater is the most prevalent type of water used for irrigation in Tunisia (supplying 48 percent of water needs for agriculture followed by deep groundwater supplying 25 percent and surface water with 21 percent) (Hamdane 2014a). In Tunisia, the number of wells doubled in 20 years reaching 120,000 in 2000 (Faysse et al. 2011). Other more recent estimates such as FAO (2009d) indicate that there are over 137,700 shallow wells in Tunisia of which around 95,000 are equipped with pumps. These same estimates indicate that for deep groundwater pumping, the number of tubewells rose from 1,791 in 1990 to 5,111 in 2005 (of which 308 are artesian boreholes) and 66 percent of these wells are located in the south of the country (Gaubí 2008). Electric pumps represent around 41 percent of the total energy use for groundwater abstraction in the country (Hamdane 2014a).

This groundwater revolution in the 1970s went also in parallel with a process of land reform in Tunisia. After the country's independence in 1956, the state nationalized in 1964 large areas of land previously colonized by French farmers (Geroudet 2004). Although these areas were to be managed through cooperatives, such model of management and production lasted less than a

decade. In 1971, land was allocated privately via decree and farmers obtained in some cases property titles. In many cases however, land division was not done officially and families organized their own land plotting and allocation via inheritance and not official allocation (ibid.).

Two types of groundwater management can be differentiated in Tunisia: 1) private, individual, and free access to the resource, which in the last few years have multiplied and become more atomized and with smaller land plots leading to an increase in the number of wells (shallow dug wells and deeper boreholes); 2) organized groundwater management, either through the state or GDAs (*Groupements de Développement Agricoles*) for irrigation or drinking water supply, and also present in most oases in the south (abstracting deep groundwater). This second type of management shows different types of arrangements between users and the degree of involvement of the state. Groundwater in shallow aquifers can be abstracted individually but also via organizations. Groundwater abstraction in deeper aquifers requires permits and organized regulation is more prevalent.

Geographically, these types of groundwater management in Tunisia exist through four types of groundwater abstraction and use:

- 1) *Individual private abstraction*, in the north and east of the country and mostly from shallow aquifers;
- 2) *Public irrigated perimeters*, organised in GDAs and representing 57 percent of the total irrigated area in the country (2005 data);
- 3) In the south, groundwater is mostly used in *oases* and managed through GDAs;
- 4) *Conjunctive use* (surface and groundwater), covering around 15 to 20 percent of all privately irrigated land in Tunisia.¹⁰

Groundwater-fed irrigation is also characterized by specificities related to agricultural production. In the Jeffara Aquifer (in the coastal plains in the south) an intensive coastal oasis system prevails with pomegranate production (Gaubi 2008). In the Chott oases in the south, intensive date production is the prevalent activity. In the Cap Bon, irrigated perimeters with groundwater intensively cultivate fruit and vegetable crops, as well as in Kairouan and Sidi Bouzid in central Tunisia (ibid.).

Groundwater in Tunisia is regulated through the 1975 Water Law (*Code de l'Eau*). The promulgation of the Water Law in 1975 transformed the legal status of water resources, establishing user rights and entrusting the responsibility of its application and overseeing to the Ministry of Agriculture. The public hydraulic domain had earlier been defined under the French Protectorate in a Decree in 1885, including all surface water bodies but not groundwater. In 1975 the Water Law (*Code de l'Eau*) included groundwater as part of the public domain (*desmène*) (ibid.). The 1975 Water Law (amended in 1987 and expanded in 1988 with the Law 88-94, later modified in 2001 by the Law 2001-116) introduced, other than the concept of the public hydraulic domain, the preeminent role of the state in water resources management and planning, the protection of the environment (controlling and banning pollution of water bodies), as well as the possibility of user-based water resources management. Additionally, the 1975 Water Law introduced water tariffs for agriculture in publicly irrigated areas as well as water

¹⁰ The conjunctive use of groundwater and surface water in Tunisia is mostly done in the designated 'safety perimeters'. The most important one is the 'safety perimeter for citrus' in the Cap Bon (*sauvegarde des agrumes du Cap Bon*) (9,000 hectares) and supplied by a water transfer from the Medjerda to the Cap bon, groundwater from the Grombalia Aquifer, and surface water from the Bezirk dam (Hamdane 2014).

supply. The public hydraulic domain was to be managed and overseen by the Ministry of Agriculture.

Groundwater users are required to obtain an authorization for the abstraction of groundwater resources deeper than 50 metres, a depth that reflects the time when wells were dug manually and has not been updated ever since. Authorizations, or use rights ('*droit d'usage*') are automatically transferred in case of change in land ownership (but this has to be declared within 6 months). They can be revised based on changes in overall supply and demand or allocation priorities. A modification of the Code in 2001 (Law No. 2001-116) gives power to the governor (wali) to establish rationing, in case of crisis.

An application decree (Tunisie 1978) addressing the exploitation of groundwater specified that authorizations to drill wells (deeper than 50 metres) do not entitle the landowner to use water, for which a 'concession' is needed. Companies drilling wells must send a detailed technical report about each operation and these companies are classified in 7 categories with different levels of capital, equipment, and specialized staff, for which Professional Cards with 5 year guarantees are delivered (and withdrawn in case of malpractices) (Tunisie 1997).

Additionally, the Ministry of Agriculture can declare some areas and aquifers as 'exclusion areas' where groundwater abstraction is only authorized by the government. Specific areas can also be declared as 'prohibited areas' where all new drillings and well upgrading are forbidden, and where abstraction can be limited by quotas or simply discontinued, should technical studies show the need for such measures (Code des Eaux 1975). In the '*Périmètres de sauvegarde*', all works must be authorized by the Ministry of Agriculture. In both areas officials are free to access properties and wells at any time, for control or conducting technical tests and monitoring.

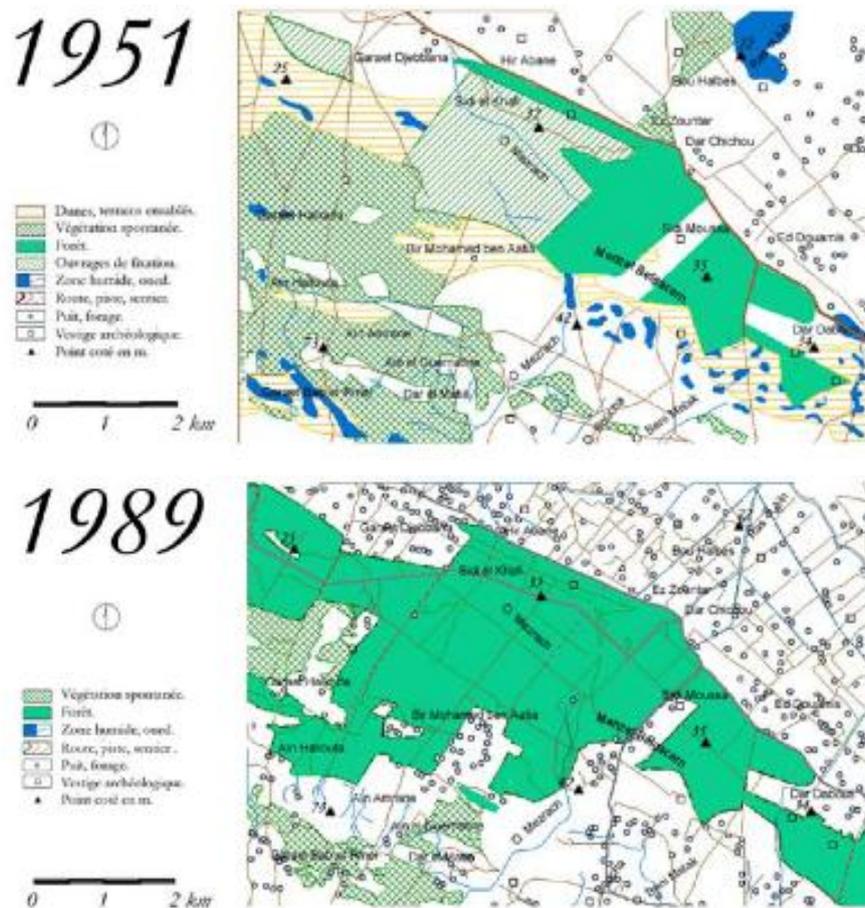
3.3 Groundwater overexploitation in Tunisia

Despite these regulatory measures, aquifer overexploitation in Tunisia is an important issue, with 71 out of 273 aquifers overexploited at an average rate of 146 percent (Frija et al. 2014). The growth of groundwater use in Tunisia is well illustrated by the region of Sidi Bouzid, Central Tunisia. In the 1960s, around 2,000 hectares were irrigated, increasing up to 47,000 hectares in 2010, 80 percent of which are irrigated privately. The state, via several PPIs abstracting groundwater, irrigates 5,740 hectares (Jouili et al. 2013). Private irrigation via shallow wells (less than 50 meters) had a rapid development in the 1970s and 1980s when the number of private wells increased from 2,700 in 1970 to 4,000 in 1980 and around 10,700 in 2013. Groundwater over-abstraction led to the abandonment of approximately 1,000 wells by 2010. Jouili et al. (2013) mention a level of exploitation of 20 Mm³ above the available groundwater resources (132 percent exploitation). For those farmers still able to abstract groundwater, they have to deepen their wells every 2-3 years (ibid.). This race to the bottom works in favour of investors and to the detriment of small farmers who do not have the capital to deepen their wells.

The case of the Haouaria plain, a quaternary calcareous and alluvial depression in the north-east of the Cap Bon peninsula in North-east Tunisia, also illustrates the growth in groundwater abstraction. The cultivated area between 1896 and 1989 increased by up to 148 percent, with an important increase in well density between the 1950s and the 1980s (Brun 2006; Ben Hamouda 2008) (Figure 12). In this plain, two types of aquifers can be found, a shallower aquifer initially at 10-20 meters and a deeper confined aquifer at 150-350 meters (ibid.). The last two official estimates by the Ministry of Agriculture established the number of wells at 4,474 in 2006 (Brun 2006) and 5,330 in 2008 (Ben Hamouda 2008, according to the last agrarian census), with mostly all of them are tapping into the shallow phreatic aquifer (only 55 deep boreholes had

been officially inventoried in 2004 tapping into the deeper aquifer).¹¹ The shallow aquifer is, according to Ben Hamouda (2008), the most exploited aquifer in Tunisia (with levels of exploitation of 194 percent) (ibid.). This has caused salinization problems with an increase of salt concentration in groundwater from 3 grams per litre to 5 grams in 2008 (ibid.). The evolution of groundwater levels in Haouaria have decreased between 1 to 14 meters in the different piezometers controlled by the Ministry of Agriculture.

Figure 12. Evolution of density of wells in Dar Chichou, Cap Bon in 1951-1989



Note: Wells are represented by white circles. Well density increase is noticeable on the right side of the forested area (in green) between 1951 and 1989.

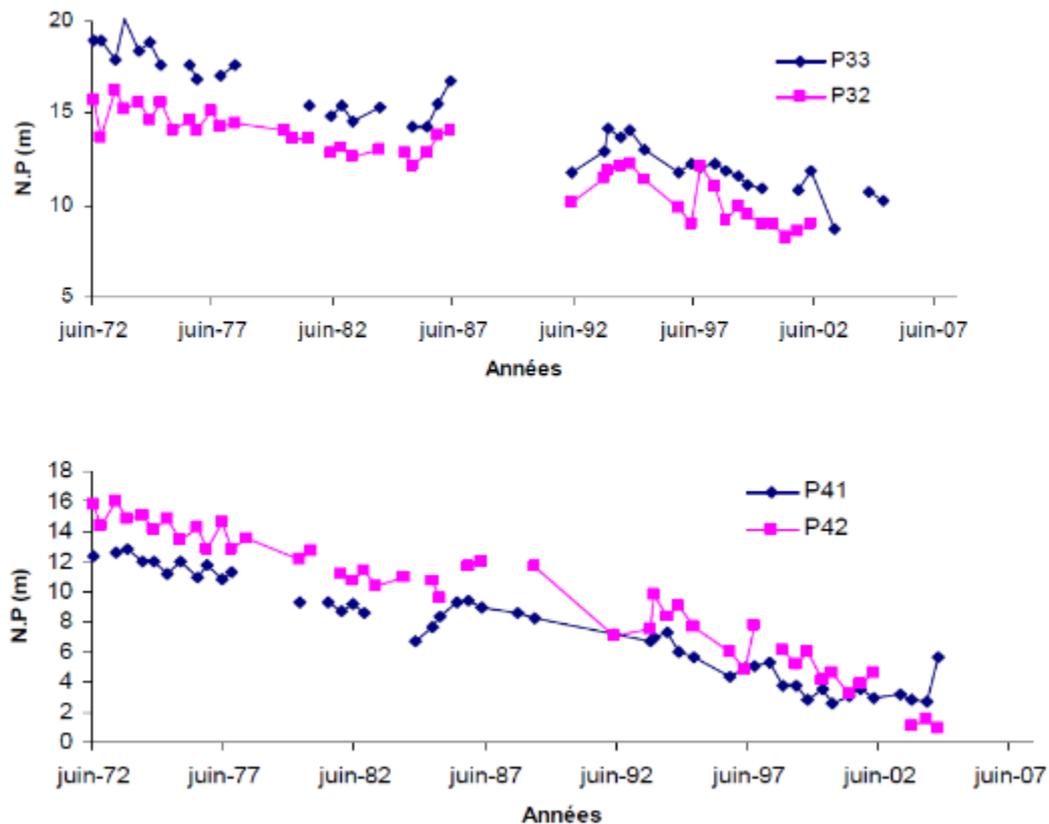
Source: Brun 2006.

Kacem et al. (2008) provide another example of overexploitation in Sisseb El Alem basin, north of Kairouan in central Tunisia, where groundwater was started to be tapped in the 60s and is now the resource for 15,000 ha of irrigated land, tourism as well as coastal cities. Well densities reach 20 well/km² in the Sisseb area. Changes have been extremely typical of such situations, with an exploitation now stabilized at the cost of a constant deepening of the wells (drop of between 30 cm to 1 m per year), the drying-up of 500 superficial wells, the abandoning of hundreds of ha of irrigated land, a growing salt content in the water abstracted. A surge in well drilling has been reported after the revolution in the Nadhour area, and some GDA have

¹¹ Field observations suggest that this number is much higher. Given the legal definition of shallow/deep groundwater, many wells are officially registered as shallow wells pumping water at depths shallower than 50 metres. However, many farmers have wells which have been increasingly deepened throughout the years, reaching depths below 50 metres (Ghazouani and Mekki 2015).

stopped supplying water to farmers outside the official boundaries of the scheme and to cap the irrigated area allowed for each farmer in order to reduce pressure in the water system (Faysse et al. 2011).

Figure 13. Evolution of four piezometers in Haouaria, Cap Bon (1972-2007)



Source: Ben Hamouda 2008.

3.4 Measures to curb groundwater use in Tunisia

In 1980 the Ministry of Agriculture evaluated for the first time the situation and abstraction levels of the shallow groundwater resources in Tunisia. Since then and every 5 years the Ministry issues a study presenting the situation of exploitation of all shallow aquifers, with estimates of abstracted volumes based on a sample study (given the fact that shallow wells do not have installed water meters) (FAO 2009e). The actualization of data for this process is problematic as the Ministry only uses, for its census of wells, new requests for subventions for the construction of a well and the installation of new equipment. This automatically excludes from the census the new wells drilled or dug without subsidies or financial help from the state. The fact that data is also not verified on the ground means that abandoned wells are still accounted for. The Ministry of Agriculture also releases since 1972 an annual study of the situation of deep groundwater aquifers (ibid.).

The National Strategy for the Development of Water Resources issued in 1991 aimed at improving the network of monitoring and control of groundwater resources, replacing old wells used to measure groundwater levels by piezometers (FAO 2009e). The first piezometric study was released by the Ministry of Agriculture in 1991. At the time the network consisted of 2,719

shallow wells used to measure the depth of the water table and 303 piezometers. By 2004 the country had 1,016 new piezometers.

Wastewater is also used for agriculture since 1989 after the official publication of treated wastewater quality standards for agriculture (FAO 2009e). In 1992, what was the testing of experimental aquifer recharge became a country priority and started being implemented at the country level with the National Strategy for the development of Water Resources (1991-2000) (ibid.). In terms of its national contribution, aquifer recharge represents 4 percent of the total recharged volume in the country (the main method used are small dams (*barrages collinaires*) recharging 92 percent of the recharged volume in the country) (Hamdane 2014a).

In 1995 in the south, the national public water utility (SONEDE) started a large program of investment to improve the quality of public drinking water (due to increasing salinity) via the installation of desalination plants (three in the south in Gabes, Jerba, and Zarzis). Additionally, the installation of smaller treatment plants to satisfy the demands of tourism and industry was completed (over 60 small-size stations) (Gaubi 2008).

Also in 1995 a large country-wide program of water savings was launched by the Ministry of Agriculture as part of Tunisia's 8th Social and Economic Development Plan (1992-1996) (Gaubi 2008). The program focused on the centre and south of the country aiming to supply the large and medium size irrigated areas with new means to save water. The program aimed at improving water efficiency at the plot level, improving the economic value of water, and maintaining water demand at a level compatible with the availability of resources. This program consisted in the installation of improved gravity systems (over 101,000 hectares), sprinklers (in over 110,000 hectares), and drip irrigation (installed in around 113,000 hectares) (ibid.). The use of drip irrigation in the country increased from 3 percent of the irrigated surface in 1995 to 28 percent in 2006. The Ministry gave financial incentives for the installation of these types of technologies (financing up to 60 percent of the investment depending on the type of the farmer (ibid.). The modernization of irrigation systems after the national program of water savings grew from 37 percent of improved irrigation techniques in 1995 to 83 percent in 2009 (with the use of localized irrigation techniques, i.e. drip irrigation, sprinklers, and improved flood irrigation) (Hamdane 2014a).

A new National Water Strategy for Tunisia is aiming to mobilize 95 percent of the country's water resources by 2016 (Hamdane 2014a). It also seeks to improve the sustainable development of groundwater resources via the drafting of a national strategy for the preservation of groundwater resources. This new groundwater strategy aims to introduce a regulatory and legal reform with the revision of the Water Law (currently being reviewed) and more stringent and coercive regulatory tools in the legal framework, reinforcing state control measures. Additionally, 9 new protection areas will be declared (Haouaria in the Cap Bon peninsula is included) (ibid.). The state is also aiming to establish specific GDAs for groundwater management (which will include every well, shallow and deep, within a designated irrigated area). The Groundwater strategy being developed also includes the improvement of the piezometric network (60 new piezometers and the installation of automatic data collection systems in 174 existing piezometers) (ibid.). The strategy is also aiming to install meters for wells deeper than 50 meters (initially in 2,000 wells) although it does not state so far who will pay for them.

3.5 Tunisia's model of decentralized groundwater management

The centralization of water and groundwater resource management which appeared after the country's independence and materialized through large infrastructure projects and the development by the state of Public Irrigated Areas in Tunisia lasted until the 1980s. At the time, the 'Office for the Development of Medjerda Valley' was responsible for the central management of all water resources in the country (Frija et al. 2014). These government-controlled Public Irrigated areas in Tunisia experienced problems in the 1980s due to difficulties in collecting Operation and Maintenance fees, which contributed to the extinction, in 1986, of the Development Offices in charge of the public irrigated areas (Le Goulven et al. 2009). As Sghaier (2010) and Jouili et al. (2013) wrote, following Tunisia's acceptance of Structural Adjustment Programme from the World Bank and the IMF in 1987, a new approach towards groundwater governance was established, aiming at progressively disengaging the state from local community water management, implement new reforms to increase the role of users and the decentralisation of agricultural development, and shift towards water demand management.

The state dissolved the Offices of Agricultural Development (OMVAs in the French acronym) in charge of the public irrigated areas and replaced them by the Regional Commissions for Agricultural Development (CRDAs) as well as local Associations of Collective Interest (AICs in its French acronym) (Jouili et al. 2013; Mouri and Marlet 2007; Sghaier 2010). The role of the AICs was established in the Water Code of 1987 as a local institution created through the initiative of users and the administration, able to collect revenues from member subscription fees, subsidies from the CRDAs and the sale of water to users (Sghaier 2010). A management agreement granting administrative control of state hydraulic infrastructure was signed giving the responsibility of the operation and management costs to the AICs. This amendment extended the idea of the AICs (until then only found in oases) and generalized it across the country for all types of water user associations (Mekki and Ghazouani 2012). Additionally, the creation of AICs was also put forward as a way to avoid the deadlock found in the CRDAs as their operational role in managing irrigation and water resources had been overwhelmed and burdened by administrative tasks and agricultural promotion, - as they were under the tutelage of the Ministry of Agriculture (Hamdane 2014b).

During the 1990s, as Mekki and Ghazouani (2012) and Sghaier (2010) relate, the AICs associations were granted increasing autonomy. In 1990, a new decree regulated that the creation of these associations could be made effective by a provincial governor proclamation and not the Ministry. In 1992, AICs were granted financial autonomy (having to directly collect user fees and membership fees, and also being able to set up water tariffs). As a result of this move, in 1999, a new law broadened the scope and mission of the AICs and re-named them as GICs (Groups of Collective Interest in the French acronym). The GICs would be in charge of the maintenance, and management of water networks and the salaries of its staff members (Sghaier 2010). The role of GICs was extended at the local level, hoping to achieve an almost complete financial disengagement with these organizations, only collecting fees through the CRDAs (Le Goulven et al. 2009).

During a third period, beginning in 2004, the GICs were eventually transformed into GDAs (Groups of Agricultural Development in the French acronym), with an increased autonomous responsibility vis-à-vis its users and managerial attributions. This later modification arose due to the fact that some GICs in Tunisia undertook some lucrative activities linked to agricultural work, and commercialization of production inputs, thus competing with already established

cooperatives (Sghaier 2010). Following this confusion, the 2004 law also redefined the mission of the GDAs and revoked such responsibilities (ibid.).

The GDAs (*Groupes de Développement Agricole*) were presented by the new law as a new mechanism allowing the triangulation between the administration, natural resources, and agriculture, fitting into a new recognition of 'civil society' with farmers considered as a group of users active in water resource management (Canesse 2010a, 2010b). GDAs were thus created as associations of irrigators that can be either located within a large public irrigation scheme, or independently managed by the users themselves (e.g. in oases). They also aimed to recognize the principle of association as part of an intrinsic process of participation and local development whereby farmers have to engage in an elective process to appoint representative members in the GDA board (ibid.).

The 2004 Law established for the GDAs, apart from their already defined water management activities (selling water to their users, collecting fees), specific management rules, asking them to elaborate activity plans, as well as financial projections, control their own management procedures, and establish salary rates (Mekki and Ghazouani 2012; Sghaier 2010). The GDAs would also act according to the Law as intermediaries between the Ministry of Agriculture (via the CRDAs) and the users, channelling subsidies for the users. The CRDA would remain in charge of supplying water to the GDAs (owning the abstraction wells, reservoirs and infrastructure supplying bulk water to the GDA network) (Mekki and Ghazouani 2012). In terms of devolution following these legal changes, Sghaier (2010) wrote that by 2006, the transfer of managerial functions from the public irrigation schemes to the GDAs at the national level had reached 75 percent.

In Tunisia, the number of GDAs in public irrigation schemes (and its predecessor, GIC) evolved from 100 (mostly in oases) in the 1980s to about 2,800 in 2004, existing mainly in the central and southern regions. These are divided between GDAs managing irrigation schemes and GDAs for rural drinking water schemes (around 1,600 in 2004) (Al Atiri 2005). According to Hamdane (2014a), in 2014 there were 1,253 GDAs for irrigation managing around 195,000 hectares of irrigated land (82 percent of the total publicly irrigated area in Tunisia). Of those publicly irrigated areas with groundwater, the level of transfer of the management and operations to GDAs represents 90 percent (ibid.). According to the country's water law, all natural resources associations had to be constituted as GDAs before the 17th of March 2007, and the GDAs could also be dissolved by the state. The creation of GDAs, according to Canesse (2010b), reflected a policy to engage rural institutions in productive activities and improve natural resource management. With a large set of competencies according to the law (e.g. local development, marketing, agricultural goods transformation, water infrastructure), the GDAs role became that of devolving management roles to the users, diversifying the role of user associations, whilst liberalizing agrarian economies and improving commercialization by transferring competencies to the private sector and civil society (ibid.). Yet, GDAs are financially accountable to the state (they are audited yearly either by the ministry of finance or by licensed private auditors). But GDAs staff are unpaid and may be quick to resign if pressured with regard to their financial management.

Despite these official objectives expressed in terms of participatory management, it has long been recognized that these associations were often under the influence of local authorities and politicians who would meddle in different ways (selection of board members, and hired staff; use of the associations as political springboards; financial takings, etc.) (Mekki and Ghazouani, 2012). Since the revolution however, these interferences have substantially decreased, while freedom of expression and demands have soared (Marlet 2013). Another problem faced by the GDAs is the fact that they were originally designed for certain farming practices, crops, and

water needs. The increasing use of water-thirsty crops and the intensification of agriculture has resulted, in some cases, in the poor performance of the GDAs' infrastructure as their water production capacity and supply are under-dimensioned. This has led farmers to expand their lands to areas outside the command area of the GDA and drill private wells to access additional water (Riaux et al. 2015).

GDAs can however be adequate partners in options of co-management of aquifers, as seen in the Bssi case. This aquifer had long been exposed to the proliferation of illegal wells, supplying water to the very intensive agriculture. In 2000, after severe social tensions and a recognition by the administration that steps should be taken to find a solution, a partnership between stakeholders was established in order to implement a management system for the aquifer. This led to the creation of the Association for the development, monitoring, and exploitation of the Bssi-Oued El Akarit aquifer. This association was instrumental in backfilling some illegal wells as well as preventing the drilling of new tubewells (Hamdane 2015), and also tried to control the allocation of the pumping capacity. It did achieve some decrease in the amount of water used, in the total irrigated area, and the number of boreholes drilled.

3.6 Authorizations and enforcement

Any person willing to drill (or deepen) a well must start a process through the CRDA, filling the adequate form and presenting the needed documents (land property deeds and a technical reports issued by a private company authorized by the CRDA which costs approximately 500 TD). The CRDA establishes a technical report, checking whether the intended use conflicts with existing or projected needs, or is situated in protected or prohibition areas, possibly reduces the discharge requested, and sends the file to the commission of the Hydraulic Public Domain in the ministry. Unless there are particular circumstances, the permit is granted, the social situation (as well as the political situation since the revolution) not allowing much room for maneuver. Although the process should not be longer than three months, cases have been reported in Haouariya where it took more than two years. Some CRDA may have some additional internal rules, such as in Nabeul where an authorization would not be granted for a plot of land smaller than one hectare (this has recently been changed to 0.5 hectares, to take account of small orchards).

In all cases well drilling is subsidized, because it is seen as a means of expanding livelihoods opportunities in the countryside (if the farmer drills a well without finding water he may even get some compensation from the state). Subsidies at the level of 25 percent are given for drilling but also for farm-level investments such as pumps, storage basins, piped networks, etc. Subsidies are also granted for a shift from gravity to drip irrigation, and for gasoline or electricity used for pumping. The authorization specifies the quantity that can be abstracted (which is expressed in l/s continuous flow - *debit fictif continu*) and the type of crops is only asked for reference. Once the authorization is granted farmers are free to do what they want with this water, as long as this is agriculture, although theoretically the CRDA is expected to check every year if the clauses of the contract are respected, while the farmer would also need to renew his license yearly at a cost of 125 TD. The fact that farmers are never sure of whether they will be granted a license (aside of course of situations where they do not fulfill the requirements), that authorizations are paid for, and that abstraction licenses need to be renewed each year make it unattractive for someone to register a well.

Those who drill wells illegally, however, cannot request subsidies or a connection to the electric grid. In 1995 it has been planned to limit the power of the connection requested based on the declared irrigated area. Meters, however, have never been made compulsory in tubewells, first because of their relatively high costs (500 TD at least) and second out of the sound and

pragmatic recognition that they would be tampered with, and that the corresponding capacity for control by the state would not be forthcoming (Hamdane 2014b). Likewise, no groundwater charge has been either planned or implemented (unless water is supplied by a public scheme).

Groundwater use in non-agricultural sectors is often planned and developed without coordination with the CRDA. Industries are planned and then their water needs are transformed into requests to the CRDA. The governors (walis) commonly go to the central government and militate against control on groundwater use and make requests to the government to support industrial and tourist development in their provinces.

The CRDA is also responsible for enforcing the law ('water police'), but engineers don't have the culture of monitoring and enforcing, are not given the means to do the control in the fields, and do not feel they are backed or pushed by any political will to constrain groundwater use. Gaubi (2008) also notes "the weak support of political local authorities to exercise control and enforcement of administrative sanctions" and estimates that "the Water Code is, on the one hand, not implemented and, on the other, insufficient to provide a legal framework for a strategy of integrated groundwater use". Aquifers such as those of Teboulba, Ksar Hellal, Grombalia or Sidi Bouzid have been declared protection zones as early as 1981, but overexploitation has remained unabated, even when some 'safeguard' surface water has been transferred from other basins. At present, for example, 60 Mm³ are transferred from the North to The Cap Bon (Nabeul Governorate) to replace failing groundwater and 'safeguard' fruit trees. Initially this additional water amounted to 30 percent of the needs, but in some places like Grombalia citrus orchard area, this percentage has risen to 90 percent (Tayeb 2016).

3.7 Groundwater in the Merguellil basin, Tunisia

The Merguellil basin is located in central Tunisia and is one of three basins flowing into the Kairouan plain towards the sea (Figure 14). Given extreme intra-annual rainfall variability causing occasional severe floods, the basin is regulated by three dams, the Nebhana dam constructed in 1965, the Sidi Saad dam built in 1981 and the El Haouareb dam built in 1989 with a storage capacity of 90 Mm³ (Le Goulven et al. 2009; Leduc et al. 2004). There are also 4 aquifers in the basin, three located in the upper basin and one in the Kairouan plain. Before the construction of the El Haouareb dam, the Kairouan plain aquifer – the main aquifer in the basin with an extension of 3,000 km² and depths of up to 700 meters, was replenished by the rapid infiltration of flood water (Le Goulven et al. 2009). Since 1989, the El Haouareb dam has stopped most of the Merguellil River flow thus changing the water balance and replenishment regime of the aquifer, now being recharged by lateral groundwater inflows from neighbouring aquifers (Leduc et al. 2004). Additional recharge for the aquifer occurs via losses from the dam through karstic cracks, an unexpected but welcomed process saving water from evaporation in the reservoir and smoothing inter-annual climatic fluctuations (Le Goulven et al. 2009). It has been estimated by Leduc et al. (2004) that around 25 percent of water reaching the El Haouareb dam is evaporated and 63 percent recharges the aquifer. The rest is piped to and used for irrigation in a public irrigation scheme downstream, the El Haouareb Public irrigation scheme (PPI) developed in 1993, with 2,245 hectares and 550 farms (which now uses also groundwater).

The lack of enforcement and effective direct measures to control groundwater abstraction in the Merguellil (e.g. a 'water police' to control groundwater abstraction in the public irrigation schemes in the Kairouan plain), have led the state to put in place indirect measures such as water tariffs (10 fold increase in 15 years) (Kefi et al. 2003). Additionally, the state has progressively given the control and management of these PPI back to the users organized in GICs. This produced, in the PPI of Chebika East in Kairouan for example, a reduction of groundwater abstraction by users supplied through the PPI down to 15 percent of the capacity

of the system at full abstraction during 24 hours (*ibid.*). These results however hide the reality of private groundwater abstraction with individual wells drilled by those farmers who can afford it and which supplies approximately one third of the area of the PPI (*ibid.*).

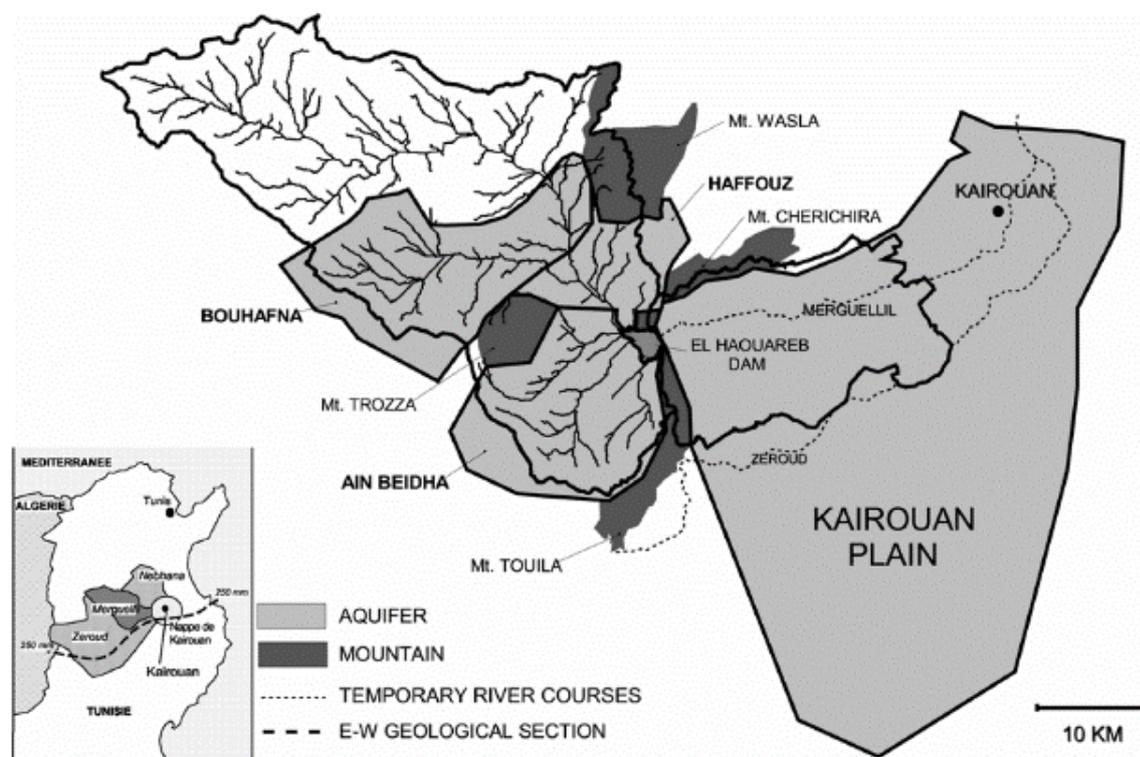
The number of wells (and year of construction) is not necessarily a good indicator of abstraction (Massuel et al. 2017): some farmers record the last time they deepened the well as the drilling year; when the land is divided within the family, sometime people prefer to drill their own well because of the will to be independent but also because of the social status, even though these new wells will be much less utilized (because the plot is smaller); sometimes 2 or 3 older wells are replaced by a deep borehole; in these situations the fact that old wells are not used anymore is not recorded. The number of wells in Kairouan is not well known. Before the Revolution official figures would indicate that between 2,000 and 3,000 wells were licensed. The costly study carried out by a private company found out a total of 6,600 wells (active or and used) on one part of the plain, which after extrapolation provides an estimate of between 8000-9000 wells for the plain (Massuel 2015). But in 2013, the Ministry of Agriculture gave farmers two months to register their (illegal) wells with the CRDA, after what they would be allowed to obtain a connection to the rural electricity grid (360 V, with preferential tariffs). In a matter of weeks 12,000 applications were made, on top of the already licensed wells. It is unclear what happened to these applications and which wells were eventually legalized (Massuel 2015). In any case, farmers are also running their pumps with domestic (220 V) electricity, and even build makeshift houses on the plot they want to irrigate in order to claim domestic extension of the domestic electricity line (*ibid.*).

Studies on the Karma 1 and Karma 2 schemes created by the state in 1975 and gradually turned over to user associations (Giraldi 2012; Riaux et al. 2015), in particular to GDAs after 2006, illustrate features that are quite similar to what has been found elsewhere (e.g. Leghrissi 2012; Gana 2009; Ghazouani et al. 2012a; Ghazouani et al. 2012b). Each scheme is based on one well that serve 73 and 35 ha, respectively. These schemes have been modernized in 2002 in order to increase efficiency, which included the building of an intermediate reservoir, from which water is pumped and distributed under pressure at the level of hydrants equipped with meters, from which farmers can use drip irrigation systems. The main problem is the lack of financial sustainability. Although all water users are supposed to pay for water ahead of the season, in practice one third of them only pays after harvest, and in some cases don't pay at all. The money collected is in any case insufficient to face major maintenance needs, such as replacing engines when their efficiency decreases, impacting the amount of water abstracted to the point that needs cannot be met. Although GDAs are direct clients of the electricity company, in practice when they don't pay the CRDA generally comes in to cover the shortfall, or transforms the GDA debt into a CRDA debt. According to one CRDA official in Kairouan, 90 percent of the GDA are financially dependent from the CRDA, and total arrears for the Kairouan Plain were reported to amount to 750,000 euros (Giraldi 2012). GDAs which do not pay for their water normally see their line cut by the electricity company (STEG). This was common practice before the revolution but became politically sensitive after it, encouraging farmers not paying their fees. But in 2014, El Karma power supply was cut because of default payment, just like several other GDA in the area, incurring agricultural losses. It appeared that collective action, and in particular the payment of the costs by all farmers, is hindered by the financial difficulties experienced by some farmers, the lack of social cohesion of the group of farmers, the alternative water sources available to some of them, the lack of legitimacy of the GDAs (seen as political springboards and instruments of control of the former ruling party), the fact that money collected by the associations was routinely diverted by the people at the helm, and the

perception/expectation that the state which built the scheme will eventually cover the debts (Giraldi 2012; Riaux et al. 2015).

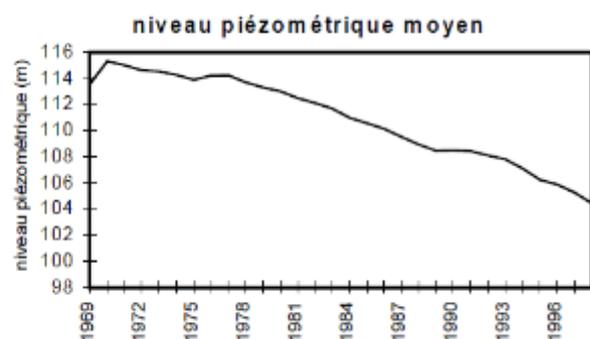
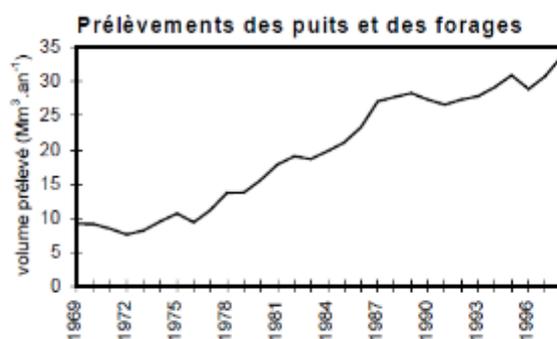
With the water table in the main Kairouan aquifer between 15 and 65 meters, private wells are manually deepened if necessary when the water table drops, in most cases without knowledge from the state authorities in charge of groundwater regulation, and in spite of the fact that according to the Water Law the depth of shallow wells without permit is limited to 50 meters (Bachta et al. 2005; Le Goulven et al. 2009; Leduc et al. 2004). The lack of control of abstractions led to the over-abstraction of the aquifer, with water table dropping by up to 1 meter per year in the 1970s and 1980s (Leduc et al. 2004). Restrictive regulation is not implemented and the CRDAs' water police section is not able to enforce the law. Hand-dug wells continue to be dug, even in the public irrigated areas as farmers try to free themselves from the rigidity of water allocation and turns, and directly access groundwater (Le Goulven et al. 2009).

Figure 14. The Merguellil Basin and groundwater over-abstraction in the Kairouan plain



Groundwater abstraction from wells in Kairouan

Average piezometric level in Kairouan



Source: Le Goulven et al. 2009 (Map); Kadi et al. 2003 and Feuillette 2001 (Graphs).

3.8 Groundwater management in Tunisia's oases

Collective duties organized around water management such as the maintenance of the hydraulic system have long been extremely important for the survival of Tunisia's oases. Landowners would send their tenant farmers to clear up the springs and dredge the canals. Wealthier families with religious links and social status formed local councils with significant influence which took charge of the running of the oasis. Allocation of water resources was however uneven and separate from property rights, linked to traditional power structures rather than land ownership. Landowners would pay for water access by participating in the collective maintenance of the oasis' irrigation system. Additionally, those who did not need all their water share could sell it to others (Battesti 2012).

In the Fatnassa Oasis in southern Tunisia, groundwater was traditionally exploited by collecting the discharge from natural springs and by allocating it according to water rights expressed in units of time. However, since the 1950s the flow of water from natural springs and artesian wells started to diminish as groundwater was abstracted directly through deep public wells for the development of agriculture in other oases. A continuous lowering of the water table led to investments in irrigation and water resource abstraction from fossil groundwater resources sponsored by the state (Ghazouani et al. 2012a).

The oases in Jerid, central Tunisia, are the scene of conflicts over fresh water resources; local people are constantly adapting to new situations, learning to diversify their practices and discourses (Battesti 2012, 2013). The arrival of deep-well drilling transformed the significance and role of water in the Jerid region. With intensive pumping, springs have disappeared and the relations established around water have also changed. Shifts in technology moved the control of water out of the hands of local farmers to the French colonial state first, and then to the Tunisian national government (Battesti 2012).

In Tunisia, the French intervention brought some of the most important changes and innovations experienced in the oases of the Jerid region, taking the resource out of the hands of landowners (Battesti 2012, 2013). With the aim to develop productive agriculture, they created their own palm plantations in the desert and cultivated new lands by drilling wells and established a new model which required hired labour. These changes freed the system of water management from the limited amount of land, water and workforce present in traditional oases systems (Battesti 2013).

With the independence of Tunisia, the trend towards removing control of water from the local authorities in oases continued. Scientific knowledge and engineering was brought in by the state to fulfill the modernization of Jerid oases region whilst the local and traditional peasant culture was considered mainly an obstacle and local knowledge and aspirations deemed unimportant (ibid.). With new groundwater abstraction technology and water table decline, springs no longer were irrigating the oasis. Water lost its social significance as it was no longer under local control. With the disruption and replacement of local traditions, collective work amongst farmers in the oasis was confined to the mutual aid between independent farmers about intensive labor periods (e.g. harvest and pollination). With intensive irrigation with groundwater happening around the oasis, workers in Jerid's palm groves also drilled wells inside their gardens in order to control risk in order to offset insufficient access and supplement irrigation share. Gardens surrounding the oasis and without access to water rights enable farmers to increase their income and are used as a means to increase revenues and social status and standard of living by growing cash crops (ibid.). Intensive drilling from deeper aquifer layers (about 500 meters) dried up the natural springs, and shallower wells became unproductive. Since 2002, more than 90 percent of water use comes from wells and less than 10 percent is artesian (ibid.).

4 Libya

4.1 Groundwater resources in Libya

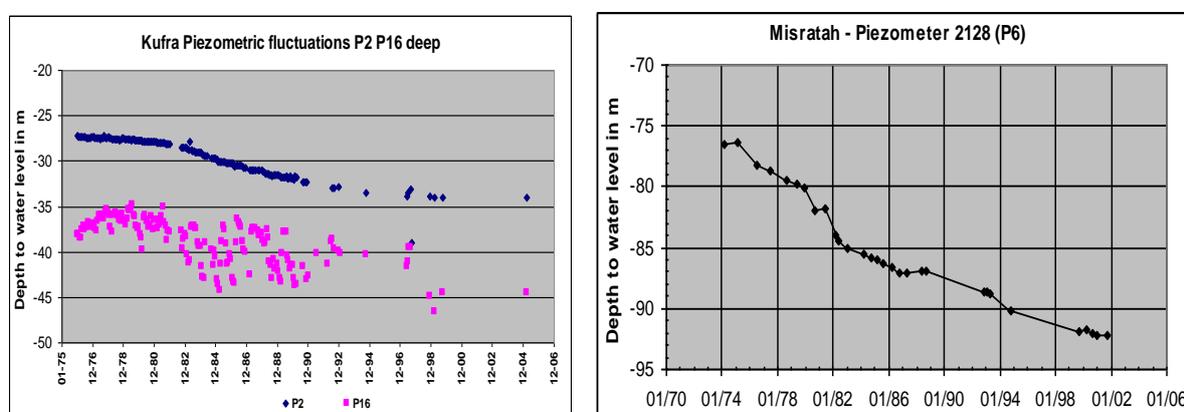
Groundwater in Libya is found in two different geographical locations. The first are the coastal aquifers in the north such as the Jifarah plain aquifer system in Tripoli, recharged naturally from rainfall infiltrating directly or through wadis (FAO 2008c). The Jifarah plain aquifer system had been severely depleted by abstractions for agriculture, with water declines reaching 60 meters between the 1960s and 2003. The second area is located under the 32nd parallel, where large reserves of fossil groundwater are found in the Kufra Sarir basin near the border with Egypt, as part of the large transboundary Nubian Sandstone aquifer system to the south and south-east of the country, and also the Continental Intercalaire and the Complexe Terminal aquifer systems to the west of the country (FAO 2008c) (Figure 16).

4.2 Groundwater abstraction in Libya

One of the most relevant aspects of Libya's groundwater abstraction is the 'Great Man-Made River' Project, a state-led and funded project aiming at abstracting groundwater and transporting it from the south to the north of the country (Figure 15). This project, expected to be constructed in 4 different phases, aims at transferring groundwater pumped from large aquifers in the south to the north where agricultural demand, industrial development and the more urbanized coastal areas need the water. The project was launched in 1984 and 80 percent of groundwater abstracted aimed to irrigate 150,000 hectares and 20 percent for urban uses. The project is designed to convey 6.5 Mm³ per day of groundwater abstracted through 1,300 wells (some as deep as 500 meters) through a 4,000 kilometre-network of pipes across the country (Custodio 2010; Sternberg 2016).

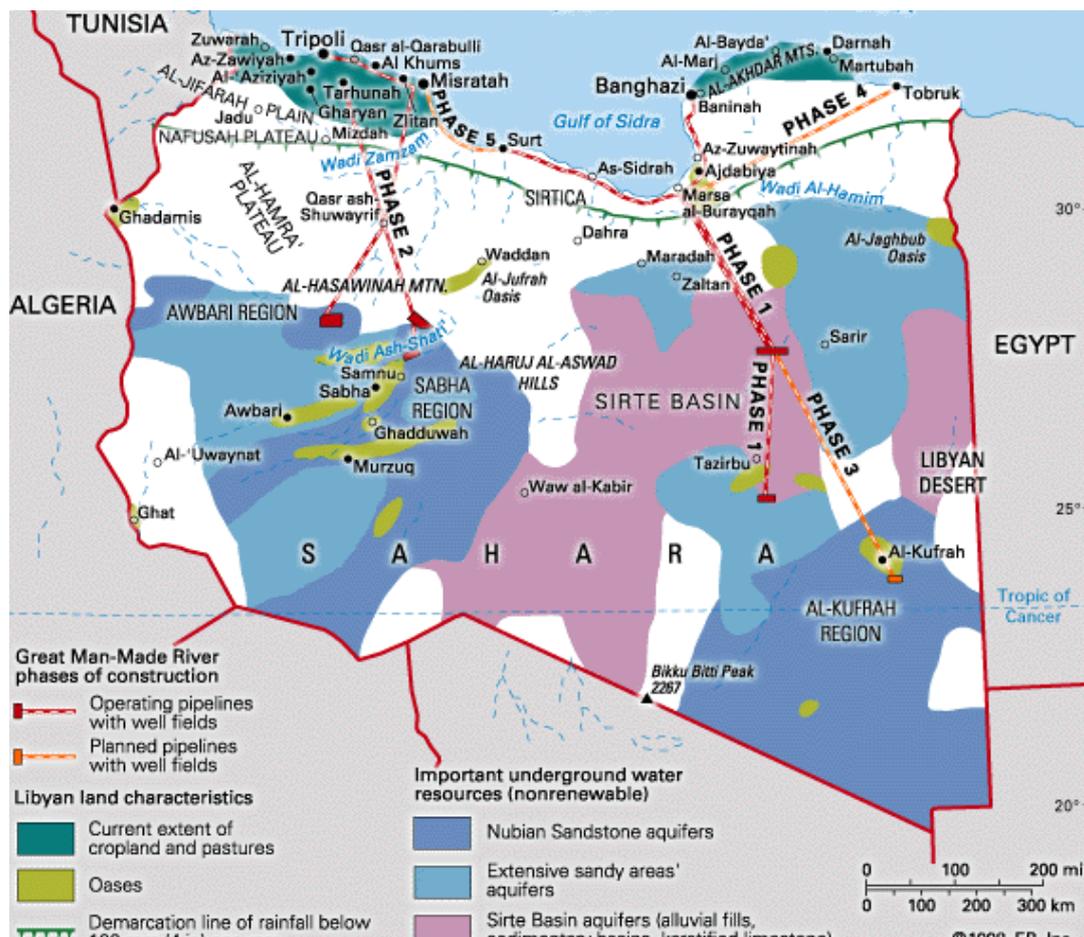
Part of the groundwater pumped for the Great Man-Made River comes from the Nubian Sandstone Aquifer System, which extends over more than 2,000,000 km² in eastern Libya, Egypt, Chad and northern Sudan. Although the regime of abstraction of the aquifer is a small fraction of its total recoverable reserves (2,200 Mm³ per year), localized intensive pumping can have sizeable local impacts, like in the Egyptian oasis of Kharga where deep wells produced a groundwater drawdown of up to 60 meters between 1960 and 1998 (ibid.).

Figure 15. Depth to water level in Misratah (northern coast) and in Kufra (South-eastern desert), Libya



Source: FAO 2008c.

Figure 16. Main aquifers in Libya



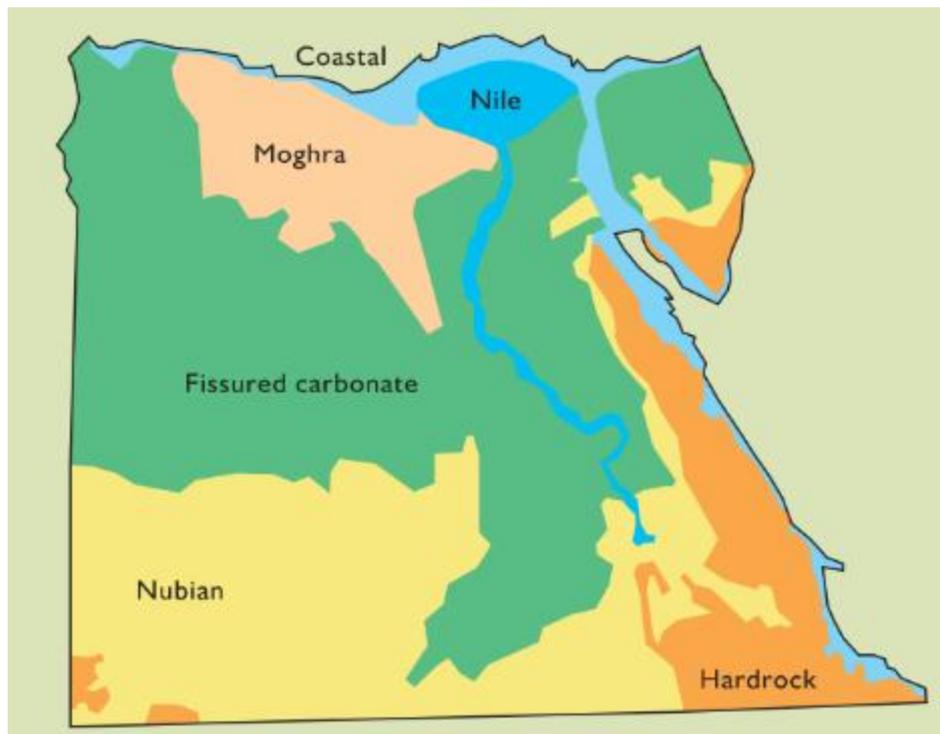
Source: Encyclopedia Britannica, <http://www.britannica.com/EBchecked/topic/243446/Great-Man-Made-River-GMR> (Accessed 14th January 2014).

5 Egypt

5.1 Groundwater resources in Egypt

Groundwater systems in Egypt can be separated into two categories: the first comprises the Nile valley and Delta system; and the second is the desert areas (Abu Zeid 1992). In the desert areas groundwater is mostly found in the Western desert as part of the large transboundary Nubian Sandstone aquifer system and also in fissured carbonate formations (Figure 17). The quaternary aquifer system of the Nile valley is in direct hydraulic interaction with the River Nile, canals, and drains found alongside it and in the Delta, constantly recharging the aquifer (Dawoud and Ismail 2013; El Tahlawi et al. 2008). The Nile Delta aquifer is semi-confined; the top of the aquifer is covered by a thin clay layer, which varies in thickness and disappears in some places. In such places, the aquifer is considered to be phreatic since its free water surface is subjected to atmospheric pressure. The thin clay layer varies from 5 m in the south to 20 m in the middle and reaches 50 m in the North of the Nile Delta. The depth to the groundwater table in the Nile Delta ranges between 1–2 m in the North, 3–4 m in the Middle and 5 m in the South (Mabrouk et al. 2013; El Tahlawi et al. 2008). In 2005 approximately 87 percent of the total groundwater abstraction in Egypt was pumped in the delta (MWRI 2005).

Figure 17. Major aquifer systems in Egypt



Source: MWRI 2005.

5.2 Groundwater regulation in Egypt¹²

In Egypt, the Irrigation and Drainage Law of 1984 legislates groundwater use, regulating the administration at the national, regional and local levels. Article 46 of the Irrigation and Drainage Law specifies that a permit from the Ministry of Irrigation is required to dig any well (whether it is superficial or deep). Well owners have to have permission to construct or operate pumps. The period for this permission will not, according to the Law, exceed 10 years and will have to be renewed every 3 years. Farmers renting land will also have to obtain permission from the owner of the land to construct or install a pump. If the pump is replaced, a new permit will have to be requested if it leads to a change in discharge or location of the well/pump. In the case of a transfer between individuals, the Law stipulates that it will be enough to “write and sign that on the permit, the previous owner shall be still responsible together with the new one to implement the provisions hereunder until the license is signed”.¹³

The law is quite demanding regarding the documents that need to be provided. These include, in addition of the land property title, maps with the location of the well, all neighboring wells (legal or otherwise) and their distance to the projected well, of the fields that are to be irrigated, in two copies to be signed by the district engineer, study of soils samples, commitment to use the wells with the discharge and type of irrigation technology indicated, payment of fees, etc.

The realization by MWRI that Egypt needed a new groundwater law with provisions for more effective controls of groundwater development has prompted several attempts at drafting a

¹² Law No.12/1984 Concerning the issue of the Law on Irrigation and Drainage, http://ocid.nacse.org/rewab/docs/Law_12_1984_Irrigation_and_Drainage_en.pdf (Accessed 7th September 2014).

¹³ Article 51, Law No.12/1984 Concerning the issue of the Law on Irrigation and Drainage, http://ocid.nacse.org/rewab/docs/Law_12_1984_Irrigation_and_Drainage_en.pdf (Accessed 7th September 2014).

revised groundwater law, to address well licensing; the registration of drilling contractors; monitoring and protection of groundwater abstraction; identification of violations and applied penalties (El Arabi and Dawoud 2012).

The proposed draft law (still to be approved) recognized the public property of groundwater under the control and supervision of the MWRI which would regulate the utilization and secure the development and preservation of groundwater resources. Also, the new law would restrict the digging of new wells to the contactors registered with the MWRI and lay penalties not exceeding 10,000 EGP (1,200 USD) for any violation. The license should be renewed every three years. The Ministry also has the right to refuse the issuing of a license and amend the design of a well according to the potential of the underground reservoir in the area.

Private companies, investors, and land owners in development and land reclamation projects are required to setup control wells at their own expense. Part 6 of the proposed new law identifies punishments in cases of violation, entitling the police to take action against the violator in addition to penalties not exceeding 25,000 EGP (3,100 USD) . The owner of the well has to install a meter to measure groundwater use and if it is not installed or remains unrepaired for more than a week, without informing the Ministry, the well owner would be subject to a fine of 5,000 EGP (620 USD). The new proposed law put penalties at not less than 20,000 EGP and not more than 50,000 EGP (2,500 and 6,200 USD respectively) for not protecting the groundwater from pollution.

5.3 Groundwater abstraction in the Nile delta

In Egypt, the Ministry of Water Resources and Irrigation has long aimed to address water scarcity challenges by developing groundwater for agricultural expansion into 'new areas', relocating people from the Nile Valley and Delta and initiate new communities and farming in areas (MacAlister et al. 2012; Nour 1996). Currently, groundwater satisfies the needs for agriculture most commonly in the fringes of the Nile Delta, both within and outside of public irrigation command areas in these 'New Lands'. Within canal areas, groundwater is a supplementary resource but the frequency of its use can be quite high at the tail end of some canals. Groundwater use is chiefly found on the northern part of the Cairo-Alexandria road, where the aquifer is fed by the delta and is of good quality. The area located between South Tahrir and Sadat city were developed based on groundwater only. The government has, for example, been issuing groundwater abstraction permits to investors in the 'West Delta' and Wadi Natrun area, south and south-west of Sadat city, since the 1990s, converting it in a groundwater-based high value export area (King and Salem 2012). By 2005 the various agricultural activities supported an economy of 300 million USD per year and claimed to employ directly and indirectly around 250,000 people (Van Steenberg and El Naouari 2010).

The strategic importance of this venture as well as the depletion of groundwater forced the Egyptian government, at the request of investors, to consider bringing in water from other sources to maintain the economic activities in the area. Thus, the West Delta Canal Project was conceptualized, aiming at substituting groundwater-fed irrigation in the West Delta Area for surface water from the Nile served via a water transfer that would irrigated 100,000 hectares including the 47,000 hectares already developed (Barnes 2012; Van Steenberg and El Naouari 2010). Due to a lack of ability by the Egyptian government to spend the loan from the World Bank to start its construction (only one company applied to the first bidding, illustrating the fact that risk was considered too high), the project was closed by the donor (Barnes 2012). Political instability in the country after the fall of former president Mubarak in January 2011 led to two consulting firms pulling out of a second bidding, thus further delaying the project and bringing it to a standstill. Because the problem is there to stay (and somehow getting worse), the issue has

recently (2015) been discussed again by the investors and the ministers of both agriculture and water resources.

Observations in the Nile Delta have also identified a conjunctive use of surface water and groundwater much more intensive than commonly believed (El-Agha et al. 2015a; 2015b). In most instances, groundwater wells have been drilled during the last 15 years (after 2000), with depths varying between 67 to 85 metres, and water found between 4 and 15 m. Many wells are shared between users and cooperative arrangements exist between them: investment for drilling the well can be shared, and each farmer connect his own pump to the well head in turn (ibid.). In other cases, farmers have arrangements with tractor owners in order to operate the pump (when the pump type is tractor powered). Wells have been spurred by localized shortages associated with long branch canals and mesqas, maintenance problems, water quality issues, or conflicts. In most cases farmers resort to the conjunctive use of surface water and groundwater and use their wells only in summer peak times. Well density according to El-Agha et al. (2015b) can be as high as one well per 2.5 hectares.

The very burdensome registration process described above readily explains why none of the farmers interviewed in the surveyed wells (60 wells) had obtained a license from the MWRI to drill the well (El-Agha et al. 2015a). Some of the interviewed farmers did not even know about the procedures for getting a license. One striking observation is the absence of distinction between wells to be drilled in the Delta and wells drilled to exploit deep (and often fossil) desert aquifers.

5.4 Groundwater abstraction in the Western Desert, Egypt

In the Western Desert of Egypt, groundwater has been used in the oases for centuries (Powell and Fensham 2015). In the Dakhla oasis, groundwater from 420 artesian wells and 160 springs was being used traditionally in the early 1920s and even centuries before in the Kharga oasis via qanats (Harding King 1917; Wuttman et al. 2000). In the Kharga oasis, Beadnell (1909: 10) observed artesian wells owned collectively with arrangements allowing the different co-owners to utilize groundwater flows “for periods corresponding to the extent of their holdings in the well. Individual shares may amount to as much as one third or one half of the well, or be only the merest fraction: in the latter case the small holders combine so as to obtain control of the flow for an appreciable period.” Moreover, as this author pointed out, frequently land irrigated by a well is cultivated collectively, and the crop divided among the owners “in portions corresponding to their shares of the water” (Beadnell 1909: 11). Traditional water lifting devices were also reported to be used in Kharga (water wheels or saqias), alongside deep boreholes down to 120 m put in place by local farmers during the second half of the nineteenth century and newer ones at the turn of the century (Beadnell 1909; Powell and Fensham 2015). In total, Beadnell accounted for 230 locally owned wells in Kharga oasis, representing a discharge of 53,000 m³ per day (ibid.).¹⁴ The concentration of shallow wells in the oasis decreased nevertheless according to Ezzat (1976) between 1931 and 1960 from 670 to 385 whilst the number of deep wells increased from 7 to 16. The reason for the decline in numbers of shallow wells, according to Ezzat (1976), is due to poor maintenance and neglect as they were not properly equipped with screens to protect them against sand accumulation, clogging the well.

¹⁴ Traditional bores in Kharga were, in practically all cases, lined to a considerable depth with wooden casing (from palm trees or acacia). Boring techniques included the digging of a hole (sometimes 30 meters deep). The shaft is then timbered and the wooden casing is placed centrally in position “so as to form a vertical pipe from the base of the shaft to the surface of the ground” (Beadnell 1909: 190). The well at the base of the shaft is then dug by using percussion hand-boring technology of European manufacture (it was observed that both hand and steam boring rigs had been employed in the oasis) (Beadnell 1909).

Additionally, the progressive drilling of deep wells in the following decades in the oasis also affected shallow well discharge and piezometric pressure (ibid.).

Early intensive groundwater developments by the state in the Western desert of Egypt began tapping into the fossil Nubian Sandstone aquifer system in the 1960s following the New Valley Project in 1959 (Clarke 1979; IAEA 2012; Mahmud et al. 2013; Powell and Fensham 2015).¹⁵ The New Valley Project was initiated in 1959 by Nasser, aiming to reclaim the lands in desert areas outside the Nile valley for agriculture (Allan 2001). One of the main tasks of the project was the investigation and development of new water resources (mainly groundwater) for irrigation and other beneficial uses (Taylor 1976). The United States' Geological Survey support and expertise to design a long-term program of groundwater investigations of the Nubian aquifer system in the four large oases of Egypt (Kharga, Dakhla, Bahariya, and Farafra) (ibid.). By 1967 the United States Geological Survey had studied artesian pressure in 210 deep wells and 963 shallow wells in Kharga and Dakhla oases and drilled 231 wells ranging from 80 to 1,232 meters (ibid.).

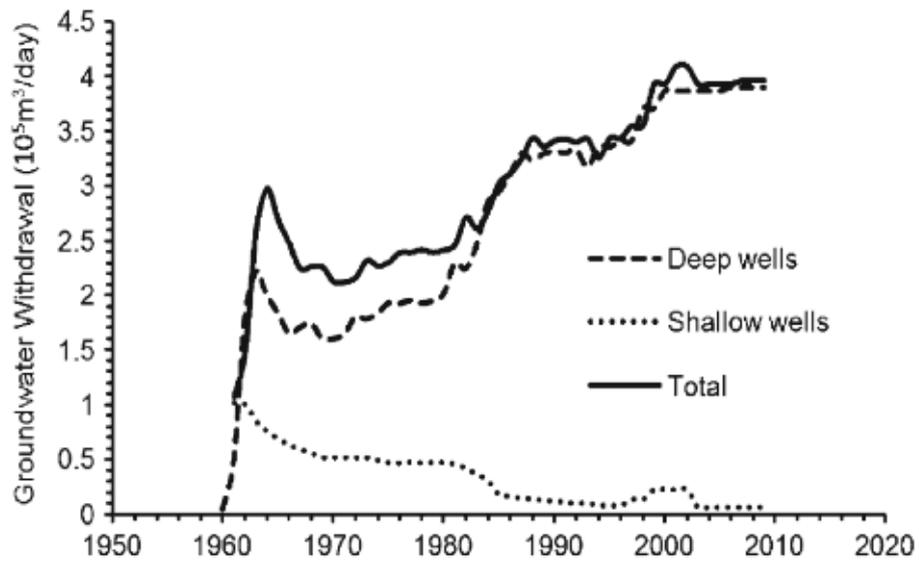
The development of deep wells meant that the total cultivated land with groundwater in the New Valley reached around 17,000 hectares by the early 1980s, of which around 4,800 were irrigated with shallow wells and the rest with deep boreholes (Hefny and Shata 1996). In the region as a whole, extraction had evolved from shallow artesian wells, springs, and a few deep wells using 100 Mm³ per year in the 1960s only in the oases of Kharga and Dakhla, to 1,300 Mm³ per year in 1998 via a dozen of well fields in Egypt, Libya and Sudan (IAEA 2012).

If the disappearance of springs is a main consequence of groundwater over-abstraction in oases in Egypt (Powell and Fensham 2015), groundwater use in irrigation is associated with an additional problem, that of water logging, as illustrated by the oasis of Siwa in the northern part of the Western Desert. Historically in Siwa, hundreds of free flowing natural springs have been reduced to less than 200 in 1963 (Ahmed et al. 2011). Poorly drilled wells in Siwa's fractured limestone aquifer have led to a reverse situation whereby the excess of groundwater abstracted has caused water logging and soil salinization problems as soil drainage is hindered by a sub-superficial clay layer (ibid.).

Further south in the East Oweinat depression, the area of Darb El-Arbaein near the border with Sudan, has been developed mostly by the army with groundwater also from the Nubian Sandstone aquifer system, in order to irrigate around 5,000 hectares (El Kashouty and Abdel-Lattif 2011) (Figure 19). The area's hydrogeology had been studied previously during the period 1975-1986 by the oil sector to assess the availability of groundwater for irrigation (Nour 1996). A pilot irrigation study had been implemented between 1988 and 1992, reclaiming 1,200 hectares of land for irrigation with 31 groundwater wells (ibid.). The Darb El-Arbaein project, designed and implemented by the General Authority for Rehabilitation Projects and Agricultural Development (GARPAD), had drilled 92 wells between 1998 and 2001 with depths ranging from 130 to 535 m (El Kashouty and Abdel-Lattif 2011).

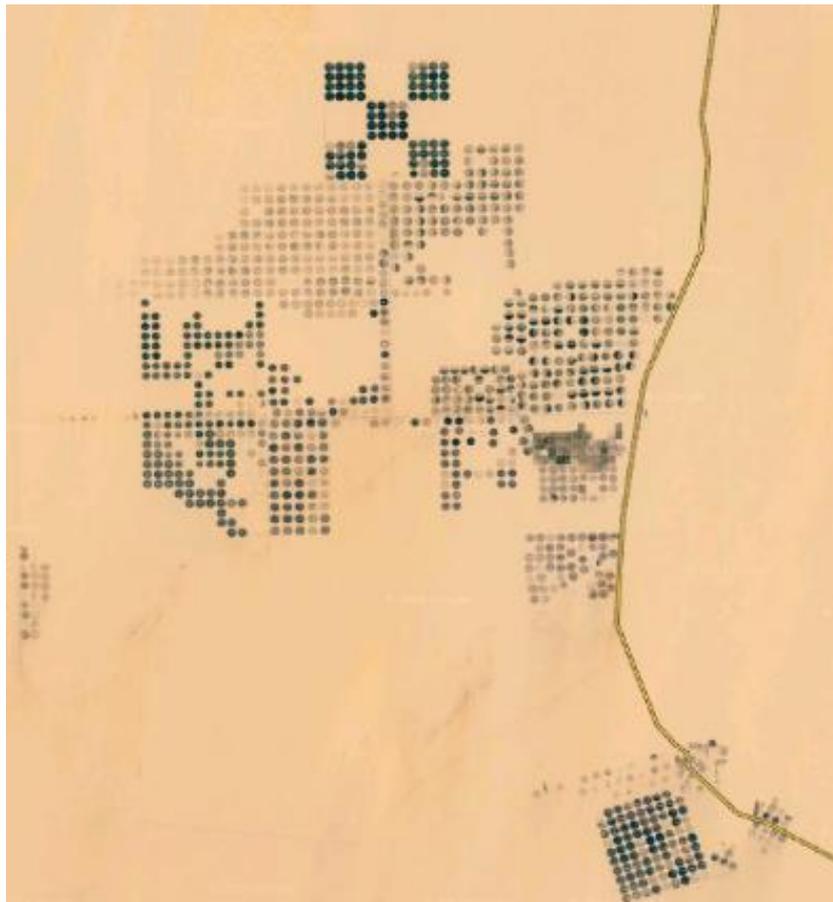
¹⁵ Despite the fact that intensive agriculture started in this area in the 1960s, during the Second World War, groundwater exploration and drilling the Western Desert in Egypt had been developed by two special 'Boring Section' of the Royal Engineers of the British Army. These two sections were deployed in the Middle East and at its peak had 35 officers, 750 men, and 40 drilling rigs, assigned to water supply. Innovations brought by these 'Boring Sections' included groundwater prospect maps. The 'Boring sections' in Egypt drilled a total of 1,032 wells of which 156 were successful, with an average depth of 21 meters and average yield of 271 litres per second. Wells drilled in parts of the Western Desert west of Burg el Arab in Egypt had an average depth of 44.5 meters (Rose 2012).

Figure 18. Groundwater withdrawals in the Kharga area, West Desert, Egypt



Source: Mahmud et al. 2013.

Figure 19. Centre pivots in East Oweinat, Egypt, near the border with Sudan (Western Desert)



Source: Google Earth 2014.

5.5 Egypt's new reclamation plans for the Western Desert

In the Western Desert of Egypt, the development of new swathes of irrigated land is unfolding on the fringes of oases (e.g. Bahariya, Farafra, Dakhla), sometimes through planned projects but also spontaneously by farmers and investors informally reclaiming new lands for agriculture (Adriansen 2009; Sims 2015). This new development comes as a result of Egypt's latest desert agricultural plan in 2014 to develop a potential 4 million feddan of irrigated agriculture. The first phase of this project proposes reclamation and cultivation of 1 million feddan, distributed throughout Egypt (Figure 20) and utilizing almost exclusively groundwater (86 percent) (EuropeAid 2015). The locations chosen are characterized by good soil suitability for agriculture and existence of high groundwater potential. Water resource requirements estimated for the initial phase indicate a need to establish an annual abstraction of 4.38 Bm³ from the Nubian Aquifer System (out of the estimated potential abstraction of 5.2 Bm³) (ibid.). About 4,600 wells would be drilled in the nine proposed reclamation areas, with well depths ranging between 200 and 1,200 metres. These areas encompass all of Egypt's famous oases in the Western Desert (Siwa, Bahariya, Farafra, Dakhla, and Kharga) as well as around Lake Nasser (Toshka area and East Oweinat), the Sinai Peninsula, the Eastern Desert, and along the Nile Valley (south of Fayoum) (ibid.).

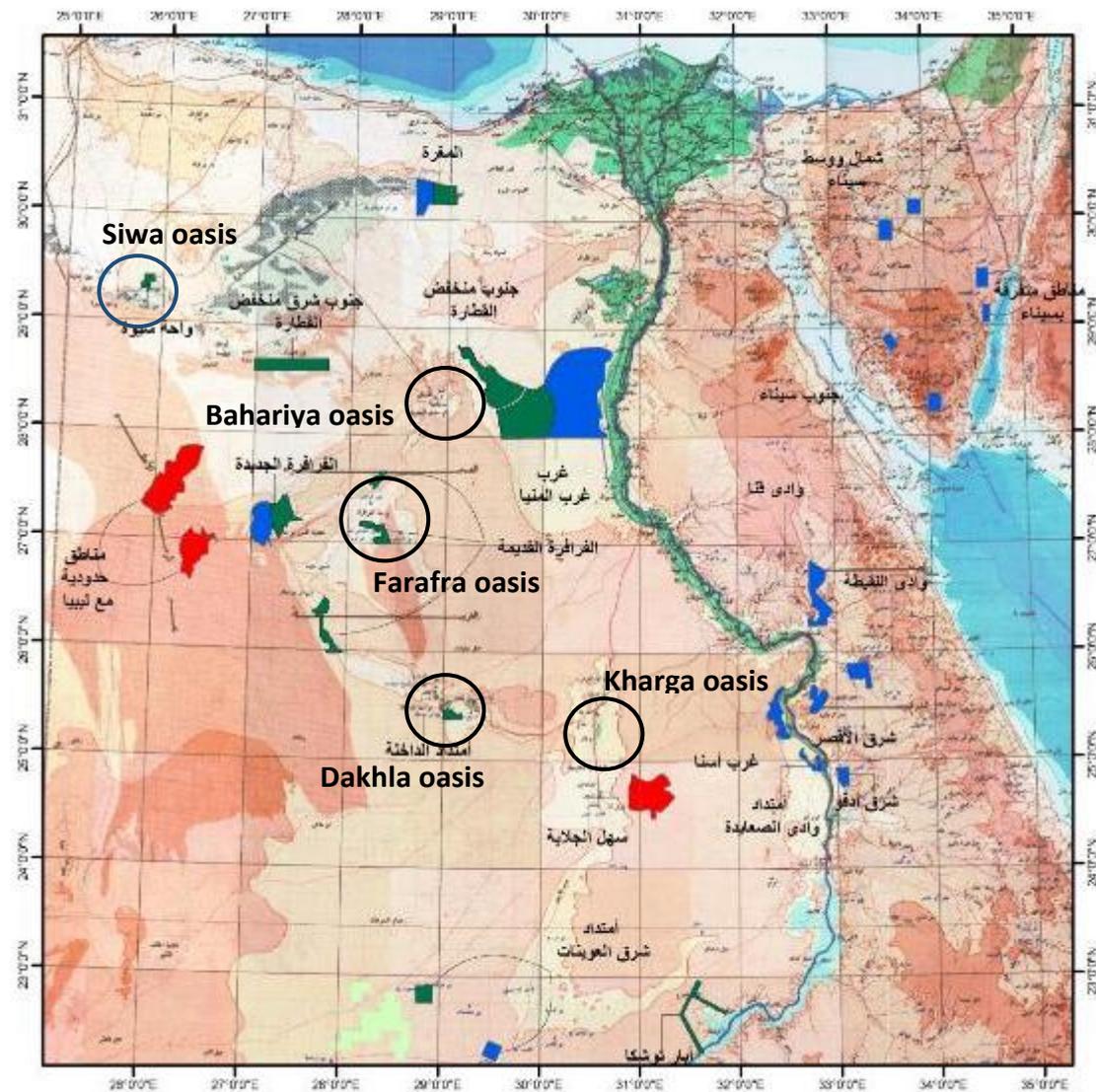
The development of these new lands is already having an impact on local communities. Main problems suffered by farming communities include subsurface drainage problems (ignored or dealt after project design) (Sims 2015), waterlogging and salinization of soils (El Bastawesy et al. 2013). Traditional agriculture in oases is also losing ground and being progressively abandoned as young farmers move away to join either the large irrigation schemes as workforce, obtain land plots in the newly reclaimed desert lands, or migrate to the city (Adriansen 2009). Decreasing spring flows and loss of artesian head in the oases have been also reported for decades (USAID 1999). Recently, over last 5 to 10 years, the loss of artesian flow in groundwater wells has increased and forced many farmers to invest in pumps on their wells to maintain needed irrigation flows (and thus increasing their production costs) (AUC 2009; USAID 1999).

Wells in oases such as Farafra or Bahariya are either owned by the government and operated by farmers or privately owned and operated by farmers. Operation and maintenance of government wells is undertaken by the farmers themselves (AUC 2009). Traditionally cultivated lands in the oases use artesian wells or wells fitted with pumps to abstract groundwater (when the artesian head has been reduced over the years). Water is channelled via earthen or lined canals to the different land plots. In the small farm plots in the reclaimed lands (5-6 feddan as the basis for each farmer), surface irrigation with relative low field application efficiency is the most common irrigation practice (Adriansen 2009; AUC 2009). Farmers coming from parts of the Nile Delta have developed irrigation practices in the new desert lands (e.g. canal systems with tertiary branches, pumping from drainage canals) similar to those they were used to. Water is abstracted also via wells (artesian or with pumps) (AUC 2009). Farmers are also members of associations in order to share the costs of irrigation (the initial investment for an electricity generator for example if the well needs a pump) (ibid.). Large irrigation schemes on the fringes of oases support intensive irrigation with modern technology (sprinklers or drip irrigation). Centre pivots are also a feature of these larger farms.

During this new wave of land reclamation, around 50 percent of the reclaimed land will be under intensive irrigation by investment companies (between 1,000 and 10,000 feddan for Egyptian companies and up to 50,000 feddan for international companies), the rest will be developed by small farmers or 'social groups' (EuropeAid 2015). Incentives for large companies

include tax exemption for 10 years, but the project feasibility must be provided by the company itself. Large international companies are given a 49-year lease and are granted an exemption from the lease value up to three years (ibid.).

Figure 20. Egypt’s land reclamation plans and desert oases



Note: Green: 1st Phase of land reclamation plan; Blue: 2nd Phase of Land reclamation plan; Red: 3rd Phase of land reclamation plan.

Source: EuropeAid 2015.

6 Sudan

6.1 Groundwater in Sudan

In Sudan, 17 percent of the country’s water use originates from groundwater (Mohamed 2014). Groundwater is found in many parts of the country from 40 to 140 meters (Omer 2008). Groundwater in Sudan is mostly used for human consumption in rural areas as well as for animal needs. Although small agricultural areas are irrigated with groundwater, the potential use could

be five times bigger than what it now is (ibid.). Easily accessible aquifers in the east (the Gash) and west of the country (the Nyala) have been seriously over-abstracted and water quality has decreased (ibid.).

Improving agricultural yields and expanding irrigated area under a 'developmentalist ideology' have been two salient political goals for every political regime and government in Sudan since the late 1800s (Fragaszy and Closas 2016). In spite of that, large government-led irrigation schemes have not been widespread, driving private investments in groundwater irrigation (ibid.). Previous experiences in Darfur failed leading to over-abstraction of groundwater and the closure of dried-up wells.¹⁶ In Dongola, capital of the Northern state of Sudan, groundwater abstraction is however being developed via the electrification of the area since the completion of the Merowe Dam, which halved electricity prices, attracting big investors from Sudan, Egypt and the Gulf.¹⁷

Challenges regarding groundwater management and regulation are due to a lack of comprehensive understanding of the resource, and an unplanned and uncontrolled development without licenses and close supervision by experts (Mohamed 2014). Although in 1995 the Federal Water Act defined water as a common good (including groundwater) and its management vested in the Federal Government, water management legislation is scattered across 23 isolated laws at the federal level and regulations and each of the states has its own Water Corporation Act (ibid.). Presently, the central government is revising the country's policy on water resource development. Also, the Dam Implementation Unit has taken institutional charge of the Ministry of Water Resources which has resulted in their agenda being pushed forward.¹⁸ Future steps towards the development of a new water policy document will likely focus on improving rainwater harvesting and agriculture mechanization, particularly in the humid south of the country as well as emphasizing managed aquifer recharge along wadi beds in order to sustain small-scale agriculture.¹⁹

6.2 Groundwater-fed irrigation in Northern Sudan

In Dongola, Northern Sudan, groundwater-fed irrigation is expanding in traditionally uncultivated areas away from the Nile River in capital-intensive farming ventures (Fragaszy and Closas 2016). This represents a shift in farming practices as groundwater was primarily used marginally in date plantations or as a buffer in the traditionally cultivated areas near the river during low-flood surface water years (ibid.). Groundwater abstraction was traditionally accessed via animal-drawn shallow dugwells. As demand increased, these traditional wells were fitted with pumps, deepened, or abandoned altogether for deeper wells.

In Sudan's Northern State, an estimated 60,000 hectares are supplied solely with groundwater out of a potential 1.4 million found in desert and wadi areas (Macalister et al. 2012 in Fragaszy and Closas 2016). The recent development of groundwater-fed irrigation is however mostly due to a lack of expansion and investment in surface irrigation by the state (along the Seleim Canal). The lack of additional surface water has forced, according to Fragaszy and Closas (2016) old

¹⁶ As S. Fragaszy (2014, pers. com.) recollected from a personal communication with Dr. Al-Khadir, "The government has generally been wary of entering into large groundwater projects after the problems in Darfur state – the Sag Nia'am project failed. It was a project of 50 wells, each to irrigate 50 feddans, and after several years the project collapsed due to groundwater level declines. Since then the government has been hesitant to get into groundwater projects. The groundwater projects in northern state are almost all new."

¹⁷ Information provided by S. Fragaszy (2014, pers. com.).

¹⁸ Information provided by S. Fragaszy (2014, pers. com.).

¹⁹ Information provided by S. Fragaszy (2014, pers. com.).

agricultural developments to rely on conjunctive use or move to uncultivated areas further from the river but with groundwater access. The development of electricity in Northern Sudan (through the Merowe Dam completed in 2009) has also improved access to energy for pumps and decreased farming costs in the region (especially for large landowners and agribusinesses) (ibid.).

7 Lebanon

7.1 Groundwater resources and abstraction in Lebanon

There are 8 major groundwater basins in Lebanon, divided in two areas, the Mediterranean (with the western flanks of the Lebanon range) and the Interior (comprising the eastern flanks of the Lebanon range, Beqaa valley and the western flanks of the Anti-Lebanon Range). Lebanon has aquifer formations able to store considerable amounts of water (Metni et al. 2004). Limestone formations with fissures and fractures increase groundwater recharge in many parts of the country and snowmelt is a relatively large contributor of recharge in the country as well (ibid.). Groundwater found in sedimentary and alluvial layers in the Beqaa valley generally follows the topographic slope from the foothills towards the centre and then south of the valley (Wagner 2011). Major aquifers in the Beqaa valley include more than 800 m thick limestone as well as karstic limestone (particularly in the southern end part of the valley (ibid.).

Lebanon's agriculture and water supply sectors are the main consumers of groundwater resources and wells are continuously drilled, mostly by the private sector, to meet increasing water demand (World Bank 2003). Private sector drilling increased considerably since 1975, when the civil war started, due to the breakdown of public services and of the delivery of water during this period (Khair et al. 1994; World Bank 2003). In the 1970s, there were around 3,000 wells between 50 and 100 m deep (Ghiotti and Riachi 2013). A few decades later, estimates in 2003 counted around 10,000 private wells in Lebanon formally approved by the Ministry of Energy and Water but it was believed that there were at least 40,000 illegal wells without permit, pumping water at depths of 150 to 500 m (Ghiotti and Riachi 2013; World Bank 2003). Information from a UNDP funded project in Lebanon in 2014 estimated that there are around 59,124 unlicensed private wells and 20,537 licensed private wells in the country up to January 2012 (UNDP 2014). Of those licensed private wells, 2,888 have exploitation permits and around 17,649 have drilling licenses but no exploitation permits (ibid.). According to the 2014 UNDP assessment of groundwater resources in Lebanon, more than 50 percent of private wells in Lebanon are found in the Beirut-Mount Lebanon Water Establishment area (ibid.).

Despite limited public groundwater monitoring capacity across the country, which limits the amount of information and data available to appropriately control groundwater drawdown and abstractions (IRG 2013), it is known that the water table dropped in parts of the country between 2013 and 2014 between 7.1 m (in North Beqaa) to 11.65 m (in Zahle, Central Beqaa) and up to 20 meters (in Tripoli) due to extreme drought conditions in the country (UNDP 2014).

Coastal areas in Lebanon also face problems related to groundwater abstraction. Tripoli, the second biggest city in the country, is supplied by a confined Miocene highly fractured karstic limestone aquifer (Amin 2002). Increasing population in the area has not been accompanied with the development of surface water resources, partially due to the fact that during the war years (1975-2000) no infrastructure was built (ibid.). The over-abstraction of the aquifer causes sea-water intrusion problems, an issue also observed in other areas of the country such as Beirut and surrounding areas (Choueifat, Jieh and Damour) (Masciopinto 2013; El Moujabber 2006). In Beirut, electric conductivity levels of water in monitoring wells studied by Korfali and

Jurdi (2010), are twice higher than the limit recommended by the United States Environment Protection Agency.

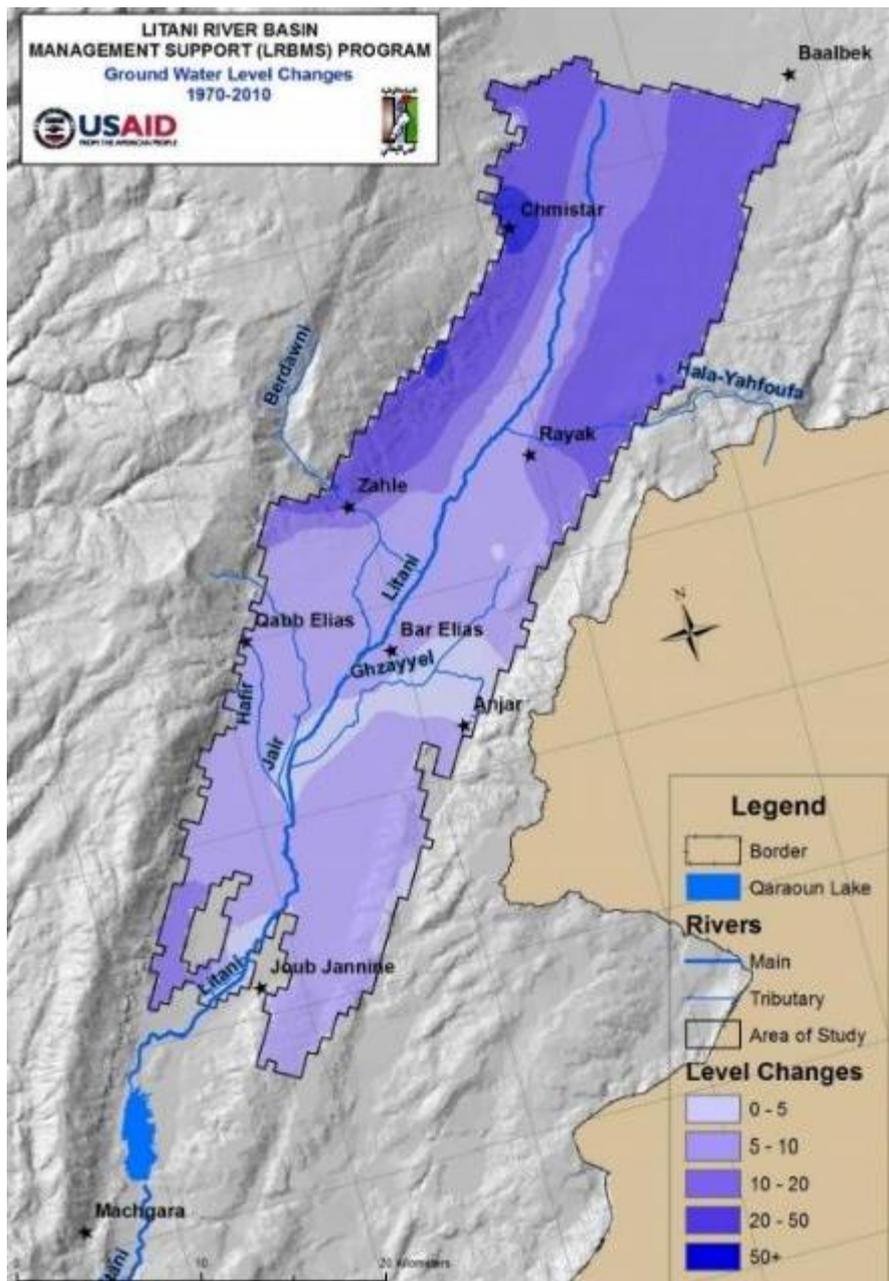
7.2 Groundwater use in the Bekaa Valley

The Bekaa valley, part of the Upper Litani River Basin, is a 60 km long and 20 km wide depression in Central Lebanon and an agricultural region with over 40,000 hectares of partially or fully irrigated cropland with surface and also increasingly groundwater (IRG 2013). Groundwater is found in five interconnected hydrogeological units, with groundwater flowing north-south towards the alluvial aquifers found in the middle of the valley (Nassif 2015). Groundwater is tapped privately, without licenses in most cases, from shallow alluvial layers in the valley as well as deeper karstic limestone deposits on the fringes of the valley (ibid.). Groundwater is also pumped for drinking water purposes, with 107 public water supply wells in the area. Impacts of heavy groundwater abstraction over the last 30 years have affected local springs fed by the same aquifers (drying up) as well as resulted in the dropping of the water table (more than 30 metres in some areas between 2000 and 2014) (ibid.). According to IRG's modeling of groundwater in the Bekaa valley, the drawdown in the aquifer system reached 40 meters between 1970 and 2010 with an average of 14 m in the basin (Figure 21) (ibid.). Groundwater drawdown is more acute in areas not served by surface water (i.e. far from the Litani River in the centre of the valley or in the south where water from the surface water irrigation scheme, the Canal 900 project, is supplied to farmers by the Litani River Authority) (ibid.).

Traditionally, groundwater surfacing through natural springs has been captured and diverted by the communities settled there, supplying drinking water and gravity canal irrigation systems managed jointly by communities of irrigators. The lands irrigated by these springs benefit from water rights entitled by Law 320/192 from 1925 recognizing acquired rights over spring water. Groundwater use in the Upper Litani River Basin in the Bekaa Valley has represented the main engine of the expansion of irrigated land and previous studies have established that around 65 percent of water use for irrigation is groundwater (Atlas Agricole du Liban 2005 in Nassif 2015). The Litani River Authority estimated that in the Bekaa Valley there are between 5,000 and 10,000 wells, and only 2,000 are licensed private wells (Nassif 2015). Other estimates put forward 18,228 unlicensed wells in the valley (UNDP 2014).

In the central Bekaa Valley, in Terbol and Zahle areas, easily accessible groundwater started being pumped in the 1950s and conveyed through earthen canals across the plain (Nassif 2015). Access to land in the high-yielding areas of the valley (near the eastern mountain range) meant that a very limited number of farmers had direct access to groundwater (not more than 10 families) (ibid.). These farmers started accumulating land and established share-cropping agreements with smaller farmers, renting out land and water. Small land plots in the area were also sustained by shallow hand-dug wells abstraction groundwater nearer the river bed (in the alluvial aquifer), partly replaced by tubewells already back in the 1960s and mid-1970s (ibid.).

Figure 21. Changes in groundwater levels in the Central Beqaa (1970-2010).



Source: IRG 2013.

7.3 Groundwater regulation and development in Lebanon

Historically, the country began to regulate groundwater abstraction in 1926 when Ordinance 320 was passed during the French Mandate (Ghiotti and Riachi 2013). A year before, in 1925, water resources had been declared public domain by the state and through this ordinance the government stipulated the different types of compensation to be granted to existing users (ibid.). It also exempted groundwater wells abstracting less than 100 m³ per day from obtaining a permit (ibid.). During the following decades and especially after the independence of the country in 1943, the development of water resources in the country faced serious limitations in terms of availability of funds and budgets. Even though the World Bank and countries such as the USA participated actively in several projects of reconstruction and development of

infrastructure in the Litani basin in the 1950s and 1960s, these projects did not improve water access in many parts of the country, with 70 percent of villages in 1956 without access to tap water (ibid.). Groundwater was then used to complement the unreliable supply of drinking water but in most cases abstractions would not be controlled by the state or public administrations (Allès and Brochier-Puig 2013; Ghiotti and Riachi 2013).

Irrigation was also marginal in the 1950s, and only used on 6 percent of arable land in the country (Ghiotti and Riachi 2013). Via large public infrastructure plans, irrigation however increased in the 1960s to around 20 percent of all agricultural land, with groundwater wells being used by approximately 5 percent of farms (especially in the Beqaa valley) (ibid.). In contrast to the efforts and priority given to new state-funded infrastructure, attempts to regulate groundwater abstractions with a seriously under-staffed 'water police' force were insufficient to enforce groundwater regulation. Facing the increasing proliferation of private wells, a specific legislation was put in place in 1970 to regulate and organize groundwater drilling and the use and abstraction of groundwater. But this regulation did not depart much from the permit system established under the French mandate, only changing the thresholds beyond which permits are required (depth beyond 150 m and abstraction higher than 100 m³ per day) (ibid.).

The widespread nature of wells for drinking water by communities (and to a lesser extent for irrigation) has recently come to the fore because of the centralization of water services under 5 regional 'Water Establishments'. In the Northern region of Akkar, near the border with Syria, several local water management committees have been opposing this water management centralisation since the last reform in 2000 (Ghiotti and Riachi 2013). As a result of these tensions, users in the area have searched for alternative sources of water supply such as private wells or buying water from tankers supplied also by private water wells (ibid.). The lack of connection to the public network of drinking water supply in the area (around 59 percent) has also created the necessity to search for alternative water sources. In the village of El Borj for example, the local community drilled a well to compensate for the intermittent water supply from a network dating back from 1950, helped financially by a local wealthy family and by an international NGO (ibid.). This well provided the village with a more secure and reliable water supply but it also helped the wealthy family maintain and increase its symbolic power, as the project was supervised by one of its members, who was also a member of parliament (ibid.).

Groundwater permits are nowadays regulated in Lebanon through Decision 118 issued in 2010. The user who wants to drill a well requires a 'notification certificate' prior to that. All wells need this certificate (even those less than 150 metres deep) but those abstracting more than 100 m³ per day or deeper than 150 metres need also to have an additional authorization from the Ministry. In order to obtain it, users need to present a hydrogeological study (there are only three companies allowed to conduct this type of study in Lebanon). The application needs to be sent to the Ministry by mail, as there are no regional or decentralized offices in the country. These studies are however expensive (~USD 800-1,000), acting as a disincentive to apply for permits to the Ministry. As a result there has been a drop in permit requests at the ministry (from 2,000 per year to around 200 after Decision 118 was issued) (Mouawia 2015, pers. com.).

The Ministry of Energy and Water receives the request and the Hydrogeology Service deals with the procedure. Once the Hydrogeology service has revised the study conducted by a private company,²⁰ the application is sent to the Water Rights and Expropriation Service with the task to

²⁰ There are only three authorized in Lebanon to do these studies, with no official bidding to choose them, selected at the ministerial level. These companies are under a one year contract which has to be renewed (Ministry of Energy and Water, 2015, pers. com.).

regularize the situation of the applicant. This service studies the legal aspects of the application while the hydrogeological service evaluates the technical aspect of the application. Once confirmed, the Water Rights and Expropriation Service sends the request for a license, that is signed by the President of the Republic (it is a license delivered as a decree published in the state's bulletin). Wells with permits have to pay a fee to the Ministry of Energy and Water (a fixed fee for the well annually and a variable fee depending on the use of groundwater).²¹ Estimates suggest that only around 10 percent of users with permits pay these fees, causing a big loss in the Ministry's finances (the Ministry gets around 2 billion L.L. instead of 50 to 60 billion L.L. from fee collection)²² (Ministry of Energy and Water 2015, pers. com.).

A year after having issued a well permit, the ministry has to issue a second permit allowing for the exploitation and use of that well. The same private company will have to do another examination of the well drilled, the yield obtained, etc. in order to issue the report. Due to a lack of staff (the ministry has no hydrogeologist and the Hydrogeology service operates with 9 staff instead of 49), these new procedures have however drowned the Ministry of Energy and Water with paperwork, thus delaying the recognition and issuing of groundwater permits. The ministry lacks of resources and ways to control that wells are actually drilled at the notified depth (Ministry of Energy and Water 2015, pers. com.). The Ministry's officials cannot enter any site where there is a well as they need an authorization from the Ministry of the Interior and Ministry's staff will have to be accompanied by police officers (ibid.).

8 Syria

8.1 Groundwater resources and abstraction in Syria

In the coastal areas and mountains of Syria, Jurassic limestone up to 1,700 meters thick are the dominant aquifers whilst, further to the east and south, sedimentary limestone and sandy formations give rise to small but numerous springs, used traditionally through qanats (Burdon et al. 1954). In Southern Syria, chalks and limestone constitute aquifers with low to moderate productivity, with some fossil brackish groundwater deposits also found (Wagner 2011). The plateau area north of the Palmyrean Mountain plain is occupied by the Aleppo plateau, a flat to hilly landscape overlying chalks and limestone formations (ibid.). The Aleppo plateau and its underlying carbonate rocks constitute according to Wagner a productive brackish aquifer. To the north-east, the area between the Palmyrean Mountains and the Euphrates is covered mainly by limestones and sandstones constituting a shallow brackish water aquifer across an area of approximately 20,000 km², with well yields in boreholes ranging between 30 to 140 m³ per hour (ibid.). South of Palmyra and towards the border with Jordan, the southern Syrian steppe, groundwater is found in more consolidated chalks, limestones and in fissured limestone aquiferous layers (ibid.). Chalks and limestones form shallow to intermediately deep aquifers recharged by wadi infiltration. Deeper limestone systems found in the Southern Syrian steppe store fossil groundwater reserves (ibid.)

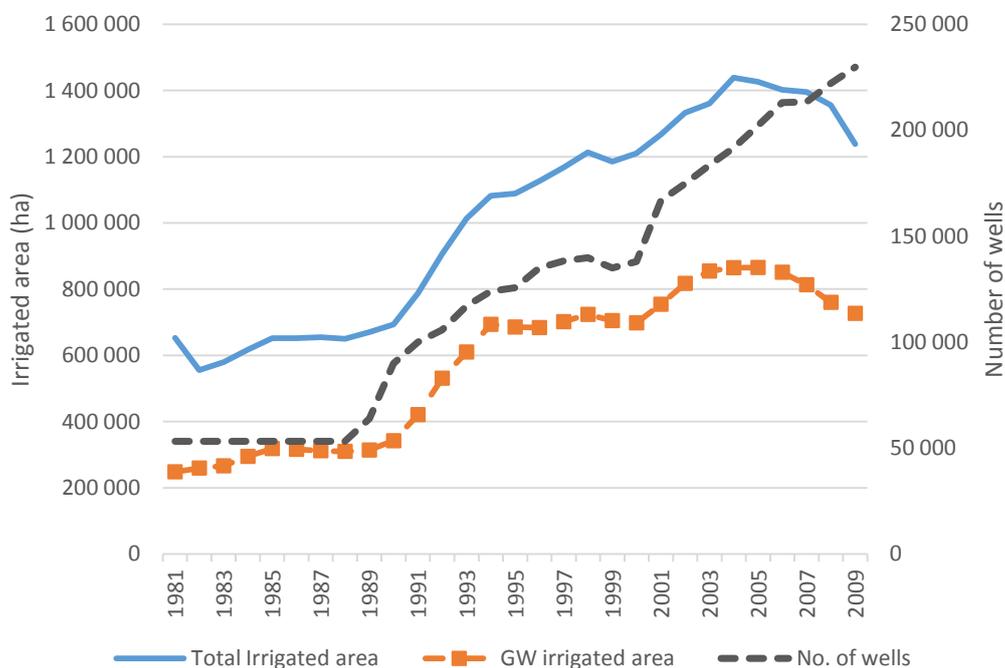
In the Hauran plateau north of Damascus, boreholes had been drilled already in the 1930s and 1940s to provide domestic water for villages as well as for irrigation around Damascus (Burdon et al. 1954). The aquifers of the Aleppo region have also been tapped for that purpose (ibid.).

²¹ Groundwater for irrigation is charged at 100 L.L. (0.07 USD, currency exchange rate 10 L.L. = 0.01 USD, 7th April 2015) per cubic metre and 600 L.L. (0.40 USD) per cubic metre for industrial and domestic use. The fixed fee is 500,000 L.L. (330 USD) per year (Mouawia 2015, pers. com.).

²² 2 billion L.L. equals to around 1.3 million USD (currency exchange rate 10 L.L. = 0.01 USD, 7th April 2015). 50 billion and 60 billion equal to around 33 and 40 million USD.

Additionally, during the Second World War, boreholes were also drilled by the military in Syria (Aw-Hassan et al. 2014; Burdon et al. 1954). Later an increase from around 53,000 wells in the 1980s irrigating about 309,000 hectares to 124,000 wells in 1994 supplying groundwater to more than 700,000 hectares has been witnessed in Syria (ibid.). As a result of this groundwater-fed irrigation boom in the 1980s and 1990s, the number of dried-up wells also increased and groundwater table levels dropped across the country (e.g. by 1.5 meters per year in areas of Aleppo province fed by an unconfined aquifer recharged from the surface) (ibid.). This groundwater ‘revolution’ in Syria since the 1990s (Figure 22) represents a second type of model of water resources appropriation: individualistic and based on private wells and pumps, as opposed to the previous model centred on state-planning surface water irrigation (Saade-Sbeih 2011).

Figure 22. Total irrigated area, groundwater irrigated area, and number of wells in Syria (1981-2009)



Source: Based on data from Aw-Hassan et al. 2014.

8.2 Regulation of groundwater abstraction and wells in Syria

In Syria, Law 165 of 27 September 1958 is concerned with surface and groundwater pumping for agricultural purposes, to which numerous ministerial resolutions have been added since then (Marina Stephan 2007). Groundwater abstraction permits were needed in Syria since 1973, following article 10 of Law no.3 regarding water usage through pumping and small dams (Saade-Sbeih 2011). New legislation in place in 1999 (*Circulaire* No.13, 31/08/1999) further regulated groundwater abstractions, limiting well depths to 150 m, as well as their duration (permits would also be granted for either 1 to 3 years or for 10 years) (ibid.). Also, an annual fee is required depending on the power of the pump (Marina Stephan 2007). The Ministry of Irrigation, responsible for issuing the permits, would also establish the maximum volume of groundwater to be abstracted, the irrigable area, as well as limitations regarding boring and drilling techniques (Saade-Sbeih 2011). According to this same regulation, groundwater users without permits will have to pay fines and permits can be revoked by the Ministry. The installation of a meter in Syria for every well follows Resolution 2165 issued in 2000 by the

Ministry of Irrigation which defines the maximum quantity of allowed groundwater to be pumped and the area to be irrigated (Marina Stephan 2007). According to Law 165, groundwater abstraction limits are fixed depending on the abstraction possibilities in each basin and the surface to land to be irrigated (ibid.).

Despite the fact that the 1999 'Circulaire 13' banned new wells in Syria as well as the renewal of licenses for dried-up wells, and that the government issued another decree in 2001 demanding the licensing of all illegal wells, 57 percent of all wells were estimated to be still unlicensed in 2010 and wells continued to be drilled without permits (de Châtel 2014; Saade-Sbeih 2011). As an example, in the region of Salamieh, east of Hama, of the 6,356 wells inventoried in 2005, 80 percent did not have a permit (Saade-Sbeih 2011). The 2000 decree also imposed meters in groundwater wells (those with permit) and the limitation to 7,000 m³ per hectare of groundwater abstracted (ibid.). In 2005 the new Water Law also outlined different measures to improve water resource management and protection, licence wells and regulate drilling procedures with the added commitment to punish law abusers with fines and prison sentences (ibid.). Moreover, the government required well licenses to be renewed annually to monitor groundwater levels. However, according to de Châtel (2014: 12), "this engendered widespread corruption as security personnel or officials forced farmers to pay bribes for new licenses, which in turn triggered strong resentment in rural areas."

Irrigation modernization programs following the National Irrigation Strategy in 2001 aimed to reduce groundwater abstraction by improving water efficiency in irrigation and installing drip irrigation technology. These programs however mostly failed as only groundwater users with well permits would be able to benefit from bank loans to buy modern irrigation technology (by the end of 2004 only 13 percent of the irrigated area had been modernized compared to the objective of 100 percent by 2005) (Saade-Sbeih 2011). Moreover, according to research in Salamieh by Saade-Sbeih (2011), the installation of these modern water efficient technologies contributed to the expansion of irrigation by around 7,000 hectares between 2003 and 2007, ultimately increasing groundwater abstraction.

8.3 Perverse incentives for agriculture leading to groundwater over-abstraction

In Syria, groundwater-based agriculture represents 53 percent of the total irrigated land (Aw-Hassan et al. 2014). The development of groundwater abstraction wells and irrigation in the 1980s (from 53,000 wells in 1988 to 124,000 in 1994) was spurred by input subsidies sponsored by the government – such as diesel fuel subsidy and crop procurement price support (Aw-Hassan et al. 2014; Gül et al. 2005). The value of these subsidies in terms of GDP was calculated at 5 percent per year, and for fuel it represented around 80 percent of the local purchase price (Aw-Hassan et al. 2014; Gül et al. 2005). This responded to a set of policies drawn in the 1980s and 1990s to improve food security, food self-sufficiency, and agricultural and rural development in the country (with wheat and cotton being the two most cultivated crops, with average growth rates of 15 and 6 percent respectively) (Aw-Hassan et al. 2014).

The cancellation of diesel and fertilizer subsidies for farmers in 2008 and 2009 by Syria's government as a move to integrate the country into the global trade system (while it was bidding to join the World Trade Organisation), pushed prices up and forced many farmers to either revert to rainfed agriculture or stop agriculture altogether (de Châtel 2014). Diesel prices increased from 7 Syrian pounds to 25 pounds per litre for agriculture and the government distributed vouchers for diesel household consumption for 1,000 litres at 9 Syrian pounds per litre (Saade-Sbeih 2011).

8.4 Traditional groundwater management systems in Syria

Before the explosion of groundwater abstraction in Syria in the 1940s and 1950s, qanats were among some of the traditional systems for irrigation with groundwater. These systems have a complex system of organization of water cycles and rights based on time, volume and discharge (Lightfoot 1996; Wessels 2012). Qanats in Syria can be owned privately, either by a family or tribal group owning the land and water; they can also be owned communally, where a community consisting of various extended or unrelated families and other groups owns the land and water rights; and they can also be owned by the state with the government owning the qanat, the land and water (Wessels 2012). Three main use rights can be distinguished for qanats: the right to drink, the right to use water domestically, and the right to irrigate. Irrigation rights are allocated via a complex system of timeshares and cycles. For each *qanat* the total number of timeshares is arranged through a rotation cycle or period of irrigation. The length of each timeshare is subject to inheritance, division, and sale. When *qanats* have a reservoir to store water, the role of opening the different gates is often controlled by a 'natur', who also directs the flow towards the users at designated times, measuring the given volume using a pole. In most cases, users pay a fixed fee per year for their irrigation shares to a committee consisting of the biggest shareholders. From this common fund, repairs, fees for the natur and other costs are paid. As in other parts of the Arab World, in Syria *qanats* have a specific boundary around the structure and the source area within which it is forbidden to drill wells (on average the distance is between 1 and 5 kilometres) (ibid.).

In Syria, land reforms since the 1950s redistributed land property and improved land tenure security, thus increasing the number of farmers and farm cooperatives and encouraging capital improvements in farms (Keilany 1980 in Lightfoot 1996). Coupled with government agriculture subsidies (Aw-Hassan et al. 2014), this led to a rapid increase in the number of electric and diesel tubewells and the expansion of modern irrigation. Additionally, the increasing repair costs and the reduction of state-funded programs for maintenance of qanats in Syria in the 1940s and 1950s also contributed to the demise of these traditional systems of irrigation (Saade-Sbeih 2011).

9 Jordan

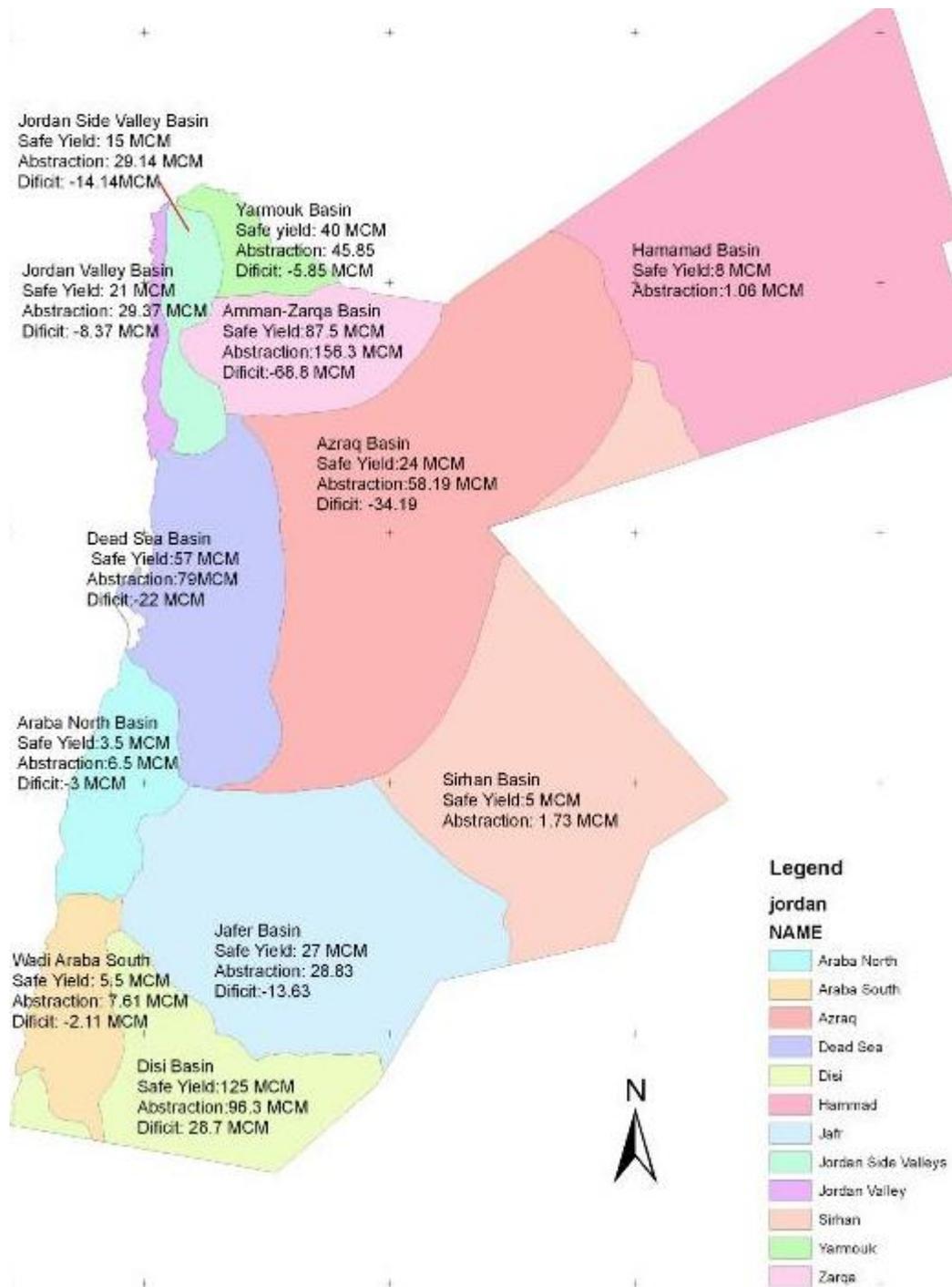
9.1 Groundwater resources and abstraction in Jordan

Groundwater in Jordan is the country's major water resource and it is found in 12 different basins (Figure 23), with two major aquifer types: bedrock aquifers containing the majority of groundwater reserves in the country (such as the Ram aquifer part of the Saq-Disi sandstone aquifer system shared with Saudi Arabia); and unconsolidated aquifers such as alluvial deposits in the Jordan River valley (GTZ 2004). Around 80 percent of the country's groundwater is contained in three main aquifer systems: the Amman/Wadi el Sir system (mainly limestones), the Basalt aquifer system (with basalt formations as well as limestones and chalk), and the Ram system (sandstone) (ibid.). The upper aquifer layers of the Amman/Wadi el Sir System found in the Highlands of Jordan are mainly limestones and 90-350 meters thick and constitute at the regional level a coherent aquifer (Wagner 2011). In the Jordan valley, groundwater reaches the valley either as surface baseflow from spring discharges or as subsurface flow (ibid.). The Ram system consists mainly of sandstone with an average thickness of 1,000 meters increasing to 2,500 meters to the east of the country near the Iraqi border (UN-ESCWA and BGR 2013).

Naturally and geographically, the Jordan valley and the Ghors of Karak form the 'breadbasket' of the country (Hjort et al. 1998), however, because of excessive abstraction, groundwater in the

Jordan valley has become generally saline. So groundwater use in Jordan mainly occurs in the highlands (Amman-Zarqa, and Azraq aquifers) and on the Disi transboundary aquifer (Figure 24).

Figure 23. Groundwater basins in Jordan



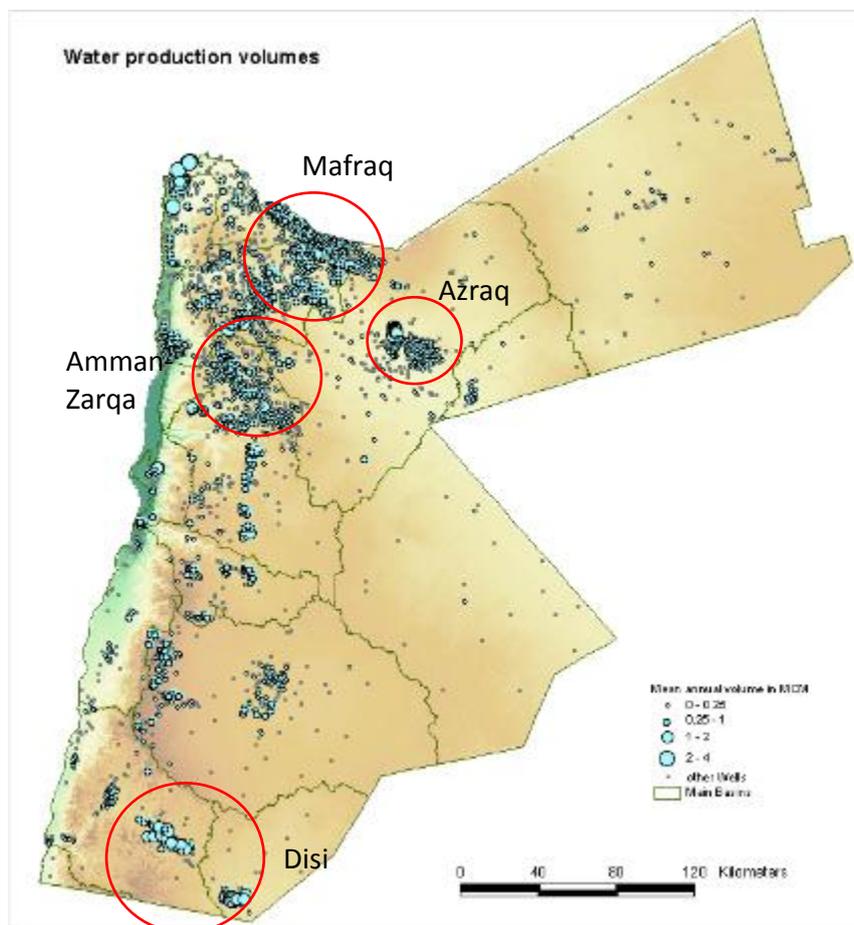
Source: MWI 2003.

The Ram/Disi aquifer, straddling the border with Saudi Arabia, is now part of a project that started to supply additional water to Amman in 2013. Conveying 110 Mm³ per year from the aquifer through 55 wells, it will provide 20 percent of the projected municipal demand by 2020 (ibid.). Additionally, this aquifer is also used to supply water for the city of Aqaba in the south of

Jordan (abstracting around 15 Mm³ per year) (UN-ESCWA and BGR 2013). Although farming activities on the Jordanian side of the Disi aquifer started to abstract groundwater (around 40 Mm³ per year) to irrigate around 11,676 hectares in the 1990s owned by various private farming corporations (ibid.), these activities have recently been discontinued. The Disi transfer project also included a project for settling Bedouins in the area, with stated positive effects in the area's unemployment rates and improved services such as transportation, access to business activities (Ferragina and Greco 2008).²³

At the country level, the total number of (known) wells is estimated at around 3,138 (in 2015, according to WAJ data), but field surveys and recent studies using remote sensing suggest that this number could be higher (USAID, 2014). The Water Master Plan of the Ministry of Water and Irrigation quantified in 2003 a groundwater deficit in the country of 120 Mm³ per year. For a volume of 396 Mm³ abstracted from renewable groundwater against a safe yield of 275 Mm³, including 88 Mm³ from fossil water (El Naqa and Al-Shayeb 2008) and 278 Mm³ used in agriculture.

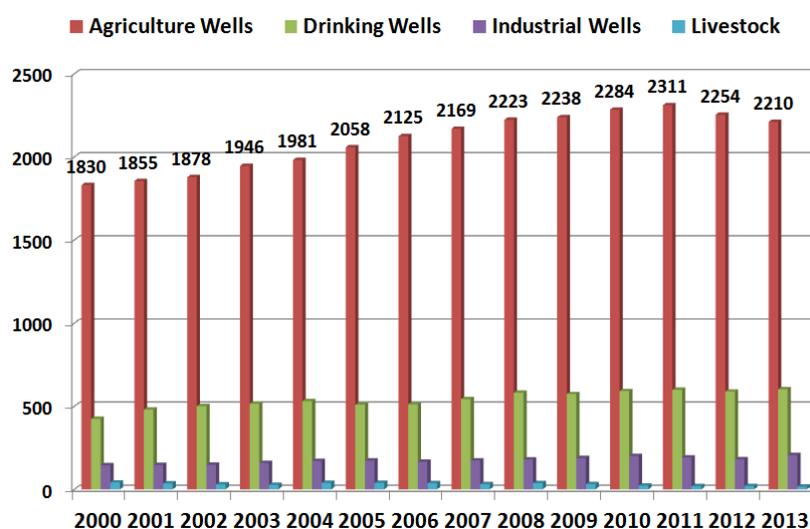
Figure 24. Groundwater production volumes in Jordan (2003)



Source: MWI 2003.

²³ This project, according to Greco (ibid.), played within the imaginary of the country's 'hydraulic mission', without accurate estimates of its economic costs. As Ferragina and Greco (2008) wrote, the project included a serious economic oversight as per its costs (mostly energy costs pumping having to overcome a 250 metres altitude difference between Disi and Amman), estimated by Dr. Munther Haddadin (former minister of water and irrigation) at five times the affordable threshold for the Jordanian population.

Figure 25. Groundwater abstraction per sector in Jordan



Source: MWI 2013.

9.2 Groundwater abstraction in Azraq

The Azraq basin, located at around 100 km northeast of Amman, is the largest groundwater basin in Jordan, representing 15 percent of the country's land surface. The basin is a depression surrounded by a hilly relief and has an area of around 12,700 km². It is formed by three different aquifer systems, an upper shallow basalt aquifer, a middle limestone brackish aquifer and a deep sandstone aquifer with low yields and poor quality water (El Naqa 2011). It harboured a wetland in its middle, declared a RAMSAR site in 1977, which was naturally fed by springs and a shallow groundwater table (Al Mes'han 2011; El Naqa 2011). This wetland was home to a very rich fauna, including migratory birds.

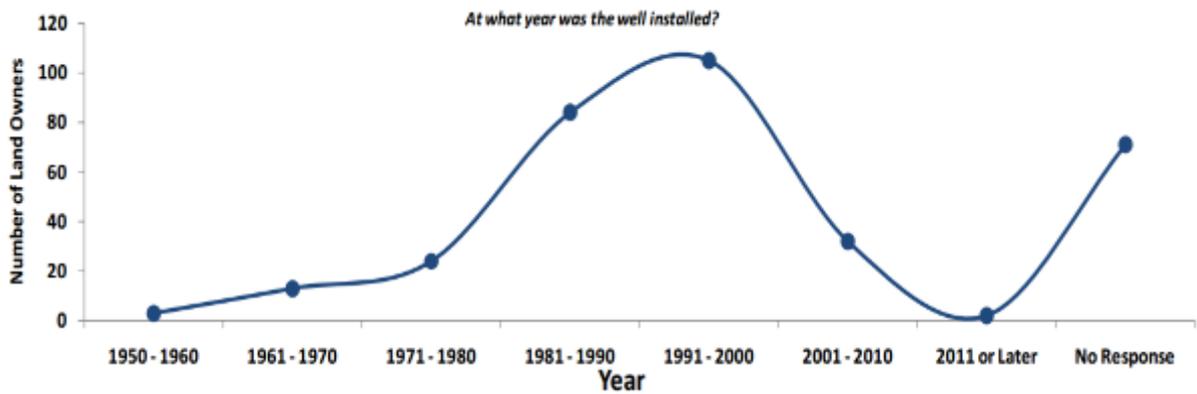
The settlement of Druze and Chechen immigrants in the 1900s-1920s developed marginally the area, as these communities depended mostly on livestock breed in the oasis and salt production (Demilecamps 2010). The further settlement of nomad Bedouins in the Highlands in Azraq via irrigated agriculture with groundwater became part of state policy in the 1960s in order to develop the region (ibid.). Back in 1981 the Amman Water Sewerage Authority (AWSA) began pumping water from the aquifer via 15 wells and in 1993 the well field was supplying 25 percent of Amman's potable water needs (Mesnil and Habjoka 2012).

Groundwater abstraction from the Azraq aquifer almost tripled between 1983 and 2003, increasing from 21.57 to 59.3 Mm³ (El-Naqa et al. 2007). The development of irrigation and intensive agriculture in Azraq was sustained by an easy access to land (cheap prices) and the almost exclusive control of land by sheikhs (using the informal right of Bedouins to sell tribe-claimed land) and high-ranking individuals (Demilecamps 2010; Mesnil and Habjoka 2012). With an estimated safe yield of around 24 Mm³ per year, estimates in 2010 established groundwater abstraction levels at 56 Mm³ per year (Al Mes'han 2011). Two sets of naturally occurring springs would discharge 15 Mm³ per year until 1986, when one set dried out completely and the other one was reduced by 80 percent until it stopped discharging in 1992 (Figure 27) (El Naqa 2011). As a result, the Azraq oasis in Jordan has been severely impacted by groundwater over-abstraction occurring at a larger scale in the Azraq basin and dried completely in 1993 (Demilecamps 2010). In 1994 the Ministry of the Environment and the Royal Society for the Conservation of Nature (RSCN) started pumping around 600,000 m³ per year of groundwater

into the wetland to artificially maintain the oasis, managing to 'save' around 5 percent of the initial wetland area (Al Mes'han 2011).

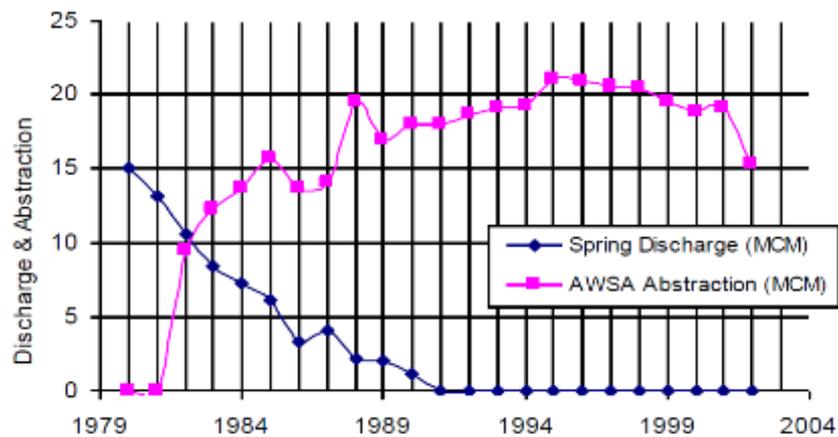
Dropping groundwater table levels by 0.8 m/year on average (between 0.14 and 2.23 m, according to Goode et al. 2013) have also caused water quality issues with average increased salinity (from 250 ppm to 450 ppm between the 1990s and 2010), although such trends are chiefly observed in wells located close to the original wetland (Figure 28) (ibid.). Groundwater over-abstraction has in turn caused a reverse in the hydraulic gradient drawing saline water into the aquifer from surrounding geological formations (upward leakage from lower aquifer layers as well as local geochemical processes) (El-Naqa et al. 2007).

Figure 26. Year of well installation in Azraq



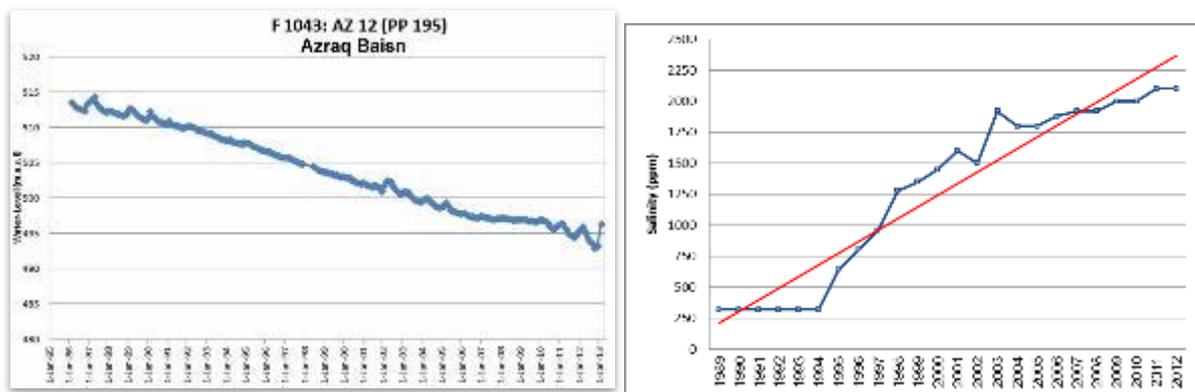
Source: IRG 2014.

Figure 27. Spring discharge and groundwater pumping levels for drinking water supply in Azraq



Source: El Naqa 2011.

Figure 28. Piezometric levels in Azraq (1985-2013) and increase in salinity in one sample well



Source: Hadidi 2014, pers. com.

In order to try to curb groundwater over-abstraction in Azraq, a ‘Highland Water Forum’ was set up in 2010 with support from the German Development agency (GIZ) in order to develop via participatory processes a Highland Water Action Plan aiming at the sustainable management of groundwater in the basin (Mesnil and Habjoka 2012). This project tried to replicate previous experiences with water user participation in the Jordan Valley and built on the development of stakeholder dialogue through an earlier project implemented by IUCN since 2007 (the Azraq Dialogue Initiative). The forum functioned as a consultative mechanism issuing recommendations that have then been integrated and formulated as concrete measures, parts of the Action plan (ibid.). Stakeholders at the Highland Water Forum were selected through a sample of 15 percent of the total 1,356 well owners registered at the Ministry of Agriculture (Katzmair 2009). Stakeholder were asked which stakeholder participants they would like to send to a stakeholder round table dealing with the issue of groundwater overuse (ibid.). The composition of the stakeholder group participating at the Highland Water Forum was ensured by selecting the top 20 most influential farmers (ibid.), which did not allow for the representation of all constituencies and social groups.

Its final output is a Groundwater Management Action Plan (2013) which lists a series of actions and measures to be taken regarding the legal and institutional framework, the improvement of on farm water efficiency, the development of alternative income opportunities, and community development. All actions have been discussed collectively and the time frame, the budget, the performance indicators, and the people responsible for its activity are indicated. In 2014 the Forum has been 'institutionalized' and formerly inserted in the ministry's structure. Most observers are pessimistic about the future of the Forum and farmers in particular have the feeling that a lot of time has been spent in vain. It is not clear whether the momentum of the forum will be sustained when support and funding are discontinued.

9.3 Groundwater regulation in Jordan

Regulation tools in Jordan for groundwater management started with drilling licenses for wells issued by the Water Authority of Jordan (WAJ). Until the foundation of the WAJ in 1984, groundwater monitoring had been carried out by the Amman Water and Sewage Authority, the Water Supply Corporation, and the Natural Resources Authority. After 1984 the Water authority of Jordan imposed abstraction quotas to new well licenses based on the size of farm areas. The government also froze well-drilling authorizations in 1992 through a decision of the Prime Minister and established a tax of USD 0.35/m³ for any water pumped and sold or used for industrial or aesthetic purposes as well as domestic purposes (Mesnil and Habjoka 2012). A

campaign was also introduced to equip private wells with meters. Although licenses have included limits to groundwater abstraction since 1962, with a maximum amount of water to be pumped (most commonly 50,000 or 75,000 m³ per year per well), they were never enforced as farmers did not feel concerned (ibid.).

In view of the high groundwater abstraction rates in the 1990s (up to 215 percent of the mean annual recharge in some areas of the Amman-Zarqa Basin), the Jordanian government designed a new water strategy in 1998, which emphasized the threats faced by groundwater resources and included demand management instruments to encourage efficient water use, preserve water quality, and reduce groundwater overdraft (Venot and Molle 2008), seeking to reach the safe yield level estimated at 275 Mm³/year by the year 2020.

A Groundwater Control Bylaw (No. 85) was passed in 2002, with further amendment in 2004 regulating abstraction and imposing a quota of 150,000 m³ per year per well (twice the value prevailing hitherto!) and a block tariff which would be activated beyond this quota (ibid.). The Bylaw imposed two other thresholds, between 150,000 and 200,000 m³ charged at 25 fils (1 JD = 1000 fils = 1.1 euro) per m³ and above 200,000 m³ charged at 60 fils per m³ (Ministry of Water and Irrigation, Water master plan 2003) (Table 2). A modification of the Groundwater Bylaw in 2004, which provided further reductions in the block tariffs in 2008, was not implemented (Yorke 2013).

Thresholds for Mafraq and Azraq vary slightly, because water availability is better in the latter and therefore abstraction is more taxed. In Mafraq, the 2014 water prices consider the first 150,000 m³ as free. Quantities abstracted over 150,000 m³ and below 200,000 are charged at 0.005 JD per m³ and more than 200,000 m³ of groundwater abstracted is charged at 0.06 JD per m³. In Azraq, the 2014 water prices allow the abstraction of 250 m³ per dunum of land for free. Between 250 m³ per dunum and 100,000 m³ abstracted, groundwater is charged at 0.02 JD per m³ and above 100,000 m³ at 0.06 JD per m³ (Table 2).

Table 2. Water pricing according to groundwater abstraction levels for private agricultural wells in Jordan

Quantity of water pumped	Water prices in wells with former abstraction license – 2002 by-law	Water prices in wells with former abstraction license – 2004 amendment	Water prices in wells without former abstraction license
0 to 100,000m ³	Free	Free	JD0.025/m ³ (\$0.035)
101,000 to 150,000m ³	Free	Free	JD0.030/m ³ (\$0.042)
151,000 to 200,000m ³	JD0.025/m ³ (\$0.035)	JD0.005/m ³ (\$0.007)	JD0.035/m ³ (\$0.050)
More than 200,000m ³	JD0.060 /m ³ (\$0.085)	JD0.060/m ³ (\$0.085)	JD0.070/m ³ (\$0.098)

Source: Venot et al. 2007b.

Jordan also required permits for drilling a well regardless of its depth and drilling is prohibited in protected areas since 2002 (in Amman-Zarqa basins and the Azraq area).²⁴ Groundwater was

²⁴ The study of irrigated agriculture by Ramirez et al. (2011) found that farmers owning wells have achieved larger water savings than farmers leasing wells (an 80 mm reduction in irrigation depth) and that they have greater incentives to account for well depreciation as well as to apply only additional water when marginal returns exceed marginal costs. These farmers show longer term planning, attentive to economic incentives and aware of their investments (e.g. well, irrigation technology). At the same time however, this study found that well tenants have little incentives to account for such well depreciation. This causes also costs and maintenance for leased wells to be higher than owned wells (ibid.).

defined as state property, and the ownership of the land does not include the ownership of groundwater (Article 3). Owners of private wells dug before the Groundwater Bylaw had 6 months to apply for a license.²⁵ The WAJ was also entrusted with the task to define maximum abstraction levels for each groundwater basin and, in cooperation with the Ministry of Agriculture, a safe yield and a maximum size of land to be irrigated per farmer were also defined. A minimum distance between wells was also put in place (minimum of 1,000 metres) (article 25) and for wells used for tourist and industrial activities, license holders would have to pay 250 fils per m³ when the amount abstracted exceeds 50,000 m³ per year (article 29).

Drilling rigs and drillers were also regulated by the 2002 Groundwater Bylaw as it requested that they obtain a license from the Authority. Issued licenses would have to be renewed every year (costing 1,000 JDs in the first place and another 500 JD every time it had to be renewed) (article 32, 33, and 37). In 2005, a WAJ board decision established a new deadline aiming at regulating illegal wells. In this instance, the government prohibited the issuance of permits to illegal agricultural wells drilled after the 1st of January 2005 (Mesnil and Habjoka 2012). A period of 3 months was open for farmers to apply for the permit. The same process was repeated again in 2007 and 2009 (Hadidi 2014). A new amendment to the Water Law and Groundwater Bylaw issued in 2013 by the Cabinet aimed to close all illegal wells in Jordan starting after the 31st of December 2014. Since the campaign started, 644 wells have been sealed (by mid-2015).²⁶ Although these wells correspond to dried-up or unused wells, the campaign sends a strong signal that the knot is tightening up. This latest effort by the Jordanian Authorities is carried out by the Ministry of Water and Irrigation alongside Jordanian security forces with the power to intervene and supervise the sealing of wells. According to Al Naber (2015), extreme measures are envisaged such as the use of dynamite to seal wells and avoid their re-opening once the inspecting team is gone.

Water policy in Jordan, faced with the challenge to enforce water abstraction limits and reduce agricultural water use in the highlands followed, at first, a strategy of avoiding sticks and focusing on carrots. Thus, the strategy was one of participation of the water users, still implemented via a top-down approach, in order to explore new management options and the development of an action plan (Chebaane et al. 2004). The hopes vested in the different policy tools have however not lived up to expectations, whether it is in terms of reducing current abstraction or limiting the expansion of wells. The assessment by Venot and Molle (2008) of the new bylaw in 2002 showed that no gross water savings should be expected either. The block tariff had not affected most of the wells given the fact that the minimum amount of groundwater abstracted for free was raised to 150,000 m³ per year per well (Venot and Molle 2008); in addition the price of water is too low and water use is not elastic at this level, especially considering that prices have not been updated since 2014 and are currently minimal.

In the Amman-Zarqa Basin in Jordan, large investment and development programs by the government of Jordan expanded irrigation as part of a larger development program in the area (including investment in water supply, roads, schools, clinics and other public services) in order to settle Bedouin tribes (Venot and Molle 2008). Irrigation for agriculture was developed as an

²⁵ Article 41.B stated that, for specific economic or social reasons, groundwater can be abstracted from unlicensed wells prior to the enactment of the law. This shall be subject from an authorization of the council of ministers approving the continuation of abstraction from these wells for a limited period of time and on the condition that the owner of the well would pay 150 JD for each meter drilled in the well. This included a provision that no losses should be incurred by neighboring well owners or third parties.

²⁶ The Jordan Times 2015 "Three cases of water theft uncovered in Jiza", 11th June 2015, <http://www.jordantimes.com/news/local/three-cases-water-theft-uncovered-jiza> (Accessed 17th August 2015).

additional source of income and the government granted licenses and low interest loans. Additionally, favorable international agricultural markets (especially towards the Gulf states) coupled with subsidized energy prices, local market protection during harvesting season encouraged private investment in irrigated agriculture (Chebaane et al. 2004). The development of groundwater has also been exacerbated by relaxed controls on drilling operations and a near absence of licensed wells (Venot and Molle 2008).

The Azraq basin in Jordan experiences illegal wells despite government policies to control and identify wells. In some cases, farmers have two wells, one legally registered in the official database and for which water is billed according to meter readings and another, registered as non-working (Demilecamps 2010). Field observations by Demilecamps (2010) confirmed however that these wells were being used, at least during the irrigation season.

The Prime Minister first forbade the drilling of wells for agricultural purposes in 1992. In 2007 a bylaw indicated that non-licensed agricultural wells drilled after the first of July 2005 would have to be backfilled. In 2010 the ministry of interior announced that all farms of less than two years would be destroyed. In 2013 a new bylaw issued by the ministry of water resources announced that wells not legalized by the end of the year would be backfilled. All these successive orders, however, are weakened by the possibility for the well owner to show that his use of the well has clear social or economic significance, in which case the regulation would not apply. Because of the political difficulties in applying such stringent regulation, the number of illegal wells has been increasing rather than declining, as confirmed by recent recognition by ministry officials that the actual volume of groundwater abstracted was estimated, based on remote sensing studies, to be much higher than the values based on meter readings contemplated up to now.

Table 3. Legislation regulating groundwater in Jordan

<i>Year</i>	<i>Law or By-Law</i>	<i>Important issues</i>
1961	By-Law No. 14 – Groundwater Monitoring System – not valid	Groundwater definition, permission and licensing for drilling and abstraction quota
1966	By-Law No. 88 – Groundwater Monitoring System - Amendment	Specify in license the water usage, water abstraction quantity, metering, measures to control water table drawdown, and quality degradation
1973	By-Law No. 12 (1973) Groundwater Monitoring System – Amendment	Installing water meters on well, over abstraction above licensed amount has to be paid
1974	By-Law No. 16 – Groundwater Monitoring System / issued under article 68 of the Natural Resources Management Act No.12 of 1968	No person may acquire excavator or use one unless it has been granted a license by the authority and it permits its acquisition or use. Fees should be paid for license
1988	Law No.18 – Water Authority Law	All water sources within the Kingdom’s borders are property of the state, whether those sources on the surface of the land or in the land
1998	Groundwater strategy	Emphasized the threats faced by groundwater resources and included demand management instruments to encourage efficient water use, preserve water quality, and reduce groundwater overdraft

<i>Year</i>	<i>Law or By-Law</i>	<i>Important issues</i>
2002	By-Law No. 85 – Groundwater Monitoring System	Establishing of water fees for private users, water abstraction requires permits and land ownership does not include the right to ownership of stored groundwater
2007	By-Law No. 12 – Groundwater Monitoring System – Amendment	Increasing water prices for industrial, commercial and livestock
2014	By-Law No. 36 – Groundwater Monitoring System – Amendment	In the absence of a water meter, invalid or tampered, water quantity will be estimated based on irrigated area and type of crop, satellite and remote sensing monitoring

Source: Compiled by authors.

9.4 Traditional groundwater management in Jordan

The effects of local tribal politics in societies such as Jordan reach further than the mere sphere of local politics in rural areas and have implications for the nation-state and wider political processes. Following Antoun (2000), the processes of conflict resolution based on tribal rule in Jordan are based on the concept of collective responsibility among stipulated and limited set of patrilineal kinsmen. In this type of tribal societies however, the social type, ethos and social organization are resilient in many political and social aspects, and they are not contained within rural communities and reach out to urban centres. Reinterpretations of tribal traditions have partly separated these structures from nation-state politics in a process of ‘de-tribalization’ of politics. However, changes in social dynamics such as social mobility, migration, the penetration of state authority into tribal areas (e.g. via the police) or the resort to extra-tribal allies for the resolution of intra-tribal conflicts indicate according to Antoun (2000) the transformation of the Jordanian economy, society and polity but not the decline of tribalism.²⁷

In the Highlands in Jordan, areas with their own springs and with long and uninterrupted settlement still manage water traditionally with water rights determined according to the sharia – Islamic law-, traditional law, tribal values and “an unambiguous common sense on the relationship between arable land and rights to water” (Salman et al. 2008: 314). Even though the distribution of water was determined by generally acknowledged rules facilitating a ‘modus vivendi’ of co-habitation in the region, the presence of these rules does not mean that power relations were nonexistent and that water was divided on the basis of equality (Kaptijn 2010). Traditional water allocation in communal systems in the Jordan valley (Zarqa triangle) was divided according clan lines before the country’s agricultural revolution of the 1960s (ibid.). Water was generally considered the property of the leader (sheikh) of the clan and he was the one who could decide where water was to be directed to. Water was allocated according to discharge and not time and a long stick with several indents called a ‘mawsim’ was used to measure the amount of water. Irrigation gates (or blockades) were operated when an area was required to be irrigated, the person in charge of the ‘mawsim’ would open the gate and measure the amount of water flowing into the area with the stick (ibid.).

²⁷ For Antoun (2000), tribal conflict resolution is the institution in Jordan that merges trust, cooperation, and social control at the local level in the mores and behavior of the community. This represents the ideological and social organizational core of both tribe and civil society in Jordan and illustrates the interdependencies created by the interaction between morality, kinship and state action in such societies.

10 Yemen²⁸

10.1 Groundwater resources and abstraction in Yemen

Yemen has four main aquifer systems with an annual recharge of 1,525 Mm³ and a total volume withdrawn of 2,110 Mm³ per year (FAO 2009b). Highly productive aquifers are found along the coast in alluvia replenished by wadis. In the highland plains, important sedimentary systems are found in the Sa'adah, Amran, Sana'a, Ma'bar-Dhamar plain, and Rada basins (ibid.)

Between the 1970s and 2000s, groundwater-fed irrigation in Yemen increased from 37,000 hectares to over 400,000 hectares (Al-Eryani et al. 2011 in Van Steenberg et al. 2012) with a subsequent increase in the number of wells from a few thousands to more than 50,000 (Hellegers et al. 2008). Most dramatically, the case of Sana'a basin where the capital of the country is located, illustrates the situation of groundwater over-abstraction in the country whereby abstraction estimates are believed to be five times the aquifer recharge (270 Mm³ against 51 Mm³) (Van Steenberg et al. 2012).

Estimates put forward over registered 100,000 wells in the country, the majority of them privately owned (Lichtenthaler 2014; Aklan 2014). In the Ta'iz governorate, exploitation begun with hand dug wells. Typically, the diameter would be 1 to 2 meters, with reinforced concrete lined with corrugated iron or plywood. As water levels continued to decline, wells would be deepened further down to 20 meters (although some dug wells can reach up to 70 meters). Deeper than that, those wealthy enough had to resort to drilling. Pumping from dug wells is usually done by shaft pump belts driven by 24 to 36 HP diesel engines. The pumps are then connected to 3 to 4-inch steel pipes connected to distribution networks via gate valves. As for tubewells drilled by farmers, they are usually between 100 and 300 meters deep (Handley 2001).

The Sa'dah plain, a major semi-arid highland basin north of the capital, Sana'a, has seen increasing groundwater abstraction for irrigation (citrus crops and vegetables). It was estimated that more than 2,500 wells tapped the aquifer abstracting groundwater at depths between 10 and 50 metres from the sandstone aquifer (Al-Sakkaf et al. 1999). The number of wells doubled between 1983 and 1986 to over 2,000 wells, fuelled also by financing from Yemeni nationals from neighbouring countries (ibid.). Groundwater depletion in the area caused the abandonment of villages in the area as wells went dry and habitants relocated. Recorded groundwater table drops show declines of 40 metres in some places in only nine years in the plain (Van der Gun and Ahmed 1995).

10.2 The development of groundwater abstraction in Yemen

In the northern area of Yemen many were seemingly unaware of the possibilities offered by deep groundwater in the 1960s until an Italian company dug a well to supply water for its activities. The development of groundwater resources was central to the Yemeni state's developmental mission after the 1960s. It sought, in particular, to strengthen its power and legitimacy by co-opting rural elites in crucial rural constituencies through preferential access to irrigation, public investment in new wells and also diesel subsidies (Al-Weshali et al. 2015; Moore 2011). New groundwater abstraction projects came to be increasingly identified by local communities with the growth of the state apparatus in many regions via these projects. As a result, rural elites also aimed at capturing the resource through wells in order to enhance their local power vis-a-vis other tribal leaders as well as the state (ibid.). The case studied by Handley

²⁸ See Annex 1 for complementary information on Yemen and groundwater management and policy.

(2001: 186) in the Ta'iz governorate in the south-east of Yemen suggests that local residents views on the state in Ta'iz reflect a lack of trust as "the state is not me, nor my family nor my tribe and therefore is to be avoided or manipulated for the purpose of society" (Handley 2001: 191).

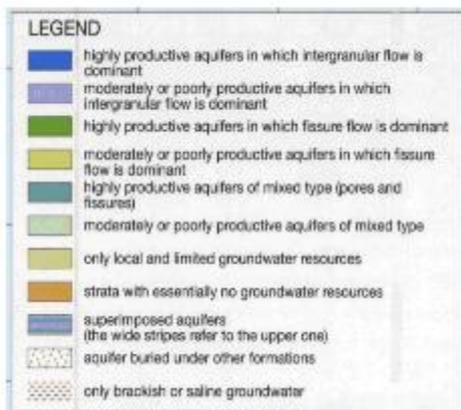
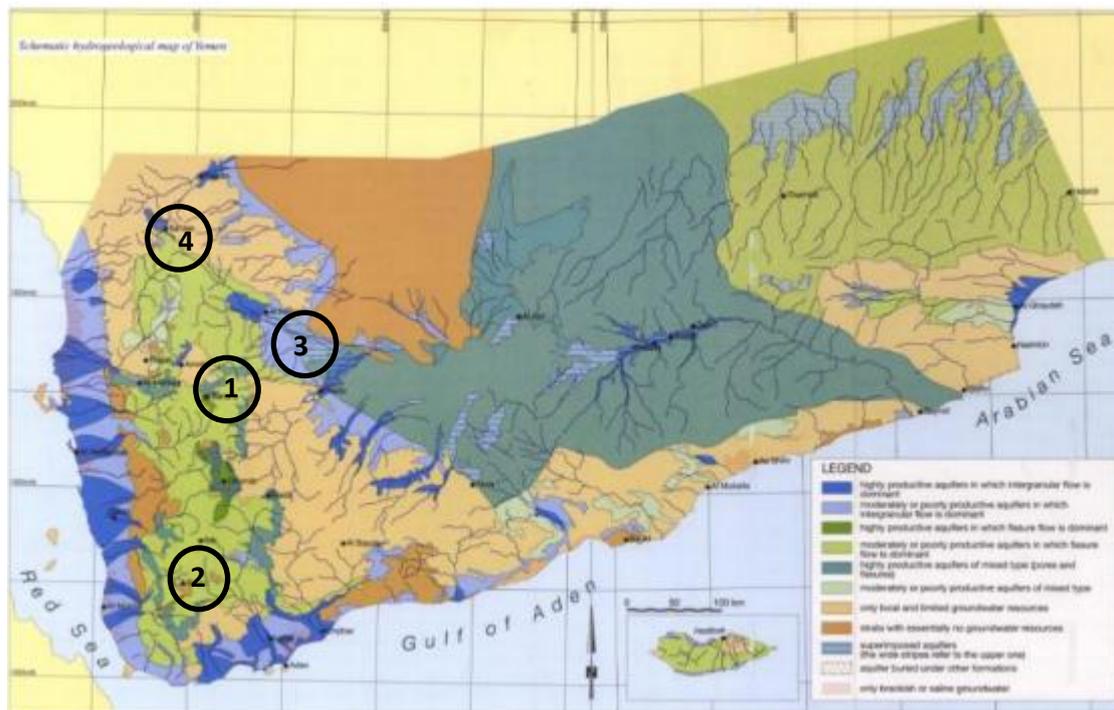
World Bank funded projects in the 1970s developed groundwater abstraction capacity in the country. In 1974 the World Bank funded a USD 6.25 million loan for a 10-year water supply project for the city of Sana'a with a field of eight production wells abstracting 200 litres per second in total (World Bank 1974). The year after, the World Bank funded Yemen's first integrated rural development project worth USD 23.2 million, aiming at increasing the productivity of 35,000 hectares of land in the Taiz area. The project provided medium and long-term credits for groundwater development, with not less than 75 percent of the loans for groundwater development extended to owner-cultivators, with preference given to loan applications originating from groups of small farmers sharing the investment costs and benefits. The project also provided as funding to drill production wells estimated to irrigate 400 hectares as well as groundwater surveys. The project expected to finance over a period of 5 years around 100 wells in the area (World Bank 1975). Additionally, the development of Saudi Arabia's food self-sufficiency with groundwater gave the idea to returning Yemenis that drilling wells and obtaining groundwater was possible (Moore 2011).

During the following decade, the government declared a ban on imported fruits in 1984 resulting in a large increase in cultivation based on wells. Data from 1990 indicate that 310,000 hectares were irrigated with groundwater compared to 37,000 in 1974. Subsidies provided for the private sector to import pumps, engines and rigs also helped the drilling of more wells in the country, while the Cooperative and Agricultural Credit Bank provided loans at subsidized rates for irrigation and diesel and electricity prices were kept low. According to the World Bank (2001 in Van Steenberg et al. 2015), in 2009 the subsidy for fuel accounted for 22 percent of all government expenditures. Additional funding coming from migrant remittances earned by up to one million Yemenis working in Saudi Arabia and the Gulf states and investing mostly in vehicles, houses, wells/pumps and businesses also sustained the development of agriculture (Handley 2001; Hellegers et al. 2008).²⁹ Additionally, the availability of drilling equipment in Yemen resulted from Saudi Arabia's policy of control and reduction of well abstractions, confiscating drilling equipment and re-selling them across the border in Yemen (or also re-shipping them by rig owners) (FMWEY 2015). In addition, due to the Gulf War in 1990, many Yemenis having had to return to Yemen invested in farming ventures and drilled wells (Hellegers et al. 2008). The endemic production and consumption of qat in the country, which expanded from a few thousand hectares in the 1970s to over 150,000 hectares in 2009, further drains groundwater resources and is intrinsically linked to local and national culture and politics (Gatter 2013).³⁰

²⁹ According to Handley (2001: 70), migrant remittances in Ta'iz were not used to purchase land as buying it is considered similar to the "ultimate dishonor of 'exposing one's women folk' [...]. Only under times of great financial stress do people sell land".

³⁰ In Yemen, the cultivation and commercialization of qat represents a very important sector for the country's economy with 12 percent of the agricultural area in the country and making more than 40 percent of the agricultural GDP and around 6 percent of Yemen's total GDP. In terms of water consumption, it has been estimated that qat accounts for a third of Yemen's current water consumption (Walz 2010; Wulfsohn 2013), representing 50 percent of the irrigated area in the country (FAO 2009b).

Figure 29. Yemen's main aquifers



Location of cases mentioned:

1. Sana's (Wadi Qarada, Khrabat Muhyab, Wadi Dhelaa)
2. Taiz (Al-sinah)
3. Amran (Hijrat Al-Muntasir)
4. Sa'da governorate

Source: Van der Gun and Ahmed 1995.

10.3 Groundwater management policy and regulation in Yemen

Since the unification in 1990, Lackner (2014) has differentiated 4 phases in Yemen's water policy since the 1990s. The first phase (between 1990 and 1995) was dominated by inertia and a lack of explicit strategy to address water scarcity in the country, with a policy of laissez-faire. The second policy phase began in 1995 when the national Water Resources Authority was given the mandate to be the sole governmental agency responsible for the formulation of water resource policies. This is the only institution authorized to license well-drilling, and it is also supposed to regulate and register drilling companies. The main policy adopted during this period was the increase in diesel prices, as a disincentive to pumping and conserving groundwater. This policy however had a negative effect on poor small holders, who still needed diesel to pump water from shallow wells. In spite of demonstrations and riots leading to the death of twenty people, the price of diesel was doubled in 1995. Further increases in diesel prices during the 2010s did not meet as strong an opposition from large landowners as before, due to the fact that they benefited also from other measures such as subsidies for the introduction of modern irrigation

techniques (e.g. drip irrigation). Additionally, high diesel prices have encouraged those landowners who can afford it, or to switch to gas, and also consider solar energy pumps.

During this phase began the long process of developing and drafting a new Water Law for the country. This process antagonized two factions within Yemen's government: the irrigation specialists in the Ministry of Agriculture, with their goal to maximize production, and the hydrologists and environmentalists concerned about sustainability (FMWEY 2015). This antagonism lasted several years, also fuelled by the vested interests and the lack of political leadership, more "in favour of the short term benefit" and "to please the land owner, and the tribes, and farmers, especially qat farmers" (ibid.).

Phase 3 began in 2002 with the enactment of the Water Law and, the following year, the creation of the Ministry of Water and Environment, which was supposed to have full authority over water management. The enactment of the Water Law took so long due to the 'vested interests' of the different parties, which were mostly in favour of keeping the 'status quo' (represented by sheikhs and landowners members of parliament) (FMWEY 2015). This was also coupled with a lack of serious leadership which impaired the decision-making process and the setting up of priorities for the country (ibid.). As a Former Minister of Water and Environment in Yemen put it "water has never been really a priority in the politics of Yemen. The rhetoric is high but actually the priority is not" (FMWEY 2015).

During this third phase, the creation of the new Ministry of Water and Environment (which was supposed to be all encompassing, responsible for all issues regarding water resources) was opposed by the Ministry of Agriculture and Irrigation, as well as landowners who went straight to the president to complain. Within a week of having formed the cabinet, the president announced that the powers of this new ministry would be reduced to water as a resource, and the Ministry of Agriculture responsible for distributing water and for irrigation (FMWEY 2015; Lackner 2014). The bylaws of the Water Law, issued in February 2011 ruled over the sole powers of the National Water Resources Authority to issue permits for the construction or deepening of wells.

Only since the Water Law in 2002 it is mandatory to apply for permission to drill a new well, deepen it, or repair an existing one for wells deeper than 60 meters (Lichtenthaler 2014). To deepen a well, no permit is required if it is the first time and the additional depth does not exceed 20 meters (Yemen 2002). Well owners must apply for a water right license within 15 days after completion of the well. The control of wells, water rights, and drilling rigs is based on the National Water Resource Authority (NWRA) mandate who issues licenses to undertake groundwater drilling or exploration activities (Morill and Simas 2009). Irrigation water pricing does not exist and tariffs are only charged for urban and rural water supply and sanitation services connected to the public network; prices for private supply via tankers are driven by the market. Holders of earlier rights to groundwater (wells) are requested to come to the NWRA and register their rights within a period of three years in order to confirm their legal access to the resource.

The law also includes the possibility to establish prohibition zones in case of critical overdraft, where new wells can be banned, water entitlements can be reduced, or even cancelled against due compensation, until the causes of the prohibition have been removed. Employees of the NWRA can freely enter properties to make measurements and control actual abstraction (accompanied by police and security personnel if need be). Fines and punishments of imprisonment with maximum between one months and two years are listed for all kinds of possible violations. The NWRA is also entrusted with the task to estimate and monitor the availability of water resources at the basin level (water balances), and to specify the quantities

that can be distributed to the various uses. In the case of groundwater, this planning of water use has little if any traction on reality.

Despite the law, uncontrolled drilling continues, with most drilling equipment remaining unregistered (Lackner 2014). According to some estimates, only around 10 to 15 percent of well drilling rigs were registered (usually those contracted for international development projects with specific rules to only use officially registered contractors) (FMWEY 2015). The difficulty resided in the fact that they were considered 'agricultural implements' without import taxes, no registration plates on the vehicles, making it very difficult to control them (ibid.). Drilling rig owners also offer financial facilities to farmers to repay the cost of wells (with the first qat crop) and low-level corruption at road check points, that supposedly should stop any drilling rig without registration from NWRA, enabled the indiscriminate expansion of wells (ibid.).

In Yemen, the government has also sought groundwater management via political and administrative decentralization. The move started with the announcement of Law 4/2000 concerning the new organizational and administrative arrangement of local authorities (Van Steenberg and El Naouari 2010). According to this law, local councils are endowed with the role of supervising the implementation of water policies and protecting water resources from overuse and pollution. The Water Law from 2002 created the possibility to establish Water Basin Committees and explicitly stated that they would have to work with local councils (ibid.). For groundwater, the specific focus of this law is the regulation of deep wells as it requires licenses for wells deeper than 60 meters. Some coastal areas in Yemen have however even made specific restrictions on shallow well development due to its importance in farming systems (e.g. in the Tihama coastal plains) but these are piecemeal attempts and usually ad hoc (Van Steenberg and El Naouari 2010). More generally, the lack of operational water management acknowledging and maximizing the value of shallow groundwater continues to threaten the possibilities to safeguard recharge, especially at the tail end of the recharge areas, and redress groundwater depletion (ibid.).

The fourth phase in Yemen's water policies started in 2011 with the National Water conference and the end of the Saleh political regime (Lackner 2014). The president held a National Conference in Management and Development of Water Resources in Yemen in January 2011. The conference proposals aimed at 'giving communities responsibility for water management' via decentralization, as well as using a combination of local traditional water rules with the water law and top level intervention on illegal drilling (with participation of local authorities and security forces).

10.4 Traditional groundwater management systems and their recent evolution in Yemen

Before the advent of drilling technology for tubewells in the 1970s, traditional irrigation technologies in Yemen have been used to provide higher productivity levels in rainfed areas. Spate irrigation systems made use of diversion weirs and associated distribution systems to store and convey seasonal floodwaters to nearby fields. *Qanats* were also common, providing a continuous flow as the gallery would intersect the water table. Qanats ensured access to groundwater and rules about the construction of new ones and their boundaries (*harim*) would prohibit the development of this type of technology, that would interfere with already existing structures or springs and water use (Taher et al. 2012). Shallow wells were also used as a possibility for irrigation, providing a more controlled source of water. Their management was based on the accumulation of knowledge through generations, and extensive practical experience and negotiated systems of rules and organizational structures evolved for the development and management of water resources. The transparency of the link between availability, location and use made these systems prone to self-regulation, with reconciliation

procedures and judgment guiding the process towards shared agreements and allocation (Hellegers et al. 2008).

In Yemen, traditional arrangements already regulate access to land for cultivation, grazing, and water harvesting and help resolve conflicts by discussion, mediation and arbitration through networks of social relationships (Lichtenthaeler 2003 in Taher et al. 2012). With the advent of tubewell technology in the 1970s, traditional systems were undermined and substituted by new pumping technology which allowed the exploitation of aquifers at much greater depths than the shallow traditional systems. A shift in the composition of the cropping pattern also took place towards more intensively irrigated crops (e.g. fruits and qat). As mentioned above, this shift towards intensive irrigation was also sustained by the central government which, since 1975, supported a major investment program to expand irrigation via regional development authorities, and the Cooperative and Agricultural Credit Bank (Hellegers et al. 2008).

10.5 Community management of groundwater resources in Yemen

Several instances of groundwater community management have been reported In Yemen (Bruns and Taher 2009; Van Steenberg et al. 2012; Taher et al. 2012). These include the use of different formal and informal rules in place to abstract groundwater and manage wells by individuals within communities. Leadership is an important aspect of these arrangements as well as user associations. For Taher et al. (2012), user associations serve as intermediaries between the users and the government authorities. Van Steenberg et al. (2012) report that in the area of Wadi Qarada in the Sana'a region, two user associations have established mutual checks and balances and implement tasks of monitoring and control of illegal abstractions for each other, lodging complaints to the government if the one association finds out that the other association has engaged in unlicensed drilling. Small cascade check dam structures were also built in the area in order to improve recharge and reduce the speed of water flow in the wadi. Also in the Sana'a region, farmers in Khrabat Muhyab decided to create their own user association after seeing the conflict and hardship arising from groundwater over-abstraction in nearby areas (Van Steenberg et al. 2012). This newly created grass-roots user association established rules for well distancing and separation from springs. The user association initially covered two villages and 7 wells but by 2012 it had been extended to 58 wells in eight villages (Taher et al. 2012).

Shared wells have also appeared in the Wadi Dhelaa, Sana'a, where ownership of the wells is divided in shares to half a day's water supply (Van Steenberg et al. 2012; Taher et al. 2012). Shares are divided between families and families can own shares in different wells. Users have also connected the different irrigation systems fed by each of the wells so that they can irrigate the area from different wells and compensate in case there is a temporary drop of water levels in one of the wells. In this area, the role of local tribe leaders was essential as they were the ones who introduced the rules for water sharing under this system of inter-connected pipes and wells. As there is no user association for farmers and local councils in this case study, security forces or members of parliament can be called upon to settle the conflicts (Taher et al. 2012). As reflected by Bruns and Taher (2009), cases studied in Yemen where community-led groundwater management has succeeded, show solid local institutions and community consensus which provide enough certainty for farmers to mobilize substantial funding to drill wells and to manage them communally and control the use of water.

In Al-Sinah, in Taiz governorate, the Al-Sinah cooperative has been in operation since the 1960s and stands out as an example of long-term institutionalized local resource management. The cooperative owns three wells and provides approximately 1,900 homes with drinking water. It is forbidden to use water for agriculture and all new plans to drill wells have to be consulted with

the cooperative. The cooperative board is elected every three years from 12 different local assemblies. The cooperative has also sought support from public agencies for part of its investment program. The cooperative bought up fields in a neighbouring hamlet in order to drill wells for drinking water supply. These cooperative-controlled wells worked to limit the number of unlicensed abstractions, as they could threaten the cooperative's access to groundwater. Additionally, public agencies in the area (the Taiz governorate branch of the National Water Resources Authority), did not issue any well drilling permits between 2005 and 2008 without obtaining an authorization from the cooperative. Since 2008 no more drilling permits have been issued (Taher et al. 2012).

Box 2. The *Marqum*, a consensus-building document for groundwater management in the Northern Highlands, Yemen

In Yemen, a document is considered a *marqum* when all members of the community concerned by a specific issue witness the process of reaching a consensus, agree to its wording and endorse it with their signatures or seals. The *marqum* studied by Lichtenthaler (2014) for the village of Hijrat Al-Muntasir, located in the western watershed of the Amran basin, 70 kilometres north-west of the capital, Sana'a, was implemented in order to protect the sole supply of drinking water for the village and to resolve emerging disputes about water entitlements to the village's spring.

The document, signed by 42 representatives of either households or village sections, regulates the fair distribution of available water from the spring according to an agreed rotation system delegated to a responsible adult male from each family. In the event of this person's absence, a substitute must be appointed or an amount must be paid as a day's wage for his replacement. The use of containers to carry water from the spring is also regulated to ensure equal access (only 20-litre containers are allowed). Fines are also contemplated, in the event non-compliance with the rules, which will then go into a general fund for the operation and maintenance of the spring.

Via this system of representation, the document is inclusive, consensus-based as all parties have to negotiate until a unanimous decision is reached, and is also transparent as all parties are involved through an open process. The document thus represents a social contract at the village level, stipulating via detailed rules, the exact fines, size of containers, roles and responsibilities of the different village members. The *marqum* is also legally binding and the non-respect of its rules can be referred to government courts, implying a mutual recognition of the state legal system and customary rules.

Source: Lichtenthaler 2014.

11 Saudi Arabia

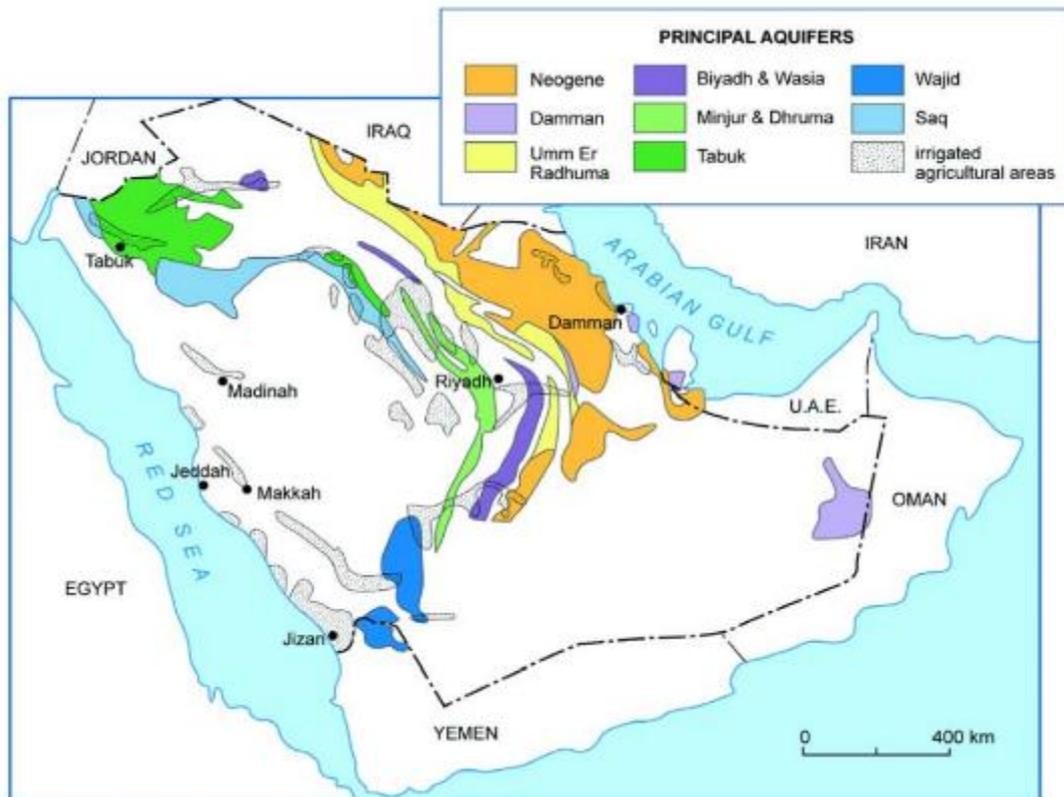
11.1 Groundwater resources in Saudi Arabia

Saudi Arabia's main source of groundwater comes from six major consolidated fossil aquifers storing 253,000 Mm³ of proven reserves (FAO 2009a).³¹ These are namely, 5 different sandstone aquifers: the Saq, Wajid, Tabuk, Minjur, Wasia, and the limestone aquifer of Umm er Radhuma (Figure 30). At the same time, renewable groundwater reserves account for only 2,200

³¹ The possible reserves estimated for Saudi Arabia are up to 700,000 Mm³ (FAO 2009a).

Mm3 per year, recharged by rainfall and runoff and collected in dams (Chowdhury and Al-Zahrani 2013).

Figure 30. Principal aquifers in Saudi Arabia



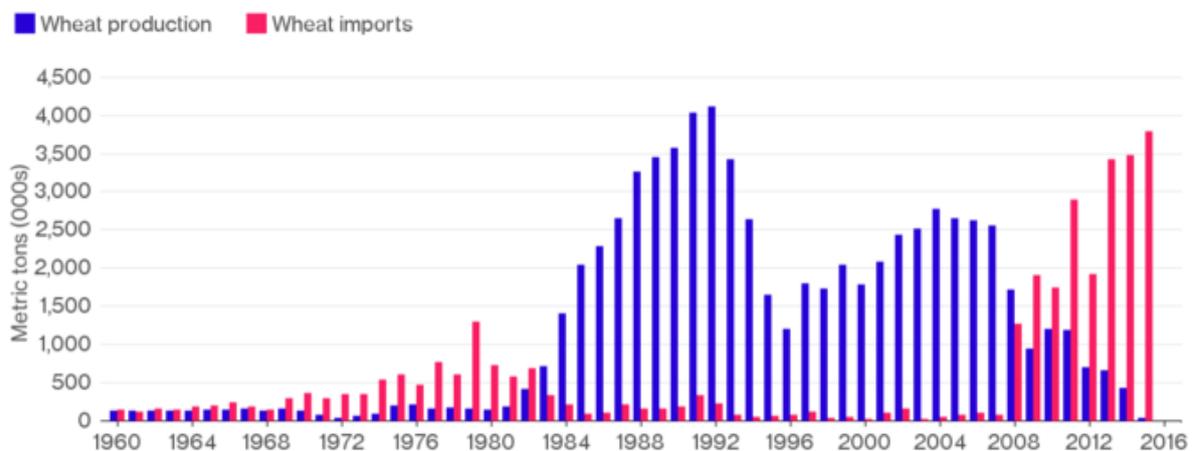
Source: Abderrahman 2006.

11.2 Groundwater regulation in Saudi Arabia

Prior to 2001, the Ministry of Agriculture and Water adopted several regulations to control groundwater abstraction such as permits for well drilling and the supervision of drilling activities by the Ministry (Burchi and D’Andrea 2003). These procedures were regulated by Executive Order 14-62 of 1989 and applied to farmers whose land exceeded 2.5 hectares (ibid.). Bans can also be issued in over-pumped areas or in aquifers suffering from water level decline or quality issue, and drilling companies without licenses as well as well owners without permits can be fined and suspended from working until the fine is paid or the permit is renewed (ibid.). The Ministry can also establish protected areas for special uses – i.e. drinking water purposes. In 2001 The Ministry of Water was given the responsibility for all water-related issues in the country. Water for agriculture is not priced and once the borehole or well has been drilled, the owner has the right to abstract water at his own cost without tariffs being collected by the water authorities.

In 2008, Saudi Arabia enacted a new policy to discourage the cultivation of water-intensive crops such as wheat and encouraged the cultivation of high-value crops such as fruits and vegetables. This policy reduced the share of internally produced wheat to 50 percent of national needs in 2010 and reduced water consumption for irrigation in Saudi Arabia from 17.3 Bm3 in 2003 to 15 Bm3 (Ouda 2014). In 2015 Bloomberg estimated that by 2016 Saudi Arabia will import all the wheat needed for its national consumption, being already the largest importer of barley in the world, used to feed camels (Figure 31) (Bloomberg 2015).

Figure 31. Wheat production and imports in Saudi Arabia



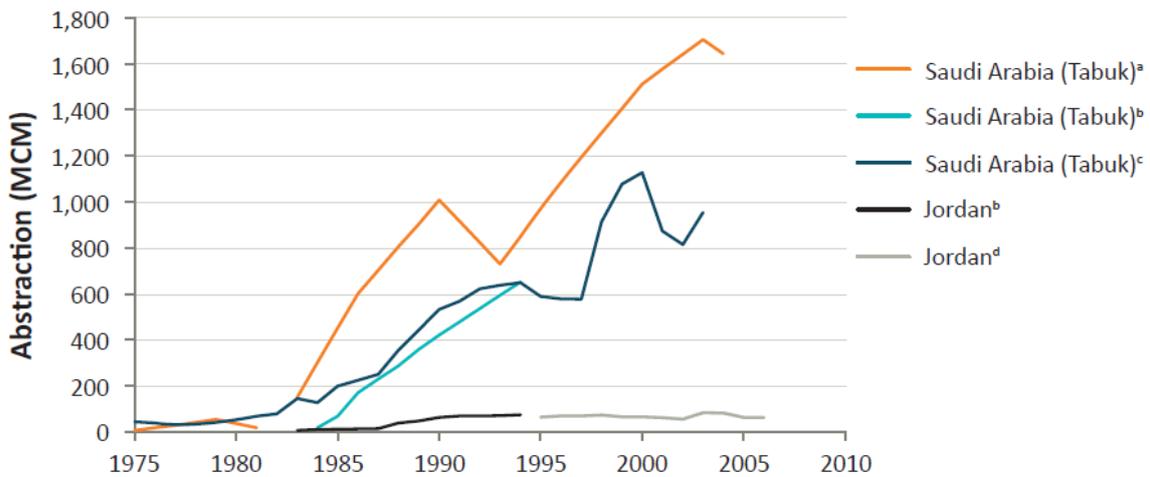
Source: Bloomberg 2015.

11.3 Expansion of groundwater abstraction in Saudi Arabia

Since the 1970s, Saudi Arabia has supported agricultural expansion through sector-support policies. These included, as Abderrahman (2005) wrote, free-of-interest loans, price incentives to crops and subsidies (up to 40 percent) for machinery and farm equipment (including pumps and generators) (*ibid.*). According to this same author, the total value of loans given by the government to the agricultural sector between 1974 and 1998 amounted to 7.7 billion USD (*ibid.*). The government also encouraged the development of agricultural communities by establishing agricultural infrastructure in rural areas in order to provide jobs and improve the standard of living of these communities as well as to protect the social structure in remote areas – notably the nomads (*ibid.*). As a result of this policy, a substantial increase in irrigated surface occurred, from less than 400,000 hectares in 1971 to about 1.6 million hectares in 1992 –mainly wheat, cultivated by large agri-businesses (Ouda 2014) and more than 100,000 wells were drilled in remote rural areas for agricultural purposes between 1974 and 2000 (Abderrahman 2005).

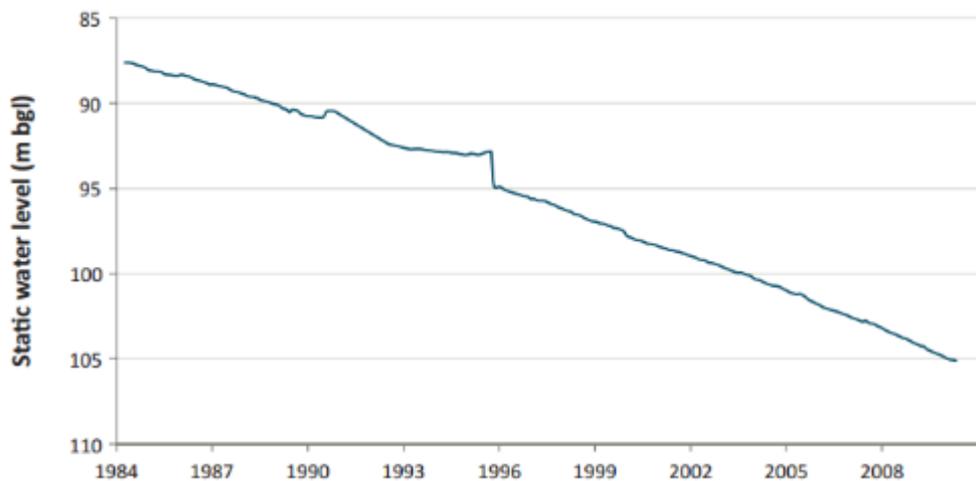
In Saudi Arabia, the Saq-Ram Aquifer System exploitation south of the Jordanian border (also known as Disi) increased dramatically between the 1980s and 2000s. This heavy pumping was mainly directed to agriculture, and has resulted in water table drops of up to 32 meters per year in the late 1980s (UN-ESCWA and BGR 2013). In the Tabuk province of Saudi Arabia, south of the border with Jordan, 500,000 people live there and the aquifer system accounts for more than half of the total nationwide groundwater withdrawals for Saudi Arabia. Withdrawals were marginal until the 1960s but have risen sharply since then from approximately 890 MCM in 1980 to 8,727 MCM in 2005 (*ibid.*). According to estimates from 2008, groundwater abstraction in the Tabuk area represented around 20 percent of the total abstraction from the Saq aquifer in Saudi Arabia. The majority of this water was used for irrigation (94 percent), benefiting two main private agri-businesses operating in the area and cultivating over 37,000 hectares (*ibid.*).

Figure 32. Historical groundwater abstraction from the Saq-Ram Aquifer by Saudi Arabia between 1975 and 2007



Source: UN-ESCWA and BGR 2013.

Figure 33. Groundwater level decline in the Ram Aquifer in the South Wadi Araba Basin



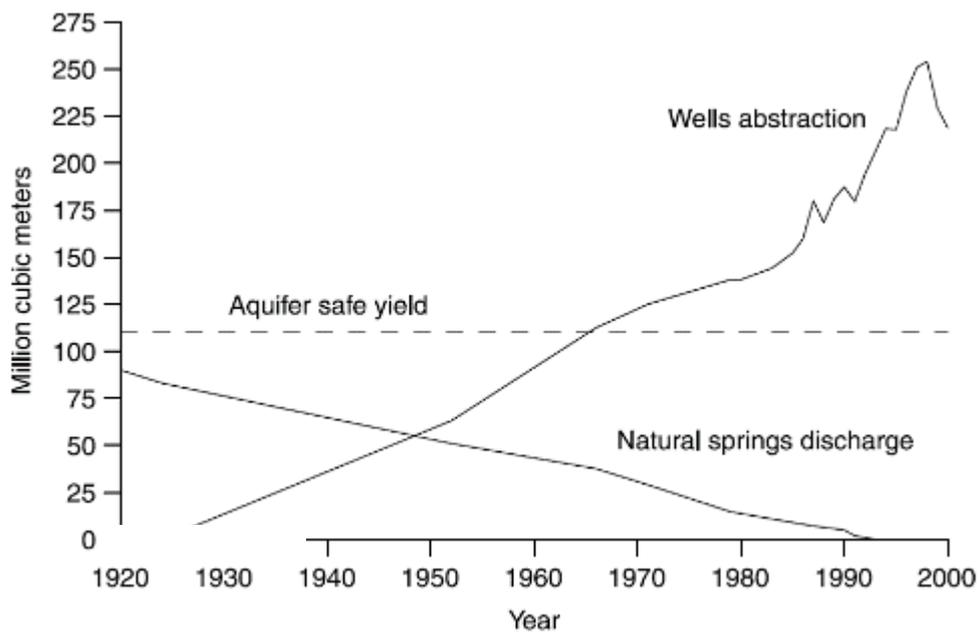
Source: UN-ESCWA and BGR 2013.

12 Bahrain

12.1 Groundwater resources and abstraction in Bahrain

The Dammam Aquifer is Bahrain's only natural source of water. The Dammam aquifer is a confined coastal aquifer and groundwater abstraction from the aquifer accounted for 60 percent of the country's total consumption in 2003. Due to its intense use, groundwater reserves have become overexploited causing the reduction of the natural discharge of springs and increased groundwater salinity due to sea water intrusion. Prior to 1925 however, the population of Bahrain depended entirely on naturally flowing spring water. Oil exploration in 1925 brought along mechanized well drilling, beginning the exploitation of groundwater (Al-Zubari and Lori 2006).

Figure 34. Bahrain's groundwater abstraction



Source: Al-Zubari and Lori 2006.

12.2 Groundwater regulation in Bahrain

Bahrain's groundwater deficit increased and in 1980 a Decree was passed aiming to protect available resources from salinization. Since then, a permit system for wells controlled by the Water Resources Directorate of the Ministry of Municipalities Affairs and Agriculture has been introduced, granting withdrawal authorizations for 5 years, limiting the withdrawal to the levels stated in the permit and charging any amount beyond this value (Al-Zubari and Lori 2006). After two attempts, in 1982 and 1997, to impose meters paid by the users (and subsequent decisions by the state to shoulder the costs after facing protests and vandalism of meters), in 2010 the government decided to make *new* licenses conditional upon users installing a meter at their cost (Al-Zubari 2016).

Permit holders were to authorize the staff from the Authority to access well sites and take readings but also requested to submit abstraction data to the Authority on a monthly basis. At present, around 800 wells out of 1200 working wells have their meters monitored on a monthly basis, a performance that is made possible by good access roads and a relatively limited number of wells and irrigated area (Al-Zubari 2016).

The 1980 decree also gave the Water Resources Directorate the right to discontinue withdrawal from wells either temporarily or permanently, if deemed necessary to protect groundwater resources. Furthermore, exclusion zones banning groundwater pumping and drilling in the Dammam aquifer from 1980 to 1984 were put in place to allow for aquifer recovery. Despite these measures, the number of wells drilled in the aquifer continued to increase, owing to non-compliance attitudes by users (ibid.). During the 1980-1997 period, well records in the ministry indicate an increase from a little over 1,000 to 1,600 wells (Al-Zubari, 2016). While the introduction of metering was partly successful, pricing posed socio-political problems and was resisted. In 1997 a ministerial order (6/1997) determined a tariff for groundwater use but the consultative council (now the parliament) did not approve it, although it was a very symbolic tariff (about 0.01 US\$/m³) designed to give the consumer a feeling for the value of the groundwater (Al-Zubari, 2016).

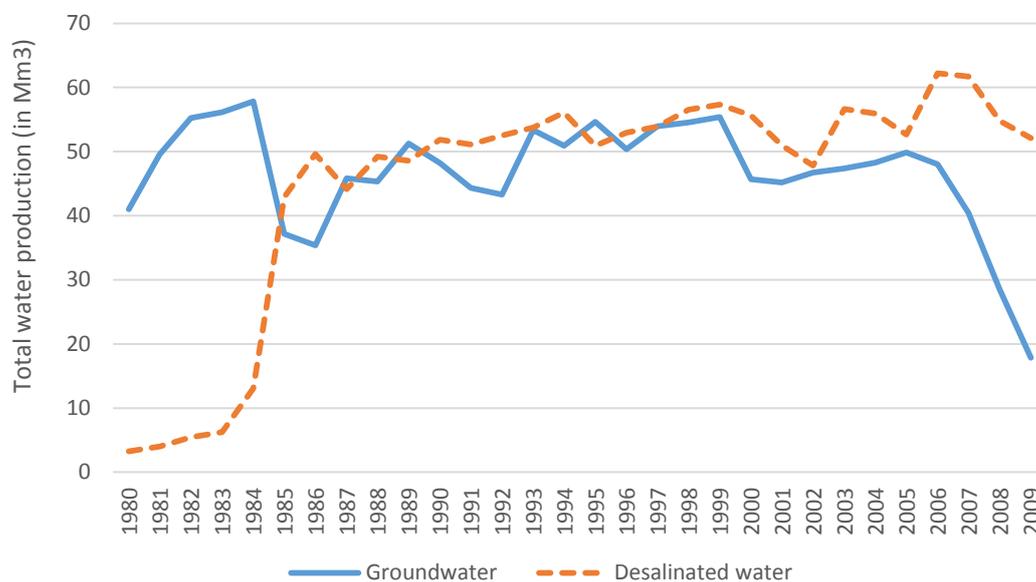
However, while desalination seemed to provide the best technological solution back in the 1980s, the installation of such infrastructure was not able to cope with the much faster increase rate water demand in the country, and did not curb groundwater abstraction (Figure 34) (Hajjaj and Hashim 2013). Lately, Bahrain has also expanded its infrastructure in non-conventional water sources (treated sewage effluent) with a total capacity to treat wastewater in 2012 of 36.1 Mm³ (Al Ansari 2013).

Since 2003, in order to overcome the situation of over-abstraction, various groundwater management options for Bahrain have been put forward. Dependency on groundwater for drinking water was overcome by building desalination plants and groundwater was reallocated entirely for agriculture.

In the agricultural sector, a growing number of wells have discontinued operation because of problems of salinity, urbanization, and replacement by the delivery of better quality (tertiary) treated wastewater (to 413 farms) (Al-Zubari 2016; Al-Zubari and Lori 2006; Al Ansari 2013). As seen in Figure 34, non-conventional sources (desalination and treated effluent) have taken over groundwater supply, despite of the fact that groundwater abstractions continued to increase until the mid-2000s.

Fragmented water authorities offer little coordination (there are four different agencies responsible for water) and there is no clear comprehensive national water policy. Groundwater regulation authority is 'weak' as it is attached to agriculture and suffers from a lack of legislation enforcement. In general, the policy emphasis for the country remains supply management and supply augmentation (Figure 35) (Al-Zubari 2012).

Figure 35. Annual production of desalinated water and groundwater abstraction in Bahrain



Note: Desalinated water includes water produced via reverse osmosis and other desalination technologies.

Source: Based on data from the Electricity and Water Authority, Kingdom of Bahrain (Accessed 7th May 2014, <http://www.mew.gov.bh/default.asp?action=category&id=65>).

13 Oman

13.1 Groundwater resources and abstraction in Oman

Groundwater in Oman is considered the most reliable source of water across the country (FAO 2009c). Renewable groundwater is found in the North, in the North Oman Mountains, and in the south in the Dhofar mountains. Main aquifers in Oman include coastal alluvial aquifers such as the Batinah aquifer lying between the North Oman Mountains and the sea and extends from the UAE to Muscat, the capital of Oman (ibid.). Intensive groundwater development for agriculture in the Batinah plain originated in the 1970s with mechanized wells being used as a replacement to traditional water lifting technologies (Wilkinson 1977). The Batinah coastal plain currently hosts 53 percent of the country's total cropped land, of which 50 percent is dedicated to date palm trees (Zekri 2009). Farms smaller than 4.2 hectares represent 95 percent of all farms in the Batinah coastal area (ibid.). In that coastal strip, 74 percent of wells are electricity-powered (out of a total of 100,000 wells).

In the arid interior of the country, three main projects have been established to develop groundwater in the As-Sharqiya basin to the east, the Massarat basin near the border with the UAE, and the Najd basin in Dhofar (FAO 2009c). This intensification of abstraction since the 1970s and decades after has led to a continuous decline of groundwater levels in most regions, increasing salinity in wells (affecting 38 percent of groundwater wells in Oman as estimated in 1994) and also sea water intrusion such as in the Salalah coastal plain in the south, bordering Yemen (Al-Said et al. 2012; Shammas and Jacks 2008).

In the 1980s Oman was, after Iran, the country with the highest concentration of qanats/aflaj in the world (Beaumont et al. 1989 in Bosi 2009). Oman relies almost entirely on groundwater and around 38 percent is still abstracted using traditional systems such as the *aflaj* system which intercepts the water table and supply traditional communal irrigation systems (FAO 2008b). In 1997, a National Aflaj Inventory programme was undertaken by the Ministry of Water Resources and estimated that the total area cultivated by aflaj was 26,484 hectares, 42 percent of the total irrigated area in the country (Al Sulaimani et al. 2007). The inventory programme in 1997 counted 4,112 aflaj in Oman of which about 74 percent were still in operation (Al-Marshudi 2008; Morill and Simas 2009). Aflaj provide 38 percent of all groundwater consumption in Oman, the rest is exploited via individual wells (Zekri and Al-Marshudi 2008).

13.2 Groundwater regulation in Oman

In Oman, permits are required for the construction of new wells, for deepening existing ones, for changes in groundwater use, and for installing a pump (Burchi and D'Andrea 2003). When stipulated in the well permit, the permit holder will have to purchase and install a meter but alternatively, the authorized Ministry can also purchase and install a meter on the well (ibid.). Groundwater supplied through government networks for urban uses is subject to tariffs. Industrial companies with their own wells however do not pay fees to the government for pumping groundwater as it is neither metered nor monitored (FAO 2009c). Farmers using groundwater for agriculture do not have to pay any fee or rent for the groundwater abstracted but pay for electricity for pumping (Burchi and D'Andrea 2003; FAO 2009c). Drilling and well digging contractors have to be registered at the ministry on a yearly basis (FAO 2009c).

According to USAID (2010), the most far-reaching regulation came in 1988 when water resources were declared a 'national resource'. Several laws have been enacted since then to specifically protect groundwater, such as well drilling regulation (no less than 3.5 kilometers from a mother well or source of a *falaj*) (Al-Marshudi 2008; FAO 2009c). This measure was

enacted as private wells drilled outside the falaj system started to be in direct competition with the same groundwater thus reducing the flow obtained through these traditional techniques (Al-Marshudi 2008).

A ministerial decision issued in 2009 (which cancelled that of 2000) containing a number of sharp dispositions (Oman 2009). All regions in the country are considered 'at risk', that is with a negative water balance and the obligation to go through an administrative procedure before rilling a well, unless specifically marked as 'open' (drilling is allowed without permit). All pending procedures or registrations are cancelled for wells dug after 1990 without licenses, dug by persons with no land title, or permanently dry; and these wells must be backfilled (*radam*) within 30 days, otherwise legal measures will be taken. A permit is requested from new wells, deepening, change in purpose of use, change in pumping equipment, use of formerly unused well, and transaction. A deposit of 500 JR has to be made before receiving such permit. After drilling of a well, under the supervision of the municipality, the owner has 15 days to present data on the well to the ministry, which will send it staff to check the accuracy of the information (in particular wells must be located at least 3.5 km away from the mother well of a *falaj*, as indicated earlier). The quantity of water that can be abstracted from the well is specified by the Ministry's license and well owners must install a meter on their well (in case it does not work the ministry must be informed immediately). A request for well deepening cannot be justified by the objective to improve water quality or the yield of the well, and the irrigated area cannot be enlarged. When a well is replaced, the former one must be backfilled in front of an official from the municipality. Drillers must register anew every two years and deposit a fee for each drilled well (which will be returned after the work is completed and checked).

Despite the introduction of measures to reduce over-abstraction since the 1980s, groundwater reserves in Oman are overexploited. Groundwater over-abstraction had already been detected as a problem in 1991 in the National Water Resources Master Plan, calling for a reduction of 215 Mm³ of groundwater pumping (Zekri 2008). Water overpumping represented around 177 Mm³ per year, 30 percent of the total groundwater abstraction (Zekri 2009). The decline of the water table reached up to 5 metres between 2002 and 2004. Such groundwater over-abstraction has been causing land salinization (reaching 12 kilometres inland in some areas of the Batinah plain).

The coastal aquifers found on the Batinah plain are heavily pumped, even though groundwater monitoring and more specific measures to reduce groundwater abstraction were introduced in the 1990s (Zekri 2008). These measures included water saving technology (in 28 percent of the cultivated area in the Batinah plain, tripling the area with sprinkler and drip irrigation over the last 10 years through subsidies from the government (Al-Said et al. 2012). These systems are however mostly found in new farms and old irrigated areas still use the traditional aflaj systems using flood irrigation (*ibid.*). The government also build 15 recharge dams with a total storage capacity of 41.5 Mm³ per year, imposed a freeze on the drilling of new wells and introduced wastewater reuse (Zekri 2008, 2009). The Ministry of Regional Municipalities and Water Resources also established several no-drill zones on the Batinah plain and well-field protection zones were also established to protect municipal water supplies (Zekri 2009).

13.3 Traditional methods for collecting groundwater in Oman

In Oman, before the introduction of diesel pumps in the 1970s, the aflaj were the only significant system used for irrigation (Al Sulaimani et al. 2007). There are three main types of aflaj in Oman: 1) the Ghaili falaj, supplying water through perennial flows from wadis or rivers and conveying water through open channels; 2) Aini falaj, drawing water from natural springs and transporting water from open channels; 3) the Daudi falaj, extracting groundwater through

tunnels dug sideways intercepting the water table of the aquifer (Zekri and Al-Marshudi 2008). The Ghaili falaj is the most common in Oman (with 1,993) according to the latest census available, followed by the Aini falaj type with 1,152 and last the Daudi falaj with 967 (ibid.). The Daudi aflaj however irrigate the largest surface in Oman, with 13,946 hectares (20 percent of total irrigated area) and supplies the largest amount of groundwater (53 percent against 26 percent for the Aini aflaj and 21 percent for the Ghaili aflaj) (ibid.).

The aflaj provide not only a distribution system for water with rules, but also a system of association between users with rules operating for hundreds of years. They are run by a wakil chosen by the owners who is in charge of water distribution, expenditure, and solving water disputes between farmers (USAID 2010). Despite the advent of modern drilling techniques and the physical threats to these constructions posed by flash floods, the aflaj system still represents 38 percent of the total water consumed by agriculture (FAO 2008b). Users of the aflaj system have been engaging in exchanges of water rights (Zekri and Al-Marshudi 2008). These markets concern either the sale and purchase of permanent water rights or the temporary lease. The unit used is the 'Athar', corresponding to half an hour per water cycle and not based on volume (ibid.). Exchanges are made through auctions usually in the village. Auctions of temporary rights are the main source of income for aflaj communities, and are usually conducted within the same aflaj community.

Contemporary changes have however affected this type of traditional irrigation technique in Oman. The level of shareholder participation in the management system of the aflaj has been reduced as well as its role in agriculture following dropping water table levels due to groundwater over-abstraction and frequent drought (Bosi 2009). Volume supplied through the aflaj in Oman was estimated at 459 Mm³ down in 1999 down to 377 Mm³ in 2003, with 14 aflaj drying up during 1996 and 2006 (Zekri 2008).

Access to private wells also reduced farmers' incentives to participate at public water auctions to allocate remaining or additional flow to other users run by the aflaj communities (Bosi 2009). This happens despite the fact that aflaj systems have senior priority over access rights to groundwater (Zekri and Al-Marshudi 2008). Such seniority is implemented through protection zones around the catchment area of the aflaj's mother wells, main and secondary canals (ibid.). Maintenance problems of aflaj systems also triggered government intervention in Oman who has spent 2.5 million USD yearly since the 1970s in funding aflaj maintenance (Bosi 2009). The government has repaired, since the 1980s, almost 1,000 aflaj and set up a special department to take care of them (ibid.).

Even though the protection zone around aflaj was meant to protect these systems (respecting the traditional rule of seniority giving preferential access to water for the aflaj with respect of newer abstractions such as private wells), this rule is however not seriously implemented in Oman, as few state resources are dedicated to enforce it (Zekri and Al-Marshudi 2008).³² This has caused the drying-out of several aflaj and oases around them have lost productivity (ibid.).

³² As opposed to the normal management of the aflaj, this rule is supposed to be enforced by the state (Zekri and Al-Marshudi 2008).

14 Iran

14.1 Trends in groundwater development

Iran is well known for its use of groundwater through *qanats*, which are believed to number between 30,000 and 50,000. Many of them, however, are out of order and statistics for the year 1999 put their number at 27,841 (Karimi 2003; Molle et al. 2004). The history of the destruction of qanats by wells is documented by several studies (e.g., Ehlers and Saidi 1989) and well illustrated by the Borkhar area, a flourishing cultivated area north of Esfahan. Starting in the 1960s, the qanats were destroyed by the ensuing spread of deep wells sunk to irrigate summer crops and orchards (Molle et al. 2004). Data provided by Karimi et al. (2012) (Figure 36) indicate that there were about 45,000 to 50,000 tubewells in Iran in the 1970s and that this number increased rapidly to reach 500,000 in 2006 (a nearly 6 percent annual growth in the last five years, from 2001 to 2006). It is believed that this number should be increased by one third to account for unregistered tubewells (Karimi et al. 2012). More recent data indicate that in 2006-2007, a total of 786,478 structures (springs, qanats and wells) provided 79.19 Bm³ of groundwater, with a total number of wells estimated at 624,838 (Table 4).

Table 4. Number and discharge of groundwater resources (Year 2006-2007)

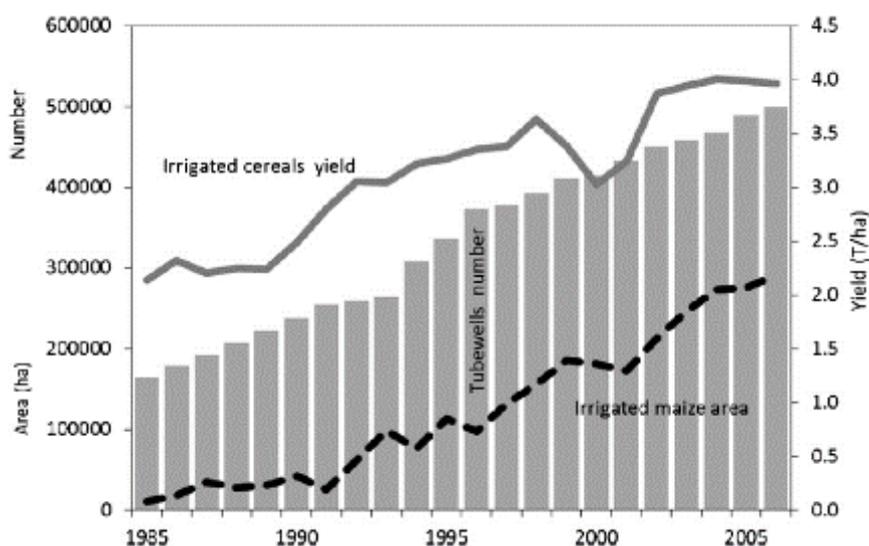
<i>Number and discharge of groundwater resources (2006-2007)</i>		
<i>Type of water resources</i>	<i>Number</i>	<i>Discharge (Mm³)</i>
Spring	124,443	22,914
Qanat	37,197	7,375
Well	624,838	48,907
Total	786,478	79,196

Source: Assadollahi 2009.

Like anywhere else, the surge in tubewells has been driven by decreasing drilling costs, the ease and security in supply offered, a growing demand for high valued agricultural products, and government subsidy and loan programs. Currently, approximately 49 Bm³ of groundwater are pumped from aquifers in Iran, and 90 percent of this amount is used by the irrigation sector (Assadollahi 2009). This means that more than half (55 percent, or even 65 percent according to Jaghdani 2011) of irrigation water supply (83.5 Bm³) comes from groundwater resources (Zehabian et al. 2010). As shown by Karimi et al. (2012) in one third of Iran provinces, more than 80 percent of lands are irrigated by groundwater (Figure 37).

Uncontrolled abstraction has led water tables in the past ten years to drop at a rate of up to 1 meter per year in most of major agricultural areas, with an average of 0.4 meter per year across the country. Niayesh (2015) reports on the criticalness citing Issa Kalantari, secretary general of Iran's House of Farmers and former agriculture minister, "Iran's water crisis was more of a threat to the country than Israel, the US or political infighting." As in other places negative impacts of over-exploitation include: a decreased in supply and available water resources; wells in need of repeated deepening; land subsidence; saline water intrusion; decreasing groundwater quality (Assadollahi 2009).

Figure 36. Growth of tubewells, irrigated cereal yields, and cultivated area in Iran



Source: Karimi et al. 2012.

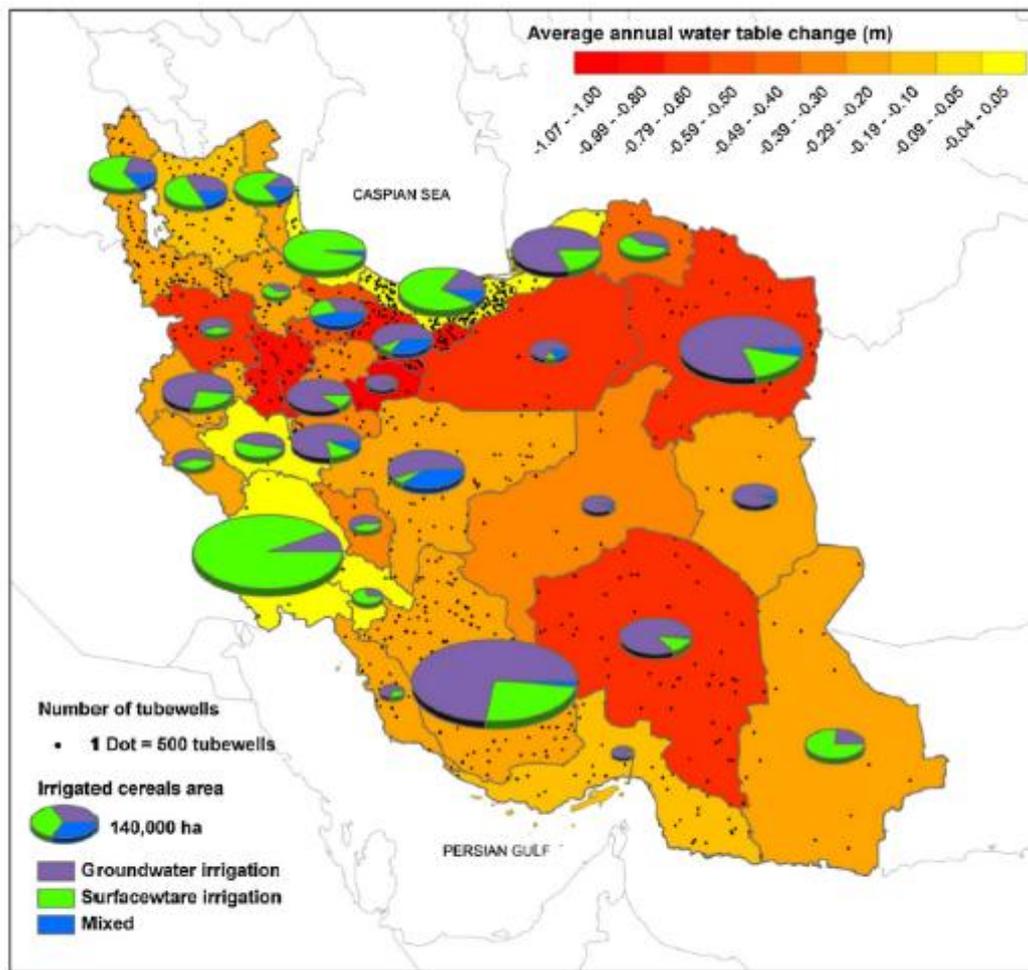
14.2 Regulation of groundwater use

According to the Water Law, "allocating and issuing permits to use the water for domestic, agricultural, and industrial purposes is the responsibility of the MOE" (FAO 2009d). Particular individuals with influence or power may be granted permits to dig wells even if this contravenes the rule that forbids digging or drilling a well within a radius of 500 meters of a pre-existing well (Molle et al. 2004). Little is known however about the details of regulations and how these are enforced. To avoid further groundwater depletion in critical areas, 'prohibition zones' can be declared. Out of 609 aquifers, 203 are classified as 'normal prohibited aquifers' and 67 as 'critical prohibited aquifers' (Assadollahi 2009). The total area of aquifer under restricted management condition is 154,854 km² where the annual average depletion rate is 0.50m and where the total over abstraction totals some 4.7 Bm³ per year (FAO 2009d).

As indicated above energy prices do not contribute to limit groundwater use, much to the contrary. Pumping costs only represent less than 2 percent of the actual production costs in agriculture (FAO 2009d). While surface water prices are quite high (around USD 1-2/m³) groundwater is free of charge for well holders. A tax on groundwater use equivalent to about 0.25-0.5 percent of the crop production was levied at some time but has now been discontinued (FAO 2009d).

A few years ago, the Ministry of Energy has spelled out 12 procedures "to overcome the groundwater crisis" in Iran (Assadollahi 2009), including the registration of well drilling companies as, according to FAO (2009d), there were about 347 drilling companies working in Iran with 1,389 rigs. Additional measures could include identifying the current status of illegal wells, 'locking' illegal wells, encouraging and training staff, raising budget and research efforts, increasing recharge and building underground dams, installing 'smart meters', raising public awareness, GIS and data management, establishing and training WUAs, and ultimately amending the Water Law.

Figure 37. Use of surface and groundwater in Iran



Source: Karimi et al. 2012.

15 Turkey

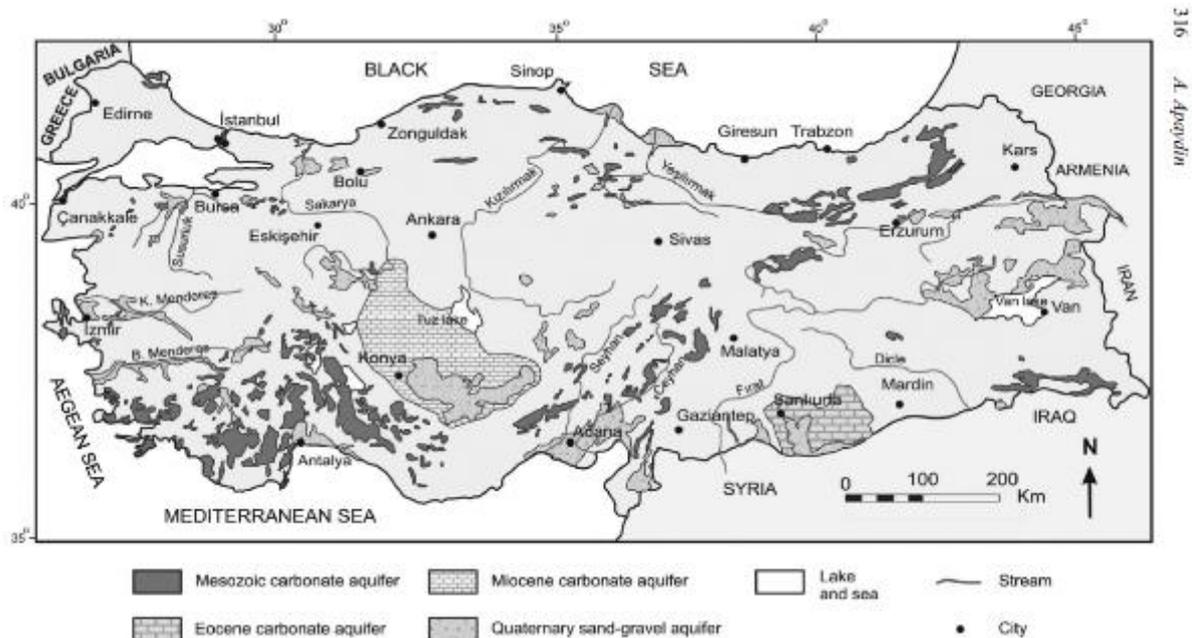
15.1 Current groundwater use and general management framework

The main aquifers in Turkey include sand-gravel deposits and carbonate formations, most of which are karstic and cover almost a third of the country (Figure 38), providing Turkey with "a great groundwater potential" (Apaydin 2011).

The Constitution of the Republic of Turkey of 1982 declares that water is a public good under the trusteeship of the State, and that consequently "natural wealth and resources shall be under the authority and at the disposal of the State. The right to explore and exploit these belongs to the State" (Zeldon 2010). The Civil Code states that "underground waters are generally beneficial to the public, and therefore, ownership of any land shall not cover the water under that land," and that "pursuant to the Constitution, underground waters and mineral waters are under the command and possession of State" (Coskun 2003). The government is responsible for the development of water resources, with the exception of privately owned springs and waters. The main legislative texts dealing with groundwater are the Groundwater Law, No. 167 of 1960, and Bylaws in 1961 and 1972, in particular, sets priorities for the use of underground water, i.e., for drinking, cleaning, animals, and last for irrigation (Coskun 2003). There has been intense

discussion on the renewal of this (old) law in past years, especially with regard to adapting legislation to European frameworks, notably with regards to water quality/pollution, definition of safe yields in an integrated manner, and participation in planning at the river basin level (Apaydin 2011; Yildiz and Uysal 2015).

Figure 38. Main aquifers in Turkey



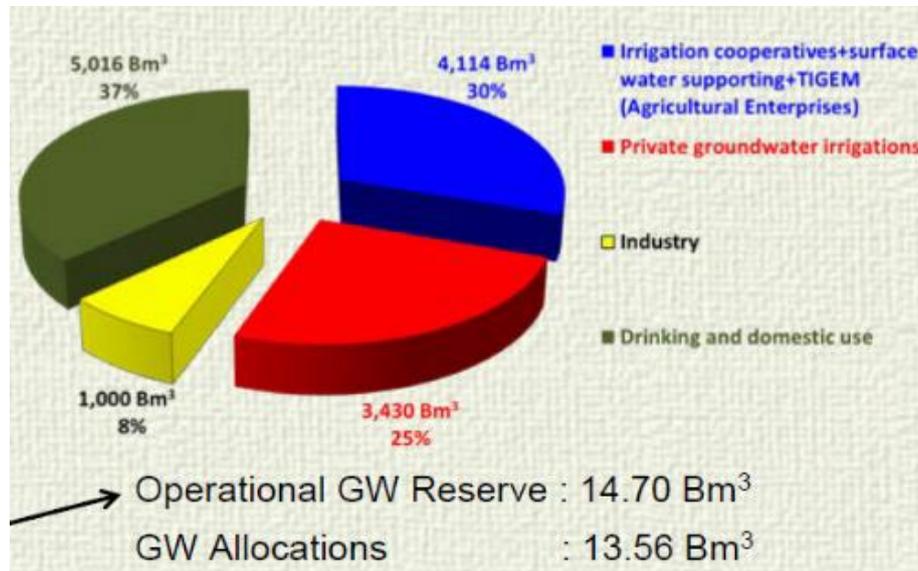
Source: Apaydin 2011.

A license is needed for all aspects of groundwater use: an exploration license is first needed to drill the well, if it is to be deeper than 10 m and drilled or excavated by hand (Apaydin 2011). This license is valid for one year and the owner has to drill his borehole during this period, after which he can apply for a "license for use". This license is given by DSI if legal and technical requirements are met, in particular the minimum distance to be ensured between the well and existing ones. Groundwater users must also apply for a "license for reclamation and alteration" if they want to deepen or change the characteristics of their wells. These licenses indicate the amount of water allocated to the user, which cannot exceed the amount of water calculated for beneficial needs (Apaydin 2011). In theory DSI reserves its right to decrease or increase the allocated water indicated on the licenses, according to the situation, and also to control at any time all groundwater works made by engineers, driller and users. Despite some recent DSI regulation putting emphasis on the installation of meters, monitoring of actual water use by both individuals and cooperatives is weak to nonexistent (Apaydin 2011; Le Visage 2015), partly on account of the very high number of wells, as well as of the crucial importance of groundwater in making/keeping agriculture competitive. In theory all borehole drilling activities have to be carried out by 'licensed drillers', who must pass a test applied by DSI every year. But illegal drilling remains pervasive (Apaydin 2011).

According to Dođdu (2013), 13.56 Bm³ out of a 'reserve' of 14 Bm³ are allocated to different uses, 55 percent of which goes to agriculture (both individual and collective wells), 37 percent to the domestic sector, and 8 percent to industries (Figure 39). A total of 3.43 Bm³ was allocated for individual groundwater irrigations, corresponding to 273,962 user licenses (Fayrap and Sargin 2015), while 180,000 wells remain "undocumented" (presumably illegal) (Yildiz and Uysal

2015). The wells operated by DSI include in particular 1,665 deep wells which have been drilled to complement supply in surface water irrigation schemes, providing conjunctive use to 83,432 ha of land (DSI 2012).

Figure 39. Groundwater use by sector in Turkey



Source: Doğdu 2013.

Turkey also has a mechanism whereby overexploited aquifers can be declared as critical or semi-critical basins. In such cases, all wells have to be equipped with flow meters, according to a new regulation issued in 2011. Four basins have been declared as critical basins (including the Konya closed basin) by decision of the cabinet, which has followed the recommendation of DSI and banned further well drilling, as well as allocation of licenses (Doğdu 2013). Elsewhere it is proposed that new licenses will exclusively be given to farmers who use drip irrigation.

Innovative technologies are being tested in order to control water abstraction: 7,000 registered wells have been equipped with a new device which automatically closes the wells when the total amount allocated has been pumped, as monitored by the meter (Doğdu 2013). The government has also carried out national awareness campaigns, with posters and TV broadcasting, water saving campaigns with popular artists on TV programs, education of students about the importance of water, gathering of local governmental officials to sensitize them to water challenges, etc. (involving stakeholders; better understanding the issues and adopting best practices; coordinating approach to resolve water issues, using resources more effectively, etc.) (Doğdu 2013).

15.2 Groundwater Irrigation Cooperatives

Groundwater Irrigation Cooperatives constitute a substantial share of groundwater-based irrigation in Turkey, but for some reason are very little documented, at least in the literature available in English. Groundwater Irrigation Cooperatives have been first founded in 1966 in accordance with the cooperatives Code 1163. DSI has the responsibility "to prepare technical and economic feasibility reports concerning the facilities to be constructed by DSI, to drill groundwater wells, to erect the electrification installations to these wells, to determine right motor-pumps and procure them for the wells" (DSI 2012). The "Transfer Contract" prepared by

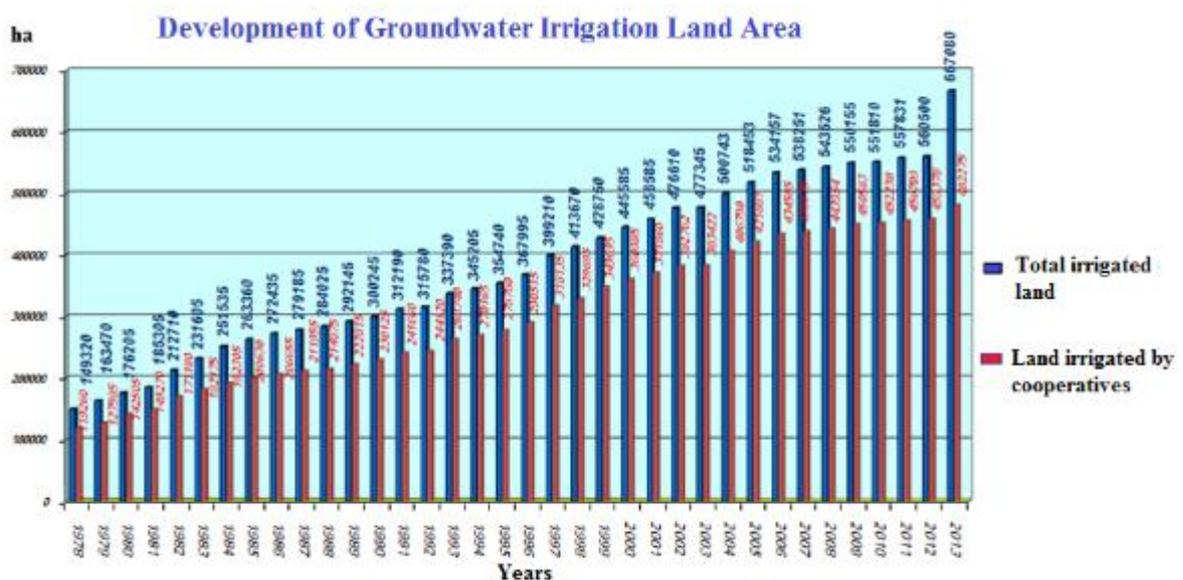
DSI includes reimbursement of the initial investment over a period of 30 years, with zero interest and a five year grace period (conditions which were changed in 1997, to three years of grace period and 12 years of annual installments). In 2010, an area of 452,238 hectares was irrigated by means of 11,235 deep wells (10,380 of which transferred to Groundwater Irrigation Cooperatives).

The creation of a Groundwater Irrigation Cooperatives (GIC) is handled by the Agricultural Development Section of the Provincial Administration. A minimum of 7 farmers are to come together as a group and to make a request, with their land title deeds and copy of identity cards to apply to the Provincial Directorate of the Ministry (Fayrap and Sargin 2015). The Provincial Directorate requests the Geotechnical Services and Groundwater Department of DSI General Directorate to investigate the status of groundwater in the area. If conditions are favorable, this services establishes a 1/2500 map, with the area to be irrigated and its size. The Groundwater Department of DSI prepares the feasibility report, after which the boreholes are drilled. If farmers cannot afford the investment cost this can be done by DSI and reimbursed later. The same applies to the irrigation distribution network, which can be done by the local Authority of Rural Service. Financing is arranged with the Agricultural Bank (Fayrap and Sargin 2015).

Licenses for individual wells are generally not given by DSI for farms located within the area of the cooperative (unless the president of the cooperative agrees, which is rarely the case) (Le Visage 2015). Where surface water is not available, the benefit of groundwater can hardly be refused, since it is the main source for irrigation (Fayrap and Sargin 2015).

Since the beginning of 1970 Groundwater cooperatives reached 482,275 hectares of irrigated area (Figure 40). Yildiz and Uysal (2015) indicate that 73 percent of the land irrigated with groundwater in Turkey is irrigated by Cooperatives (but this does not take into consideration illegal individual wells). 2,500 Irrigation Cooperatives are grouped under 27 Regional Associations and a National Central Union of Cooperatives, with a total of 1.8 million farmers concerned.

Figure 40. Evolution of groundwater-irrigated land area



Source: Yildiz and Uysal 2015.

Cooperatives, like other irrigation organizations (WUAs), establish water charges that are calculated to cover O&M cost, most particularly electricity costs and staff salaries, and proportional to the area irrigated, and sometimes modulated depending on the type of crop cultivated (Çakmak 2010). Collections rates are usually higher than 80 percent (Çakmak 2010; Yercan et al. 2009; Le Visage 2015). The expenditures on durable equipments (i.e. trucks, other equipments) are charged separately depending on farmers' area of irrigated land.

There are both legal and political constraints to recovering the capital costs of irrigation schemes developed by public institutions. Areas developed by the now abolished General Directorate of Rural Services (GDRS) were taken over by the irrigators free of charge since there was no legal basis to recover any investment costs incurred by GDRS. If a tube well is necessary, it is installed by DSI, and DSI was supposed to be reimbursed for the expenses in compliance with the DSI law. The conveyance canals or pipes from the source to the field were constructed by GDRS without any pay back required from farmers for projects mobilizing water under 50 l/s.

Le Visage (2015) has looked in more details at the functioning of three GICs, in Kemalpaşa, near Izmir, where 10 GICs of between 50 and 700 members are in operation. In Kemalpaşa, GICs have allowed economies of scale and farmers without enough capital to access groundwater, and by providing water, substantially boosted the intensification and diversification of agriculture, in particular towards fruit trees. The cost of groundwater varies substantially depending on the depth (between 20 and 250 m) of the well and local geology. Some cooperatives are proactive and also try to access surface water or to construct small reservoirs, in order to lower prices and increase security in supply.

Irrigation Cooperatives depend on the Ministry of Agriculture, which is very little involved in their functioning, since they are considered as private, unlike in the case for Water User Associations which are considered as public entities and have their accounts audited annually, with the obligation to have at least 30 percent of their budget devoted to maintenance. GICs are not taxed like commercial companies, and have enjoyed subsidies through projects implemented free of charge by the GDRS. This service has been recently discontinued in 26 regions out of 88. DSI is the remaining administration which can be mobilized by cooperatives for technical projects (creation of new wells, deepening, storage and other projects, advice for financial management, etc.), but at the expense of the cooperative (Le Visage 2015).

The main problem faced by irrigation cooperatives (just like irrigation WUAs in general) is financial sustainability, on account of the relatively expensive cost of water abstraction (with variations according to the depth of the well). According to one DSI official, only 10 percent of the cooperatives in the region would be financially fully autonomous. Financial sustainability has been dented in some cases by individual strategies (members managing to drill wells and get independent extra water), lack of leadership of the management board and weakness in collecting fees, the need to invest in new wells or to access alternative sources when discharge decreases or wells dry up, but more generally is now being challenged by the recent privatization of electricity services, with an increase in the price of electricity of 22 percent in 2013. Delay in payment is now sanctioned by the private company through systematic power cuts. This sudden policy change and increase in costs has met the opposition of farmers who seem, in many cases, to have retaliated by stopping the payment of their yearly installments to DSI (for reimbursement of investments) (Le Visage 2015).

The cases studied by Le Visage (2015) suggest that the presidents of the cooperatives need to receive a salary and to be highly professional in order to efficiently administrate the

cooperative, which includes developing a good relationship with the electricity provider and being flexible enough to accommodate the personal situation of members. This also applies to administrative staff and technical staff in the field, in charge of water distribution. According to Ozdemir (2005), 70 to 90 percent of the members of cooperatives (devoted to credit, marketing or development) consider that the facts that the cooperatives originate from their own initiative and that they enjoy administrative autonomy is key to their relative success. They can determine the price of water by themselves, engage in additional activities such as agricultural extension/advisory services, propose development projects, decide to pay for staff or not and to define their own internal regulations, etc. and are quite independent from the government.

PART 2. Analysis

1 Groundwater development in the Middle East and North Africa

Groundwater is a strategic resource for the region (Table 5). The generally poor surface water endowment coupled with rapid population growth rates since the 1970s (the region's population has doubled between 1980 and 2011 from 170 million to more than 350 million) have decreased the region's per capita water consumption from around 3,500 m³ per year in 1960 to 700 m³ per year in 2011 (Al-Zubari 2012). Groundwater is the region's second conventional water resource and in countries like Bahrain, Jordan, Oman, and Yemen groundwater contributes more than 50 percent of total water withdrawals (UNDP 2013; Wada et al. 2012). The over-abstraction of this resource has not only environmental but also economic and social implications. Even though it has been estimated that the value of national GDP consumed by groundwater over-abstraction could be equivalent to 2 percent of Jordan's GDP and almost 1.5 percent in Yemen (The World Bank 2007), these estimates do not take into account the strategic importance of the resource at the local level for rural livelihoods, food production and also drinking water supply for cities (in countries such as Jordan, Bahrain, or Yemen).

Table 5. Groundwater use in Arab countries

	% of full/partial control irrigation water from groundwater	% Groundwater withdrawals of total withdrawals
Algeria	68.5**	35.6
Bahrain*	90	67
Egypt	10.6**	10.8
Iraq*	6	-
Jordan*	53	59
Kuwait*	61	45
Lebanon*	22	53
Libya	98.7**	87 (a)
Morocco	30**	19.6
Oman*	100	89
Qatar*	93	50
Saudi Arabia*	97	90
Syria*	60	-
Tunisia	61.3**	75.5
UAE*	100	70
Yemen*	100	71

Note: (*) FAO Water Report 34 (2009); (**) FAO Irrigation in Africa figures, Aquastat Survey 2005; (a) groundwater withdrawals from non-renewable sources.

Source: FAO Aquastat.

2 The role of the state in groundwater management

2.1 The state and groundwater development in the Arab world

The role of the state in water management and planning in the Middle East and North Africa is almost ubiquitous.³³ During a high-panel conference on groundwater governance in the Arab World organized within the framework of a GEF-funded project, the participants highlighted the

³³ For a further discussion and clarification of the role of the state in the Arab World see Annex 2.

fact that in all countries of the Arab region the government was the main entity responsible for water governance (Tutundjian 2012). The various country representatives at this high-level forum (mostly from official ministries and public agencies) perceived that the countries had adequate formal institutions especially at the national level but that these institutions needed a lot of support (capacity building, strengthening of technical capacities of staff, and budget support) (ibid.). Additionally, as it usually happens, it was perceived that “although policies exist, enforcement is lacking” (Tutundjian 2012: 9). This characterization of the state in water and groundwater management as centralizing system of rules and management but with lack of enforcement capacity, is the first aspect this second part will analyse.

What comes across in this section is first the idea of the state as a pivotal entity in groundwater development and management. The state can have an active role in the direct control and development of these resources, with aims ranging from raising rural incomes, ensuring food production and food security, or access to drinking water supply for expanding cities and urban areas. The development of groundwater in turn, as Allan (2007) wrote, played a pivotal role in strengthening family livelihoods.

Secondly, states in the region have also sought to develop agriculture as a strategic sector bringing in private capital under the form of large agri-business companies (e.g. Saudi Arabia, Morocco, Jordan, or Egypt). In Egypt, 75 percent of all desert reclamation (for agriculture and urban projects) has relied on private investors and corporate modes of farming (Sims 2015). These capital ventures in agriculture have in general benefitted from generous subsidies and financial incentives, and have been motivated by permissive state regulation and a lack of control of groundwater abstractions.

A major example of the direct role of the state in such ‘hydraulic mission’ and specifically on groundwater is Libya and its ‘Great Man-Made River’ project. The project includes the transfer of 6.5 Mm³ of groundwater per day from large aquifers in the desert in the south to the north, to be used for irrigation and urban uses. Egypt’s development projects in the desert since the 1950s have included well fields in various oases as part of the ‘new valley project’ in the western desert. The government reclaimed thousands of hectares for irrigation in oases such as Kharga and Dakhla and more recently, since the 1990s, further south near the border with Sudan (East and West Oweinat).³⁴

The development of irrigation by the state via public irrigation projects in Morocco and Tunisia also benefited from the access to groundwater. Since the 1970s, the Tunisian government has developed works and infrastructure to regulate its water resources. By transferring surface and groundwater from the hinterland to coastal areas, the country has built a series of water infrastructure ensuring agricultural water consumption and water needs for tourism in coastal areas (Le Goulven et al. 2009). In the Merguellil Basin, the government implemented 15-well based public irrigation schemes in the 1970s abstracting groundwater but since that decade and the following, private irrigation via wells have burgeoned reaching around 5,000 wells in 2005 (Bachta et al. 2005). Support to individual well development through various types of incentives for drilling wells, buying pumps or, indirectly, buying micro-irrigation equipment, has also been a central aspect of agricultural policies, with the aim of supporting rural livelihoods and income (e.g. Morocco, Tunisia).

³⁴ Figures regarding the actual surface reclaimed for agriculture in Egypt’s deserts (called ‘new lands’) differ according to sources. Sims (2014) gathered the main statistics until the mid-1990s put forward by different agencies and ministries, spanning from the more conservative figures of the Ministry of Planning, with 0.815 million feddan reclaimed by 1997 to the more rosy figures issued by GARPAD (the General Authority for Reclamation Projects and Agricultural Development) with 2.6 million feddan reclaimed from the 1950s to 1997.

Additionally, the state can also have an active role in the development of groundwater resources as part of a campaign to settle tribes and nomads in rural areas linking it in, some cases, as part of a wider program to ensure rural livelihoods or supporting the development of rural water supply via wells (e.g. Jordan). The development of groundwater can also be linked to sustaining patronage relationships within the state apparatus and its relationship with local leaders (e.g. Yemen) (Zeitoun 2009; Zeitoun et al. 2012). Via the passivity or laissez-faire state rule, local leaders or specific groups or elites (e.g. the army in Egypt) benefit from permissive regulation and/or connections in order to develop agriculture ventures and drill wells.

Donor funds can be also used to support state activities within the management and regulation of groundwater. In Yemen however, donor money from international development agencies such as the World Bank financing wells in the 1970s or bilateral funds such as German or Dutch have been used to develop the country's water management infrastructure and institutions. In Yemen, between 2005 and 2009 achievements in irrigation and watershed managements only came from 3 World Bank funded projects, with little additional funds committed by the Government of Yemen (Redecker 2007). These international institutions have however been driving water management, putting "pressure [...] for more sustainable management of the resource", and "with idealist views, [...] too much interested in the shape, not the product" and too keen "to spend the money, than to spend it right" in the opinion of a former Minister of Water and the Environment (FMWEY 2015).

2.2 State legislation and regulation of groundwater abstraction: a panoply of policy tools

The role of the state in groundwater management and governance manifests itself mainly via the use of various policy tools deployed to contain groundwater over-abstraction, develop and control abstractions and regulate the use of groundwater. Research by Faysse et al. (2011) has examined comparatively the extent of different modalities of groundwater management instruments in the Maghreb (Table 6). He observes that although there is a variety of policy instruments being used to limit groundwater withdrawals, there are no instruments used simultaneously that reduce withdrawals and improve water productivity. As this author reflects, the main constraint to the implementation of strict groundwater management is not its costs but the determination and close involvement of local authorities (Faysse et al. 2011).

Table 6. Groundwater management and policy instruments, tools, and areas of implementation in the Arab world

<i>Instrument</i>	<i>Tool</i>	<i>Examples of Implementation</i>
Control of wells	Well fees Permits Well spacing Well drilling prohibition zones or well bans Limitation or ban of electric connections to wells or labour permits Well buy out or backfilling	Algeria, Morocco, Egypt, Lebanon, Algeria, Egypt, Jordan, Lebanon Tunisia Jordan
	Control of drillers	Algeria, Jordan, Oman, Yemen
Control of abstractions in existing wells	Quotas Well zoning Metering Tariffs Reduce or remove energy subsidies	Syria, Tunisia Jordan, Morocco, Syria Jordan, Syria Syria
	Compensations for reduced abstractions or water rights buy-out	Envisaged in Jordan
	Control of agriculture: Limit irrigated land (e.g. remote sensing), change input/output subsidies	Jordan
Technology fixes and supply-side solutions	Aquifer recharge	Cap Bon, Tunisia Central Mitidja, Algeria Souss, Morocco Bahrain
	Supplement groundwater with surface water transfers	Guerdane, Morocco Cap Bon, Tunisia
	Reconversion of farms to more 'efficient' irrigation methods	Morocco, Algeria, Tunisia
Social learning	Increase participation and representation (decentralization via, for example, user associations or forums)	Tunisia, Morocco, Jordan, Yemen
	Training campaigns and awareness raising	Syria, Jordan

Source: Authors with complementary information from Faysse et al. 2011.

2.2.1 Controlling well expansion

2.2.1.1 Registration of wells

All countries studied have put in place a system of license or permit needed for groundwater abstraction (Table 7). In these cases, usually the Water Law of the country (or other type of regulation, decree, or by-law) will establish the different modalities and procedures to obtain a permit or a license for a well. In Yemen for example, the National Water Resource Agency mandate issues licenses to undertake groundwater drilling or exploration activities (Morill and Simas 2009). Licensed wells have a permit to abstract specific quantities of groundwater per year although no monitoring takes place and the majority of wells do not have a permit (ibid.).

In the Saiss, Souss, and Berrchid regions in Morocco, River Basin Agencies opened the possibility for farmers to register their wells during a given period of time. The registration applications

would be followed by a field visit and investigation and, in general, would be approved. The procedure considered by the 1995 Water Law was to ask groundwater users to apply for a new authorization altogether according to the new rules established by the water law and a 5-year application period was opened for these users (BRLI and Agro-Concept 2012; Del Vecchio 2013). Farmers however have been suspicious of the state's intentions and in the past they have only declared their boreholes if they needed a deepening authorization or a subsidy for localized irrigation (Faysse et al. 2011). Due to the publication in 2009 in Morocco of a new decree defining new rules for granting groundwater abstraction authorizations, the application deadline was extended for another 3 years. Also, although farmers needed an authorization to drill a well, this regulation was never seriously implemented and non-authorized pumps (around 70 percent of the pumps found in the Souss for example) were never dismantled or closed (BRLI and Agro-Concept 2012).

In the Saiss Basin in Morocco, the authorization for new wells requires the submission of a detailed file which includes topographical documents as well as a technical study for the well and its impacts on neighbouring wells and local water resources (Del Vecchio 2013). The lack of information on the aquifer makes the implementation of this rule sometimes difficult. However, the fact that state subsidies via the 'Plan Maroc Vert', a national plan aiming at improving the country's agricultural efficiency, can fund up to 100 percent of drip irrigation and 80 percent of the cost of drilling a well, are linked to obtaining this license (in practice a receipt showing that the process has been initiated is sufficient), the River Basin Agency has seen in 2013 a rise of new applications of up to 3,000 per year compared to 2010 (ibid.).

In Morocco, the Water Law 10/95 had little impact on the ground and has not been able to stop the over-exploitation of groundwater due to the importance of groundwater for farmers' livelihoods (Bekkar et al. 2009). The little correspondence between the legal framework in Morocco focusing on sustainability and the farmers' short-term objective (regarding their farming systems, revenues, crops, and investments), drives the gap between policy direction, implementation and results on the ground as the reality of the dependency on the groundwater economy in some areas in the country is difficult to ignore (ibid.).

A similar situation prevails in Egypt, where non-registered wells have appeared over the last 10-15 years as a complement to surface water irrigation. Moreover, a large majority of farmers have not bothered register their well in the Nile Delta due to the fact that it is a burdensome yearly process and, after the 2011 revolution, to the undermining of state and police authority.

The use of well registration or drilling fees does not reduce groundwater as it is only a tax on the drilling or use of technology. Syria and Lebanon charge an annual fee for wells and in Syria the fee is dependent on the abstraction capacity of the pump (Marina Stephan 2007) and in Tunisia fees for individual groundwater withdrawals are necessary according to Tunisian law but these are not applied (Hamdane 2014b). As an example, in Ras el Jebel, northern Tunisia, the administration has unsuccessfully tried to ensure that farmers benefitting from aquifer recharge programs pay fees (Frija et al. 2013).

In the Souss and Chtouka aquifers in Morocco, the various measures that had to be enacted by the different ministries were not implemented (such as raising the fees as well as the definition of a protection zone for the Souss and Chtouka aquifers) (BRLI and Agro-Concept 2012). As for the payment of fees, the River Basin Agency did not issue any specific rule to levy these fees so spontaneous payments by farmers were very rare (ibid.). Problems also arose with the application of the agreement as fees were not collected.

2.2.1.2 Enforcement of rules regarding well registration

Despite these regulations, enforcement is difficult and well registration encounters many obstacles in the Arab World. In Tunisia, even though the regulation of groundwater abstraction via permits is required by law, weak enforcement capacities limit extent of groundwater regulation, even more so after the 2010 revolution (Frija et al. 2013). The lack of understanding and awareness of farmers about the state of depletion of many aquifers is believed to add to the situation (ibid.). In Tunisia, since the events of January 2011 and a weaker presence of the state in rural areas, new wells have appeared in areas such as Nadhour where, in a matter of months, 70 of the existing 210 illegal boreholes had been drilled (Faysse et al. 2011).

The implementation of well use licenses does not always work, as officials on the ground can be prone to corruption and would require payments, like in Syria, in order to hand out licenses for wells (Albarazi 2014; de Châtel 2014). In Aleppo, Syria, the lack of clearly defined administrative roles within the ministry of agriculture (in charge of issuing groundwater permits) has led farmers to seek an 'informal permit' from the local police to abstract groundwater (Albarazi 2014). In the eastern parts of Jordan, farmers have drilled illegal wells taking advantage of "lax government supervision" (Barham 2014). Also, agri-businesses in Disi (southern Jordan) were already violating their abstraction limits a year after having obtained their pumping permits (ibid.). In Jordan, despite new legislation issued in 2013 to control and reduce illegal water use and 'water theft' from main supply lines through sealing illegal wells, drilling rig confiscation, and fines, the Cabinet still issued a grace period to farmers in November 2013 until the end of 2014, allowing them to irrigate crops from illegal wells.³⁵

In the Souss, Morocco, the social and relational capital of some larger abstractors well connected prevents the 'water police' from interfering and controlling groundwater abstractions (Del Vecchio 2013), although the River Basin Agency has formally the right to close down wells without authorization (BRLI and Agro-Concept 2012). However, these prerogatives granted by the water law to the River Basin Agencies regarding the control and enforcement of the water law were not met with sufficient human and financial resources (ibid.). Thus, the Souss Massa River Basin Agency for example has only two agents acting as water police and the provisions aiming at involving regular police officers as part of the water police force have not been met (ibid.). Similarly, the provisions included in the water law regarding the water police functions were poorly received by the agricultural development regional offices (ORMVAs) as they felt dispossessed of this role, something that also did not contribute to the effective implementation of the water code (ibid.).

In Yemen, the organization set up to regulate and control groundwater in Yemen is the National Water Resource Authority (NWRA). Between 2003 when the Water Law was passed, and 2007, the NWRA had received almost 2,000 license applications of which 47 percent had been approved. Despite this, reporting and overseeing illegal drillings remained insignificant according to Redecker (2007) against close to 100,000 wells existing across the country (in 2005 and 2006 NWRA collected around 60,000 USD in fines). Additionally, little is known about these wells in terms of condition, use, age, and ownership.

³⁵ The Jordan Times 2014 "Farmers should seal illegal agricultural wells by year end – Water Ministry", 9th of July 2014, <http://www.jordantimes.com/news/local/farmers-should-seal-illegal-agricultural-wells-year-end-%E2%80%94-water-ministry> (Accessed 17th August 2015).

2.2.1.3 Controlling well drilling and well drilling bans

The fact that it would be extremely costly to control each and every single one abstraction well, has led some governments to focus on controlling new drillings and the depth of existing wells (Faysse et al. 2011). In Yemen, all heavy drilling rigs and water metal casing must meet technical specifications issued by the NWRA (Morill and Simas 2009). However, in spite of the 125 drilling contractors licensed until the end of 2006, there were around 409 drilling rigs known in operation in Yemen, most of them unlicensed (NWSSIP 2008; Redecker 2007).³⁶ Despite the use of sophisticated technology (e.g. GPS tracking and satellite imagery in the hands of a 'rig tracking unit'), illegal drilling has continued in Yemen, with blatant regulation violations under the eyes of everyone carried out by influential people (Ward 2015).

In Oman, well construction, maintenance, yield testing, or pump installation must be carried out only by government-registered contractors and permits are issued for a year and are subject to renewal so is the case for Jordan (Morill and Simas 2009; MWI 2003). In Algeria, severe measures by the state have put farmers in jail for illegal drilling (Faysse et al. 2011; see also www.Djazairiess.com³⁷). There, and elsewhere in the region, fingers are being pointed at Syrian operators, specialized in legal/illegal well drilling.³⁸ The 2002 Groundwater Bylaw in Jordan also requires licenses and authorizations for drilling equipment and drillers. In Jordan, new legislation since 2013 has allowed the cooperation between the Ministry of Water and Irrigation and Jordanian Security forces to confiscate drilling rigs (up to 159 rigs appropriated by April 2015 since the campaign started in 2013).³⁹

The use of drilling techniques rather than the hand digging of open wells makes this control easier via borehole drilling bans such as in Algeria, with a ban on new boreholes in Collective Farms, or in Morocco where the drilling ban exists in aquifers considered over-exploited by legislation (Faysse et al. 2011). The level of real implementation of these bans is however uneven and dependent on user compliance with weak control systems by the state (ibid.). In Yemen, although feasible, a GPS tracking system for drilling was never made operational (Van Steenbergen et al. 2015).

In 2005 in the Souss-Massa, Morocco, the River Basin Agency launched an initiative to control borehole drilling and by 2006, 70 drilling machines had been impounded and between 2006 and 2010 another 120 drills had been seized (ibid.). The Souss River Basin Agency is also trying to organize the different drilling companies into a professional association which could potentially become a management interlocutor. Furthermore, in the Souss and Chtouka regions in Morocco, the water police remained short-staffed whilst users drilled overnight and during holidays and weekends (BRLI and Agro-Concept 2012).

2.2.1.4 Backfilling of illegal wells

In Jordan, the enforcement of new legislation concerning well registration by the Ministry of Water in 2013 has been accompanied by fines for those who dig wells without a license as well as the sealing and backfilling of illegal wells. According to newspaper sources, since the

³⁶ Some estimates consider that there would be up to 900 drilling rigs in Yemen (4th August 2015, personal communication, Former Minister of Water and Environment, Yemen).

³⁷ <http://www.djazairiess.com/fr/liberte/131056>; <http://www.djazairiess.com/fr/infosoir/80977>

³⁸ See <http://www.djazairiess.com/fr/infosoir/80977>

³⁹ The Jordan Times 2015 "748 illegal fixtures removed from water mains in March", 18th April 2015, <http://www.jordantimes.com/news/local/748-illegal-fixtures-removed-water-mains-march> (Accessed 17th August 2015).

beginning of the campaign in 2013 the authorities had sealed 644 illegal wells by mid-2015.⁴⁰ This last effort by the Jordanian Authorities is being undertaken by the Ministry of Water and Irrigation alongside Jordanian security forces. The task is however made more difficult in some cases by resistance by landowners. For example, as recently quoted in the press a large landowner in the Balqa Governorate had drilled an illegal well and deployed guards and dogs at the property gates and denied entry to the water inspectors.⁴¹ In other instances however, the sealing of illegal wells does not require the intervention of security forces as it is enabled by agreements between the Ministry of Water and local tribal leaders (e.g. in Al Lubban, Madaba Governorate).⁴² Off-record information, however, indicates that the wells that have been sealed were either dry or unused. Yet, this heralds a clear tightening of regulation by the government.

Illegal wells identified through campaigns carried out in some provinces of Algeria, such as in Oran in 2006, were also supposed to be sealed later on. There is no sign that anything effectively happened on the ground (Amichi 2015), in a context where famed orchard areas are dying out,⁴³ farmers demand for water becoming critical,⁴⁴ and the state is trying to keep the political support from the countryside (Amichi et al. 2015). It seems that cases where authorities have cracked down are linked to over-abstraction threatening domestic use, or to very specific situations where the owner of an illegal wells had conflicting relationships with the authorities or the police (e.g. refuse to pay bribe, etc) (Amichi 2015).

2.2.2 Controlling and reducing abstraction in existing wells

Groundwater regulation tools can also aim to control and reduce actual groundwater use. Metering, pricing, abstraction quotas, and technology improvements for irrigation are four of the main instruments used by governments to control the use and abstraction of groundwater in the Arab world. These different policy and regulation tools have been implemented with various degrees of success in several countries across the region.

2.2.2.1 Groundwater metering

Even though groundwater metering is not a tool in itself to reduce groundwater abstraction, it is a control mechanism and a prerequisite for the implementation of pricing instruments and abstraction quotas. Jordan prescribes the obligatory use of meters which controls the extraction and the different charges for groundwater (Marina Stephan 2007; Venot et al. 2007a, 2007b). However, in the Amman-Zarqa Basin in Jordan, where metering was reported to be incorporated in almost 90 percent of the wells, only 61 percent of the meters installed were

⁴⁰ It has not been possible however to determine whether these sealed wells were in use or not at the time. Additionally, official accounts found differ and the number of illegal wells sealed varies according to sources (stated as 644 illegal wells sealed by June 2015 but another newspaper stated that 1,155 illegal wells had been sealed by February 2015). Herald Globe 2014 "Jordan examining satellite images to locate illegal water wells", 19th November 2014, <http://www.heraldglobe.com/index.php/sid/227753817> (Accessed 17th August 2015); The Jordan Times 2013 "Priority is combating illegal wells, not raising water tariffs – Nasser", 5th October 2013, <http://www.jordantimes.com/news/local/priority-combating-illegal-wells-not-raising-water-tariffs-%E2%80%94-nasser> (Accessed 17th August 2015); The Jordan Times 2015 "Three cases of water theft uncovered in Jiza", 11th June 2015, <http://www.jordantimes.com/news/local/three-cases-water-theft-uncovered-jiza> (Accessed 17th August 2015).

⁴¹ The Jordan Times 2015 "Cracking down on water theft", 14th July 2015,

<http://www.jordantimes.com/opinion/editorial/cracking-down-water-theft> (Accessed 17th August 2015).

⁴² The Jordan Times 2014 "Illegal wells in Al Lubban sealed under agreement with tribal leaders", 16th August 2014, <http://www.jordantimes.com/news/local/illegal-wells-al-lubban-sealed-under-agreement-tribal-leaders%E2%80%99> (Accessed 17th August 2015).

⁴³ <http://www.djazairess.com/fr/elwatan/3098>.

⁴⁴ <http://www.djazairess.com/fr/liberte/131056>.

working in 2004 (Chebaane et al. 2004; Venot et al. 2007b). The results of a socio-economic survey on groundwater in Jordan suggest disparities in the implementation and installation of water metering. In Azraq for example, 192 water meters were reported to be working but 136 had not been installed (out of a total of 334 wells surveyed) (IRG 2014).⁴⁵ Most farmers claim that metering is not a reliable tool for monitoring and control of groundwater pumping as tampering and vandalism is common (Chebaane et al. 2004). In eastern Jordan, whenever wells are licensed, owners “tamper with the meters and do not report the exact amounts of water consumed” (Barham 2014).⁴⁶ According to this same researcher, rural areas where theft occurs are sometimes remote and thus difficult to monitor by the Ministry (ibid.).

In Syria, despite the fact that current regulation requires groundwater wells to have meters installed, the lack of training by engineers and public officials also affected the implementation of this measure (Albarazi 2014). They lack technical skills (for installation and controls) and were also not able to train farmers in the proper installation and use of the devices (ibid.). This, however, is a typical explanation from the point of view of the administration, and obscures the likely lack of political will to enforce such regulations. In Tunisia, no meter is required for wells, even for deep wells (deeper than 50 meters).

In the Souss, Morocco, the installation of meters was a key measure of the ‘contrat de nappe’ but this measure was eventually postponed and the ‘contrat’ not signed because of delays in the completion of the various infrastructure projects by the state due to budget limitations (promised as a counter-part to the agreement). This was used by the farmer associations as an argument to postpone the installation of meters. Abundant precipitation during that year and the year immediately after the signing of the agreement reduced the interest of the parties to the agreement to jointly and sustainably share groundwater (BRLI and Agro-Concept 2012).

2.2.2.2 Groundwater pricing

Tariffs for volumetric abstraction have the potential to encourage users to abstract less groundwater but have rarely been used in the region. In Tunisia, groundwater users in publicly-managed small irrigated areas, covering around 24 percent of the irrigated area in the country, have to pay for groundwater supplied through pressurized networks via state-established but user-run decentralized associations (GDA) (Frija et al. 2014). Yet prices are not high enough to affect behaviours and if they rise farmers tend to shift to individual wells (Ghazouani and Mekki 2015). Additionally, there is a debate about the possibility to establish an electricity-based pricing system for private borewells, an idea negotiated according to Frija et al. (2014), between the Ministry of Agriculture and the Tunisian Society of Electricity and Gas.

In Jordan, water pricing is in place for groundwater via a system of block tariffs. This system was introduced in 2002 by the Groundwater Bylaw and charged any water use over a threshold of 150,000 m³ per year per well. A further amendment in 2004 that did not come into force aimed to lower abstraction tariffs for abstracted volumes even further, with charges of 0.007 USD per m³ instead of 0.035 USD per m³ for volumes between 150,000 and 200,000 m³ per year (Venot et al. 2007a; Yorke 2013). Research by Venot et al. (2007a) also found out that at the beginning of the introduction of groundwater tariffs in Jordan, water bills corresponding to groundwater consumption for over a year (2003-2004) had not been paid. This was mainly due to an initial slackness from the part of the Ministry of Water and Irrigation as no employee had been entrusted to collect fees until November 2005. However, fees are cumulative and can still be

⁴⁵ According to the results of this survey, Azraq is the basin in Jordan with the highest number of non-installed meters, other basins such as Mafraq have 8 non-installed meters (out of 298 wells), Deir Alla has 52 (out of 110 wells) (IRG 2014).

⁴⁶ Quoting a water expert, former employee of the Ministry of Water.

collected later) (ibid.). This is indeed what happened in 2008, when the government asked for arrears to be paid.

Recent policy changes, however, include a drastic increase in the price of water for non-licensed wells, as well as an intent to reduce the 'free block' from 150,000 to 75,000 m³ (see next section). With people not paying their bills now being barred from accessing other state services or obtaining official documents, this double pressure is now starting to be felt and sends a strong signal about the growing resolve of the ministry.

2.2.2.3 Abstraction quotas

Abstraction quotas are put in place to limit groundwater abstraction by users. Quotas can be progressive or by blocks but in any case wells will have to be metered, so that a record of groundwater abstraction is kept in order to establish whether the user is respecting the quota. Quotas can be issued when users apply for well permits or established/modified afterwards. As seen with other tools however, its application and enforcement is difficult, prone to corruption practices like in Syria, or users' tampering with meters like in Jordan and elsewhere.

In Jordan, historical abstraction levels with quotas had been fixed between 1962 and 1992 through abstraction licenses specifying the amount to be pumped (two thirds of the licenses granted by the government during that time) (Venot et al. 2007b). These quotas were most commonly 50,000 or 75,000 m³ per year and in some cases up to 100,000 m³ per year after 1990 (ibid.). However, as Venot et al. (2007b) add, these limits were rarely enforced. In 1984 the Water Authority started to impose quota for new well licenses based on farm size (Venot et al. 2007a, 2007b).

The Groundwater Control Bylaw of 2002 established a new quota system with a free volume to be pumped and a block-rate tariff system in place for abstraction levels beyond this volume. However, the 2002 Bylaw also endorsed the previous system of quotas and licenses in place, raising the maximum limit of abstraction to the minimum threshold of 150,000 m³ per year (Venot et al. 2007a), which practically removed the effectiveness of the measure.

The enforcement of these measures in Jordan has proved difficult according to Yorke (2013), due to a lack of means provided by the penal code to charge offenders. Initial tariff reforms in the 1994 were also met with opposition in Jordan, leading to the occupation of the Parliament floor and the intervention of the King in the matter (Venot et al. 2007b). In the particular case of the Disi aquifer, vested interests from large farmers in the south with licenses to farm in Disi until 2011 resisted the new Groundwater Bylaw (Yorke 2013). It was only as a result of a Supreme Court ruling that they later paid for water consumed above the allowed volumetric limit (ibid.). Despite these quotas, by 2010 groundwater withdrawals still exceeded 55 percent the safe yield at the country level and by over 176 percent in the Amman-Zarqa groundwater basin (ibid.). The Azraq basin had abstraction levels 215 percent over the safe yield (ibid.). In Jordan, the debt from fines from illegal groundwater abstraction by farmers exceeds JD24 million.⁴⁷

⁴⁷ At the current currency exchange rate (August 2015), JD24 million correspond to around USD 34 million. The Jordan Times 2014 "Farmers should seal illegal agricultural wells by year end – Water Ministry", 9th of July 2014, <http://www.jordantimes.com/news/local/farmers-should-seal-illegal-agricultural-wells-year-end-%E2%80%94-water-ministry> (Accessed 17th August 2015).

2.2.2.4 Buying out wells

The measure of buying out wells by the state could be considered as a last resource measure for meeting abstraction quotas in a given area or controlling the number of wells. Such option has been considered by the government of Jordan with the objective to reduce groundwater pumping (Chebaane et al. 2004; Venot and Molle 2008; Zekri 2007). As stated by Zekri (2007) however, groundwater gains achieved by this option can be pumped again by the active farmers in the area if no further abstraction limits are imposed and controlled. This measure also needs to be met with funds in order to be implemented successfully. In Jordan, Chebaane et al. (2004) found out that 50 percent of farmers studied were in favour of such measure.

2.2.2.5 Technology fixes to reduce groundwater use

At a national scale in Morocco, the latest structural plan to tackle the problems of agriculture, the 'Plan Maroc Vert' (the 'Green Morocco Plan') and some of its measures are not without side-effects, as the increase in productivity for the sector -with an increased density of plants per hectare cultivated (from around 200 plants per hectare to up to 800 plants), and more efficient use of resources with drip-irrigation - in general further increase the depletion of groundwater by allowing the intensification of crop cultivation (BRLI and Agro-Concept 2012). Access to land however remains a major driver for the expansion of crops, especially with the recent increase in private leases of state owned farms by individuals and firms (ibid.). The 'Plan Maroc Vert' however is, according to Del Vecchio (2013), fuelling the over-exploitation of groundwater as it provides farmers with investment incentives in irrigation, and can fund up to 80 percent of the costs of a borehole for agriculture.

In Tunisia, the National Programme for Water Savings, established in 1995, offers subsidies for farmers of 40 to 60 percent of the total investment costs for water saving irrigation technologies (Frija et al. 2014). Despite this program, national-level data does not show a decrease in water use and extension of irrigated areas (ibid.). This is believed to be due to the fact that farmers have not mastered the application and use of technology, nor properly value water resources at the farm and national level (Al Atiri 2004 in Frija et al. 2014).

Well expansion control or existing abstraction levels can also be monitored indirectly with the use of technology such as remote sensing and satellite imagery. In Jordan, the Ministry of Water uses this technology to identify land use with irrigation and locate illegal wells.⁴⁸ The control of irrigation surface in dry areas via this type of technology is available through different donor programs (the MAWRED project funded by NASA and USAID) in several countries in the Middle East and North Africa Region, but its use is incipient.

2.2.3 Supply-side measures

Groundwater over-abstraction can also be reduced via supply augmentation, either of surface water or groundwater (with aquifer recharge), and also desalination. All these measures have been applied in the Arab world as part of the array of interventions used by the state and groundwater users to try to neutralize or stabilize increasing groundwater abstraction and avoid further depletion. These additional technology-fixes can play a part in the continuation of the state's hydraulic mission which finds the use of technology and the appropriation of additional resources as the most 'conflict-free' management option. Bringing more water, especially if it is cheaper and/or of better quality, will help decrease the pressure on groundwater and

⁴⁸ Herald Globe 2014 "Jordan examining satellite images to locate illegal water wells", 19th November 2014, <http://www.heraldglobe.com/index.php/sid/227753817> (Accessed 17th August 2015).

potentially reduce its use. However, in the mid to long term, more water available at the farm plot may well result in expanded use and increased depletion.

2.2.3.1 Bringing more surface water in

The option of 'bringing more water in' and partly replacing the existing demand for groundwater for surface water via infrastructure projects is used by different countries in the region. In Morocco, the country's Water Strategy for 2030 has planned a large water transfer (a 'water highway') from the north of the country to the south, expected to transfer around 800 M m³ of water per year. This approach comes from a long tradition of dam construction which started during the French protectorate (1912 to 1956) and was continued after independence in 1957 (Richards 2001).⁴⁹ New water could in particular relieve pressure on the Haouz aquifer by supplying Marrakech with drinking water.

In Egypt, new investors in the West Delta area have been expanding groundwater-based high value agri-businesses since the 1990s. The West Delta Canal project was conceptualized to complement or replace dwindling groundwater stocks by surface water from the Nile, via a water transfer (Barnes 2012). The project however has so far not been implemented due to bidding and procurement issues, and lately to the 2011 Revolution.

Tunisia has established several safeguard measures to protect irrigated agriculture in the Cap Bon such as the water transfer from the Medjerda basin (north-east) to Sfax (western Tunisia). In Tunisia, approximately 30,000 km of networks ensure that inter-basin water transfers are performed between northern regions towards the coast and from the western regions to the eastern part of the country (INECO 2007). The transfer for the Cap bon provides water for cities as well as agriculture, and serves the western (Grombalia) and southern parts of the Cap Bon region, where 15,000 hectares of citrus represent an important part of the region's economy.

The Souss Massa basin, in Southern Morocco, is also home to a famous transfer project, whereby the Guerdane groundwater irrigated area (10,000 hectares of citrus plantation spread over an actual area of 30,000 hectares) is now provided surface water derived from a reservoir upstream in the basin, in order to make for declining groundwater resources. This project is a PPP, where half of the investment costs have been charged to the users, most of whom are large national and foreign investors (Houdret 2012). The current River Basin plan for the Souss-Massa, with 2030 as its planning horizon, includes the mobilization of additional water resources via new dams, sea water desalination, wastewater reuse, and rainwater harvesting. These new resources should bring an additional supply of 20 percent according to the River Basin Agency (from 901 Mm³ per year to 1,171 Mm³ per year). This strategy however reflects, according to a study (BRLI and Agro-Concept 2012), a conceptual approach derived from a continuation of the hydraulic paradigm that prevails within water resources planning in Morocco, emphasizing supply-side measures without tackling and controlling water demand. The construction of several dams in the 1980s and 1990s across the Souss basin, aimed at providing additional surface water for irrigation and also to recharge the aquifer, did not suffice to stabilize water table levels. The Saiss River Basin in the north of the country is also the object of 4 large surface water infrastructure projects (i.e. dams) as well as a water transfer from the Sebou region, aiming to reduce aquifer abstraction and stop groundwater pumping for drinking water altogether in 2030 (Del Vecchio 2013).

⁴⁹ In Morocco, between 1912 and 1967, 17 dams were built (Richards 2001). In 1968, the government of Morocco declared a 'politique des barrages' (a policy of dams) designed with the assistance of the World Bank, building 14 dams between 1968 and 1991 (ibid.).

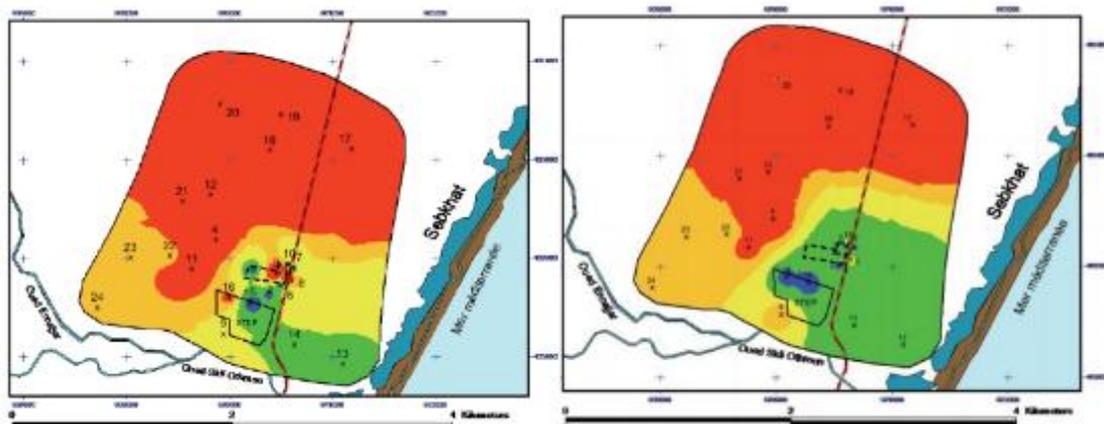
2.2.3.2 Aquifer recharge

Managed aquifer recharge or storage can be used especially when groundwater is a strategic reserve for emergency situations. The injection and infiltration of water can serve as a way to store excess rainfall which otherwise could turn into flooding, or as intermediate storage of treated effluent for later agriculture and industrial uses.

Tunisia has been using aquifer recharge since the 1970s as a measure to improve groundwater quality and prevent seawater intrusion (Bouri and Ben Dhia 2010). In Tunisia, wastewater represents around 30 percent of the country's agricultural water supply and aquifer recharge with wastewater has helped prevent coastal aquifer salinization caused by groundwater over-abstraction (e.g. in the Korba plain in the Cap Bon peninsula in North-East Tunisia) (El Hedi Louati and Bucknall 2009; Ouelhazi et al. 2013) (Figure 41).

In Lebanon, aquifer recharge is being contemplated to fight seawater intrusion in coastal aquifers and also because managed aquifer recharge can be used to remove colloid and pathogen removal from injected water (Masciopinto 2013). Bahrain also applies aquifer recharge technology, using gravity-fed aquifer recharge through gulleys, pits, chambers and recharge wells, to direct urban runoff from storms to the Khobar aquifer (Klingbeil 2014). Treated effluent has also been recharging this aquifer since 1986 (ibid.).

Figure 41. Evolution of salinity in a recharge site in Korba, Cap Bon, Tunisia, before and after 3 years of recharge



Note: green colour indicates salinity levels of 0.5 to 1.5 g/litre; Yellow indicates levels between 1.5 and 2.5 g/litre; Orange indicates levels between 2.5 and 3.2; Red indicates levels of over 3.5 g/litre.

Source: Cherif et al. 2013.

2.2.3.3 Desalination

The increasing use of desalination as a viably economic option to supply drinking water to urban centres in some of the countries in the region has allowed for the reduction of the dependency on groundwater resources. Half of the world's desalination capacity is found in the Arab world whilst Saudi Arabia and the UAE jointly produce more than 30 percent of the world's desalinated water (UNDP 2013; UNESCO 2012) (Figure 42). Countries with less intensive use of desalination such as Tunisia, are already considering expanding the sector.

Even though desalinated water contributes around 1.8 percent of the region's total water supply, some countries are heavily dependent on this resource (UNDP 2013). More than 55 percent of water supplied to urban areas in the Gulf comes from desalinated water, used directly or mixed with groundwater (UNDP 2013). This 'technological fix' aimed at augmenting

water availability and thus solving the problem of groundwater dependency has also allowed complementing groundwater abstraction and consumption for individual sectors of the economy with additional resources. It is also estimated that by 2025, 8.5 percent of the Arab region's total supply will be supplied via desalination plants (with an estimated investment cost of 38 billion USD) (UNDP 2013). In Algeria for example, desalination plants have been ensuring the supply of drinking water in coastal areas since the inauguration in 2008 of the Hamma desalination plant near Algiers. Its inauguration kicked off the country's programme to ensure drinking water supply via this type of technology, supplying 200,000 m³ of water per day to the capital.⁵⁰ Since its inauguration in 2014, a second plant built near Oran is capable of producing 500,000 m³ of water a day.⁵¹

This increase in desalination capacity, however, can have different implications. Energy consumption is the first one as desalination plants are energy-hungry (costs per delivered desalinated water can vary between 0.50 and 4 USD per cubic metre in the Arab region depending on the level of subsidies) (ibid.). The most serious environmental impacts of such dependency can be the release of discharge (e.g. brine) as the end product back to the sea affecting the surrounding ecosystems, and the emission of pollutants, and the carbon footprint linked to the energy bill of these plants (Lattemann and Hopner 2008).

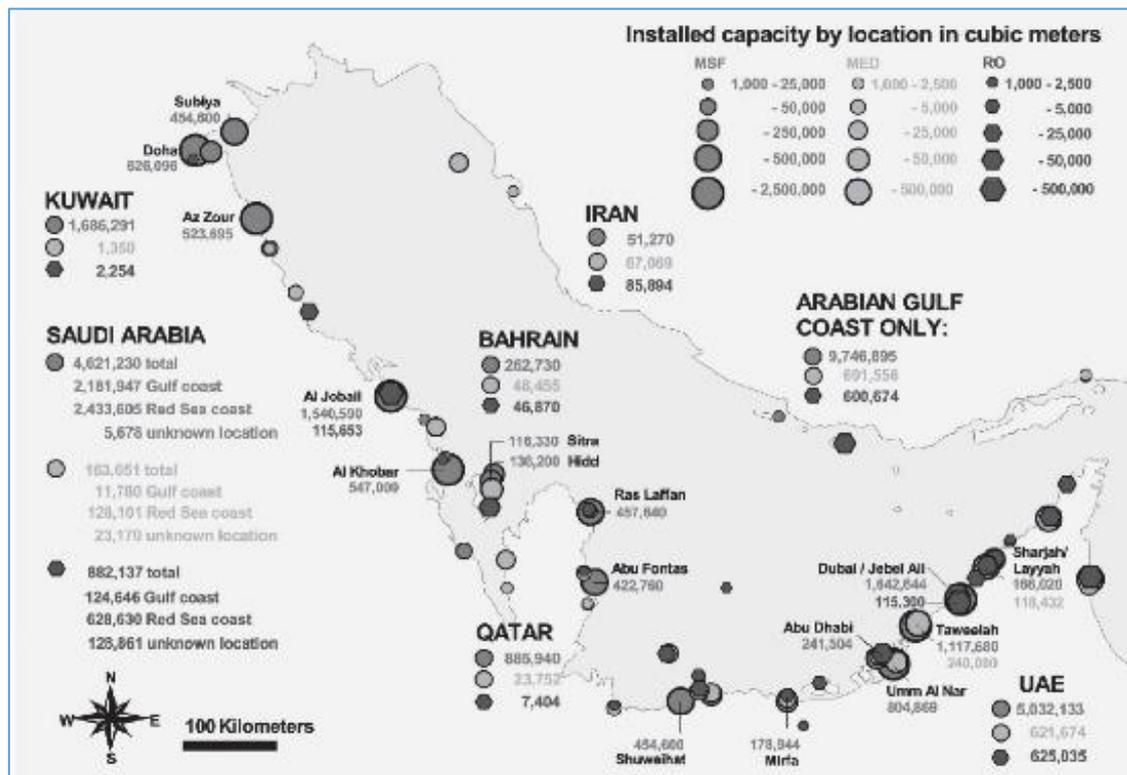
In Jordan, the Red Sea-Dead Sea project envisages to connect the Red Sea to the Dead Sea and supply desalinated water to Jordan, Israel, and the Palestinian Authority. The project is also aimed to replenish the Dead Sea and save it from further environmental degradation (its levels have been declining at a rate of over 1 metre per year and its surface has shrunk over the last 50 years by 340 km²) (Coyne et Bellier et al. 2012). The project is expected to pump up to 2,000 Mm³ of sea water annually over a distance of over 190 km in order to produce hydroelectricity with the downward flow from the Red Sea towards the Dead Sea that would power a desalination plant providing up to 850 Mm³ of water to the region (ERM et al. 2012). This project has been questioned for a variety of economic, political and environmental reasons such as the mixing of water from the Red Sea with the Dead Sea. If, as the project describes, an additional 400 Mm³ of sea water and brine are added to the Dead Sea, the body of water could be affected by algal blooms and the formation of gypsum crystals.⁵² The project is also, according to its terms of reference, aimed at creating 'a symbol of peaceful cooperation in the region' with an anticipated 'peace dividend' arising as an outcome from the project (Coyne et Bellier et al. 2012).

⁵⁰ Science Business 2014 "Desalination technology: Algerian plant highlights the challenges of getting drinking water to a parched region", 24th June 2014, <http://www.sciencebusiness.net/news/76602/Desalination-technology--Algerian-plant-highlights-the-challenges-of-getting-drinking-water-to-a-parched-region> (Accessed 17th August 2015).

⁵¹ WaterWorld 2014 "Algeria's supersized 500,000 m³/day desalination plant open for business", 11th November 2014, <http://www.waterworld.com/articles/2014/11/algeria-s-supersized-500-000-m3-day-desalination-plant-open-for-business.html> (Accessed 17th August 2015).

⁵² Nature, "Environmental concerns reach fever pitch over plan to link Red Sea to Dead Sea", 27th February 2013, <http://www.nature.com/news/environmental-concerns-reach-fever-pitch-over-plan-to-link-red-sea-to-dead-sea-1.12515> (Accessed 15th September 2014).

Figure 42. Seawater desalination capacity installed in the Arabian peninsula (in 2008)



Note: Mainly found in the Gulf, thermal processes to desalinate sea water include MSF (multi-stage flash) and MED (multi effect distillation) and account for 90 percent of the production. The other main technology to desalinate sea water used in the region is reverse osmosis (RO).

Source: Lattemann and Hopner 2008.

2.2.4 Government-led participation and attempted groundwater management decentralisation

Some countries in the Arab world have tried to instigate a process of groundwater co-management alongside communities, empowering user associations via decentralization processes (Box 3). In such instances, the state realized that the management and regulation of groundwater cannot be done by one single actor and thus sought the support and participation of users. This process also goes along with the development of demand management policies and the community participation rhetoric. Despite this trend, as this section will show, the role of the state in local agricultural development remains preponderant, hence the need to continue portraying it as a major actor in the process of natural resource management and agriculture policy in the region.

Tunisia presents a case of government-led user participation for groundwater management when in 1980s institutional reforms brought the approach to promote user associations responsible for managing water resources and infrastructure. This approach was based on the development and promulgation of an enabling institutional and legal framework aimed at sustaining the development of these user associations; the elaboration of a national strategy to follow up the creation of the associations; the implementation of training programs, and technical assistance for members of the CRDAs, and staff of the user associations (presidents, pump operators, treasurers) (Al Atiri 2007). For groundwater, it is usually the small and medium-size publicly irrigated perimeters with boreholes that are more autonomous and the CRDAs support the weaker groups in terms of maintenance and replacing equipment (ibid.).

Due to prohibitive drilling costs for users, the GDAs associations are created by the state amongst small farmers little integrated to markets to pull resources together and offer them an alternative solution (Frija et al. 2014). As these authors purport, groundwater management performance becomes highly dependent on the performance of the GDAs themselves: their internal management can be affected by a large range of factors such as the educational level of its community members and of its staff, or the social capital of farmers participating in the association (ibid.). Problems of coordination and cooperation with the CRDAs have also been reported, with CRDA staff over-stretched controlling many GDAs at the same time (as many as 45) (ibid.). Many GDAs face financial problems due to the inability/resistance of its users to pay the fees (water and membership fees), as well as fraudulent practices (illegal use of water and lack of enforcement of rules) (Mekki and Ghazouani 2012). These financial difficulties translate into poor system maintenance and poor delivery services (ibid.). Problems with GDAs also include a lack of training and a lack of alignment with the objectives for which they were created (Gaubi 2008). Mouri and Marlet (2007) have reported the co-optation of GDAs for political purposes, sustaining the interests of the ruling parties.

The creation of the GDAs was intended to limit the number of interlocutors between the administration and the farmers, but it also signaled an apparent withdrawal of the state. The GDAs in Tunisia were supposed to be the product of a political will to change water resource management and the institutional structure in agricultural areas. The establishment of these community associations attempted to establish a dialogue between the different actors in order to improve resource allocation and management (Leghrissi 2012). In the GDA of Bsissi, although according to the official approach the participation of groundwater users as members of the community in the GDA is ensured via the development of specific clauses in the statutes of the GDA developed through a democratic and participatory process, only 10 percent of the members pay their annual membership fees (Leghrissi 2012). As another example, the internal management of the GDA of Dar Chichou in Haouaria, northern Cap Bon, is regulated via sanctions but these are not issued automatically, they are decided amongst all members annually at the general assembly and exceptions can be made according to the case. As reported by the manager of the GDA in Dar Chichou (Cap Bon), the General assembly usually gathers around 15 percent of the members of the GDA.

At the national level in Tunisia, the development of rural participation through the establishment of the GDAs has been discursively presented as an important policy change by the state towards improved resource management, decentralization, and user participation. Canesse (2010b) argues more critically however that the development of new forms of decentralization of agricultural activities and natural resources management in Tunisia are only a continuity of Tunisian public policy stemming from the state and the country's central institutions. The newly created technical decentralized agencies – the GDAs, would seem to have taken away some of the state's competencies only on paper, developing normatively the principles of international recipes of 'good governance' (ibid.). The author argues, on the contrary, that GDAs remain a state-administrative technique developed to monitor the land and its population in a sustainable way. This represents a contradiction however as even though they appeared as part of a normative and liberal recipe of 'less state engagement' developed by an international donor agenda, they also reflect classic state policy instruments of coercion and control. The GDAs' fate remains controlled by the governor, and they are under increasingly strict financial scrutiny of the Ministry of Agriculture Financial. The governor may request a financial audit that can result in the dissolution of the association (Canesse 2009). This, following Canesse (2010b), represents the continuation of the same framework which evolved since the Protectorate but with a different name.

In Morocco, even though the provision of water management services and responsibilities had been partially decentralized, the liberalization of water management has affected the ability to provide decentralized services by the *Office Regional de la Mise en Valeur Agricole* (ORMVA) and limit the effectiveness of decentralized organisms such as River Basin Agencies (Houdret 2008). For this author, the failure of state institutions to develop sustainable resource management in the Souss, is due to the fact that these institutions are “caught between the often conflicting demands of liberalization and resource protection. In addition, field investigations have shown the considerable weight of large agricultural investors at a high political level, which limits the room of manoeuvre of these institutions” (Houdret 2008: 33). The establishment by the state of consultative and decentralized structures considered by the 1995 Water Law, aiming at achieving “a partial withdrawal of public institutions in the agricultural and water management sectors” is found largely insufficient due to a serious lack of funds, personnel, training, and equipment, as well as a lack of adequate political support (Houdret 2008: 34). As an example, this author cites the case of the ‘water police’ responsible to ensure the enforcement of regulation measures for the River Basin Agency. For the Souss, in 2008 there were less than ten agents without sufficient transport means, in charge of covering 27,000 km². Moreover, River Basin Agencies in Morocco, despite being created as part of this new change in water politics towards integrated water management resources, are mostly controlled by the state (Del Vecchio 2013). In its Administrative Boards, around 57 percent of its members are direct representatives of the state or of other public institutions (ibid.).

According to Del Vecchio (2013), the implementation of the ‘contrats de nappes’ in Morocco did not reflect the consultative process expected in the first place by the government as in many cases each stakeholder/actor had a specific role to play, usually corresponding to its sectoral competencies. In the Souss, large-scale farmers supported the Ministry of Agriculture and the River Basin Agency in setting up a ‘contrat de nappe’ in order to obtain state support for new resources, but small-scale farmers were not involved in this coalition (Faysse et al. 2012). The association with the ‘contrat de nappe’ was limited to actors who were actively involved in the design and implementation of policies (ibid.). The motivation of public organizations to develop an active stance regarding curtailing groundwater abstraction would seem to be linked, according to Faysse et al. (2012), to the importance of the aquifer in the area managed and the importance of the groundwater economy in the region and at the national level.

For the case of the Saiss-Sebou River Basin Agency and its ‘contrat de nappe’, the coordination expected pre-existed in some cases the ‘contrat de nappe’ itself (e.g. relations between drinking water production and distribution, or between the Ministry of Agriculture and the regional chambers of agriculture) (ibid.). Also according to this author, the state performs an interventionist role via its water legislation, as these contracts never arose from the communities themselves but from a consistent and conscious approach from the state (ibid.). Additionally, the ‘contrat de nappe’ in the Saiss River Basin does not address the control of groundwater wells nor abstractions for agriculture or other uses of groundwater within the basin. The contract is mostly aimed at regulating the relations between users within the context of large infrastructure projects and therefore largely represents a continuation of the state’s planning role via the increase of surface water available, rather than a real change of water management paradigm (ibid.).

In Yemen, the move to create decentralized structures of water management in river basins was a long process which varied according to the area and population pre-disposition and also how flexible and receptive to government control were the local communities (FMWEY 2015). In the area of Taiz, these water user associations brought power struggles as small local sheikhs became empowered by the formal structure of these associations, with some of them defying

the authority of the 'big sheikhs' and governors (ibid.). In the end however, as a Former Minister of Water and Environment explained, even if the project was 'ambitious', it played "with the social structure" and "had very little way of success", as it lacked political will even from the main donor, the World Bank, who stopped in the end the whole process of creation of user associations (ibid.). Moreover, the lack of appropriate borders for these user associations was also, according to the Former Minister, and additional layer of complexity as the imposition of a new structure following aquifer and river basin lines was opposed to the traditional delimitation of tribal territories following the natural watersheds along rivers and valleys and with an already established tradition of cooperation (albeit informal) (ibid.).⁵³

Box 3. Decentralization in the Arab World

Across the Arab World, the process of 'community participation' has been part of a wider process of decentralization fostered partly by international organizations and bilateral agreements (Bergh and Jari 2010; Carapico 2002). Participation is thus regarded as a key element and a main tool in the process of community empowerment aimed at establishing good governance practices and legitimization of the democratic and ruling system (Bergh and Jari 2010). The international as well as internal pressure to grant more liberties and rights to their own societies has pushed governments in the region to an 'authoritarian upgrade' via decentralization reforms (e.g. Morocco), devolving part of its resources and power to lower instances of government (ibid.).

As Belghazi (2003) pointed out, this process is in many cases led by the state and implemented from the top downwards. Even if governments have devolved some powers to local authorities, central control is still maintained via a number of means such as central auditing, tax money and financial resources channeled from the Ministry of Finance, or the power to remove local councilors (ibid.). In Yemen, the water and sanitation sector went through a decentralization process which was supported by the Country's Cabinet in 1997 via Resolution No. 237. This process however has been characterized at most as a process of delegation rather than devolution of power (Al-Saidi 2014). Government reforms followed administrative boundaries and channeled resources following political alliances. The performance of this delegation process has been affected by country-specific difficulties as well as the absence of hydrological basins as management units and internal institutional overlapping (ibid.).

In Morocco, even though decentralization is a mantra well adopted and used across many instances of government, implementation is lacking. The country's Municipal charter requiring locally-elected members to create development plans based on community participation and budgetary support from provincial and national instances of government is full of good intentions according to Ben Meir (2014), but there is no know-how amongst local staff nor sufficient resources to implement it.

Implementation problems with decentralization are, in the case of Egypt, deeply rooted in the country's political history. Egypt's past autocratic rule has 'informalized' Egyptian society and the result has been a lack of capacity to rule (Dorman 2007). Authoritarian rule was also circumscribed and constrained by state-society disengagement, "the subordination of state capacities to the exigencies of regime reproduction, in other words the effects of patrimonialism, clientelism, and personal rule", and political strategies by the state apparatus to avoid provoking bottom-up opposition to the rule (Dorman 2007: 21). Combined, according to

⁵³ See Annex 1 for further details on Yemen's decentralisation policies for water and groundwater management.

Dorman (2007), these elements had curtailed the state's ability to govern locally (e.g. govern Cairo and its informal sprawling areas).

2.3 Effectiveness of state action in groundwater regulation

2.3.1 Enforcement weaknesses

As studied in the previous sections, different policy instruments and tools exist across the North Africa and Middle East region in order to regulate and control groundwater abstractions by users. Governments in general face three main problems: 1) how to limit well expansion; 2) how to regulate and control existing wells, knowing their number; and 3) how to limit groundwater abstraction in existing wells (e.g. via installing meters or establishing abstraction quotas). Some of these instruments and their use in water legislation and regulation are presented in Table 7.

The fact that groundwater use is diffuse and mainly done by individuals makes it virtually impossible to control its abstraction through command-and-control and top-down regulatory instruments only (Hammani et al. 2009). Lack of regulation is as much an informational problem (no capacity from actors to determine the volume of water abstracted) as it is a problem linked with the type of action model and the lack of 'levers for action' for individual users (Shah 2009 in Hammani et al. 2009). When attempted, enforcement of these rules is in general done 'without teeth'. Although in theory all countries included in Table 7 issue permits for wells and have appealed to a large panoply of instruments to regulate and control groundwater abstraction, the application of these tools proves difficult in practice. Many countries in the region have tried to implement and put in place institutional and organizational apparatuses to control and reduce groundwater over-abstraction. In Syria, Yemen, or Jordan, despite comprehensive regulatory frameworks aimed at limiting abstractions, issue permits for wells, establish bans on drilling, etc. wells are still being drilled without permits, control or monitoring from the state. The logistical nightmare of effectively implementing a regulation campaign for existing wells is further hindered by short staffed departments, and a lack of funds. The real enforcement of these instruments for users remains a challenge and their mere codification within the law often makes a small difference to farmers' choices and strategies.

In Yemen for example, despite several legislative attempts since the 1990s at regulating groundwater abstraction, challenges remain political. As Alhamdi (2012) reflects, "the challenges are really the implementation of these policies. In Yemen we have a water law, we have good policies, reasonably good strategies and policies, but the problem is implementation and enforcement of those". There is no real political will to tackle the problem and water management policies are not on top of the political agenda. Influential ministers, sheikhs, wealthy farmers, and army and security officials continue to drill wells without permits due to their connections and ability to pay bribes (Zeitoun et al. 2012). As an example mentioned by Alhamdi (2012), "when the cabinet in 2005-2006 passed a decree banning all drilling in the Sana'a basin, no further drilling, that day the minister of interior and the ex-president's son were drilling private illegal wells in their homes". Additionally, despite the existence of a set of policies aiming at curbing groundwater abstraction, the results of these policies are rarely followed-up as, according to Alhamdi (2012), "it is not the culture of Yemen to do monitoring and evaluation".

In Tunisia, the enforcement of regulation is problematic despite the fact that groundwater management is structured around the use of regulatory and economic instruments to control groundwater abstraction, collective action instruments with the GDAs, and supply side measures to increase water availability. Public irrigated areas with groundwater or wells for drinking water supply can have meters (not private wells) and privately owned wells are subject

by law to state fees (0.002 Dinar per cubic meter), although in practice the fee is not systematically collected (Hamdane 2014b). For public irrigation areas and drinking water supply, beneficiaries are subject to tariffs but these can vary from one system to another. Quotas are included in the modified Water Law from 2000 but they have never been put into practice (ibid.). Economic instruments in Tunisia to limit groundwater over-abstraction are in the form of subsidies for investment costs in water saving technologies for irrigation (40 percent for large farms, 50 percent for medium farms and 60 percent for small farms) (Frija et al. 2014).

Problems in the application of the water code in Tunisia also include a lack of enforcement due to a lack of authority and an absence of 'water police' checking the application and compliance with rules and imposed restrictions (in the case of protection and prohibition 'perimeters'). According to Hamdane (2014a), there are 20 perimeters of protection in Tunisia in 12 governorates and 9 perimeters of prohibition in 6 governorates. Moreover, the distinction between shallow and deep groundwater appears to be totally arbitrary (Hamdane 2014b). It does not take into account the aquifer characteristics (heterogeneity as in many instances groundwater is hydraulically connected through intermediary layers).

Table 7. Groundwater regulation tools for agriculture in selected Arab countries

	<i>Well licensing (permits)</i>	<i>Metering</i>	<i>Volumetric pricing (tariffs)</i>	<i>Abstraction quotas</i>
Algeria	Yes (1999)	No	No	No
Bahrain	Yes (1980)	Yes	Yes	Yes
Egypt	Yes (1984)	No	No	No
Jordan	Yes (2002)	Yes (2002)	Yes (2002)	No
Lebanon	Yes (1926)	No	No	No
Morocco	Yes (1995)	Yes (1995)	No	No
Oman	Yes (1990)	Yes (1990)	No	No
Saudi Arabia	Yes (1989)	-	No	No
Syria	Yes (1958)	Yes (2000)	Yes	Yes
Tunisia	Yes (1975)	No	Yes	Yes (2000)
Abu Dhabi (UAE)	Yes (2006)	Yes	No	Yes
Yemen	Yes (1998)	No	No	No

Source: Compiled by authors.

This dual nature of regulation instruments on paper and lack of real enforcement emphasizes the existing gap between policy and practice across the region. As seen in Box 4 for example (Section 2.3.5.1), the various tensions between local powers, elites, and economically powerful groups can undermine the nature of the state and the implementation of policy at the national and also local level. The lack of trained officials, for example in Syria, to implement water legislation on the ground and train farmers in the use of water meters can also be an obstacle to the enforcement prerogatives stated legislation (Albarazi 2014).

Additionally, poor enforcement can also be linked to a lack of presence and contact between the state and farmers. In Syria, albeit the Water Law introduced communication between the government and water users, information flows are prevented due to a rigid top-down approach and the use of ineffective information channels (ibid.). As Albarazi (2014) also found out, 88 percent of surveyed farmers in Syria stated that they had never received any water

related information from the government and 94 percent answered that the local government never contacted them directly.⁵⁴

2.3.2 Administrative and organizational regulation of groundwater abstraction

The administrative and organizational regulation of groundwater abstraction within state structures and governments in the Arab world can be problematic. The development, tacit via state inaction or explicit via direct action, of groundwater resources by different actors within the state (e.g. ministries, regulatory agencies) has the potential to create contradictions or conflicts of interest between these different actors within a government or between different sectors in a country. In some cases, the amalgamation of regulator and operator roles (the poacher/guard roles) within the same administration, department, or ministry, bears the risk to confuse these roles and result in weakened legislation implementation.

Apart from this amalgamation of regulation/enforcement tasks, it is also possible that administratively groundwater management in the Arab World is organized in silos, without a shared framework between irrigated agriculture and water resource management actors (Faysse et al. 2011). In Tunisia, the Ministry of Agriculture and Environment is responsible for groundwater monitoring and control. In Algeria, the National Water Resource Development Agency is responsible for aquifer studies and the River Basin Agencies are mainly tasked with the registration of water users (ibid.). The organizational culture and professional background (mostly hydraulic engineering) of these agencies and departments attach great importance to data acquisition and modeling but grants less importance to understanding the agricultural sector, have only limited information on aquifers and their users, and lack human resources to coordinate multi-actor consultation processes (ibid.). When information is available, bureaucracies and water departments attach a great deal of zeal to data as statistics are a powerful tool in the hands of governments (ibid.).

In Tunisia, as Frija et al. (2014) wrote, despite many administrative reforms, weak regulation enforcement still exists, mostly due to weak financial and human capacities of regulatory administrations, as well as organizational and coordination issues problems. In Morocco, groundwater regulation is the responsibility of the River Basin Organizations but these lack funds, are understaffed and with budget deficits. A focus on coordination and regulation rather than implementation and service delivery has impeded the full development of these River Basin Organizations (Van Steenbergen and El Naouari 2010).

Inter-ministerial conflicts hinder the application and implementation of norms aimed at reducing groundwater abstraction in Morocco (BRLI and Agro-Concept 2012; Del Vecchio 2013). The race to the bottom by farmers is sustained and increased by structural and political tensions between the Ministry of Agriculture and the water resources administration, as the management of water resources has oscillated between the management and construction of public works and the development of irrigation policies for agriculture (Del Vecchio 2013). The 1995 Water Law for instance was fought over between the Ministry of Public Works and the Ministry of Agriculture, with the Ministry of Agriculture against some of its dispositions as it represented a 'loss of prerogatives' against the Ministry of Public Works and its more 'global vision' regarding water management (ibid.). These tensions could explain the difficulty in establishing coordinated joint actions for the water sector.

⁵⁴ According to Albarazi (2014), the government informs farmers through newspaper articles and campaigns but 60 percent of farmers surveyed were illiterate. Many farmers therefore revert to local leadership given the strong community ties in Syria. This method of community association and information sharing is not prescribed in the Water Law however.

The adoption of the new Water Law in 1995 and the creation of an inter-ministerial water commission chaired by the Prime minister, have not been sufficient to establish coherent water management policies between these two ministries (BRLI and Agro-Concept 2012). The Ministry of Agriculture has never really agreed to depend on the water administration and the management and regulation of hydraulic and public works (ibid.). Moreover, because of its interests in agricultural development, largely based on irrigation expansion, it did not want to be subjected to the administrative constraints imposed by the water administration on the use of surface and groundwater resources (ibid.). The reluctance of farmers to establish and follow a regulatory framework echoes these tensions between ministries, as water meters and the control of abstractions are undertaken by the water administration and not the Ministry of Agriculture (ibid.).

The division of roles between these two ministries has not been clear, even in areas under public irrigation. Up until 2009, the water law exempted the areas controlled by the '*offices d'irrigation*' and belonging to the Ministry of Agriculture from obtaining concessions (ibid.). This was interpreted as part of the co-management between the River Basin Agencies (Ministry of Water Resources) and the irrigation offices (Ministry of Agriculture). It was in fact understood that the River Basin Agency would be responsible for granting drilling and boring authorizations and the irrigation office would grant abstraction authorizations associated to these wells, when located within their administrative areas. After 2009 however, a unique application controlled by the River Basin Authority was introduced with a favourable prior notice (ibid.).

In Libya, coordination problems between administrations have led to similar groundwater developments and projects between the Secretariat of Agriculture controlling state-operated projects and the General Water Authority (FAO 2008c). The development of the Great Man-made River project initiated its Phase III stage by building a new well field with 300 new boreholes in the Kufra area, the same area where the Secretariat intends to develop 100,000 hectares for irrigation to produce wheat (ibid.). This problem is underpinned by the lack of a clear national water strategy defining the overall long-term priorities and objectives. In Algeria, the proliferation of illegal wells was partly due, according to an FAO report (2008b), to a lack of coordination between administrations in charge of water resources, with the division of administrative tasks between the wilayas (in charge of issuing drilling permits) and the National Agency of Hydrological Resources (in charge of understanding and monitoring the resource).

In Egypt, as Sowers (2013) relates, the implementation of Integrated Water Resources Management (IWRM) concerned different government ministries at the national level. The elaboration of a National Water Resources Plan was prepared by a number of inter-ministerial meetings and committees. The Ministry of Housing, Utilities, and Urban Communities was involved as well as Ministry of Irrigation, the Ministry of Agriculture and Land Reclamation, and the Ministry of Defence participated in these meetings. The final strategy proved inadequate in many ways as the legal mechanisms to foster coordination between ministries were not in place (ibid.). Some ministries were not aware of the plan and some other sectors simply pursued their own agendas and plans without any reference to the National Water Resources Plan (ibid.).

In Yemen the primary authority resisting attempts to control water is the Ministry of Agriculture and Irrigation. As Alderwish et al. (2014) write, "at least until the updated 2010 Sector Strategy [...], the Ministry of Agriculture and Irrigation looked upon the Ministry of Water and Environment 'as a menace to its power'" and resentment between these ministries is expressed through inequitable budgets (Alderwish et al. 2014: 13). The newly created NWRA (depending on the Ministry of Water and Environment) is seen by the Ministry of Agriculture as "ineffectual and hostile to the interests of farmers", and with not much ability to plan and act (Ward 2015: 127).

In some cases the legal definition of water is problematic, which causes administrative and implementation challenges. During the process of de-colonization, some states in the Middle East and North Africa inherited parts of the Ottoman Civil code (or *Mejelle*) which regulated in writing and for the first time water rights (Marina Stephan 2007). The *Mejelle* declared all waters vested in the state, or incorporated in the public domain (Caponera 1992). Water was also declared a non-saleable commodity to which everyone had a right with groundwater also belonging to the community (ibid.). Israel and Jordan replaced the *Mejelle* by a new set of legal documents stating that the state was the owner of groundwater and that the ownership of the land does not grant ownership of groundwater. In Lebanon and Syria however, parts of their water legislation have kept some of the traditional Islamic values attributed to water which defined this resource as a common good that can be privately owned following specific conditions. The case for groundwater is different however as the *Mejelle* states that water flowing underground is not the property of any person (ibid.). This has created a situation where groundwater's ownership is granted to the state according to a traditional legal system.

2.3.3 The role of international donors in water management: the example of Yemen

In Yemen, international donors have had a considerable influence in groundwater management and regulation and, more generally, in national water sector reforms. Many projects have made the country's institutions dependent on foreign funds such as the NWRA where, by 2009, more than a third of its staff was contractual and paid by donors (Ward 2015). According to Alhamdi (2012), "Water is always perceived in Yemen as a donor sector, pushed by donors, with weak role of the Yemeni side". This presents a problem according to this author in terms of low level of leadership and ownership by the Yemeni authorities. The main players in the water sector in Yemen since the 1990s have been the Netherlands, Germany, and the World Bank (Lackner 2014). These donors however have had differences in terms of policy direction for the water sector in particular, leading to a confusion in policies and approaches which has hindered the progress of reforms.

In Yemen, by the late 1990s, an informal distribution of responsibilities was agreed between donors, with the Dutch focusing more on urban water, Germany on rural domestic supply, and the World Bank on irrigation (ibid.). Projects funding the introduction of modern irrigation techniques have helped mostly larger and wealthier farmers, partly due to the fact that smallholders often cannot afford the contribution required for these schemes (ibid.). On this latter matter however, despite investments in more efficient irrigation methods since the mid-1990s (ibid.), Alhamdi (2012) remains critical, and pinpoints how "there has been no clear policy on irrigation [in Yemen]", with the focus most recently being on modern irrigation techniques (i.e. drip irrigation), mostly donor funded, small scale and with little public interest amongst the population.

World Bank funded aid packages for Yemen include the country's Water Sector support project, for a total of 340.5 million USD (of which 90 million USD have been committed by 2015) (World Bank 2015). As part of this project, Yemen would receive support for implementation of the National Water Sector Strategy Investment Program (NWSSIP), in strengthening the country's institutional basis for regulating and managing water, improving community-based water resource management, increasing access to water supply and sanitation, increasing returns for water use in agriculture, and stabilizing groundwater abstraction for agricultural use. Despite the conflict engulfing the country since 2015 (which has put a stop to all disbursements in the country portfolio), the implementation of the loan had already suffered delays since it was

approved in 2009, causing the under-expenditure and under-disbursement of funds for components of the project.⁵⁵

2.3.4 Perverse incentives for agriculture and irrigation

The use of subsidies by governments to develop agriculture performance has had perverse effects on the rate of groundwater over-abstraction and the development of wells. Further agriculture incentives such as domestic price support, barriers to imports or energy subsidies have fuelled groundwater abstraction and irrigated agriculture expansion, allowing farmers to over-irrigate or use water for low-value crops (World Bank 2007).

As can be observed in Table 8, many countries in the region have in place incentives for irrigation. The most common instrument in place is subsidized credit for farmers, found in 16 out of 19 countries considered in the World Bank (2007) study. Jordan's agriculture sector has benefited from reduced interest loans through the Agricultural Credit Corporation (ACC), a government corporation funded through the Central Bank of Jordan as a commercial bank entity (Hjort et al. 1998). As Hjort et al. (1998) have described, during the 1980s and 1990s the ACC provided seasonal and short term loans for operational purposes (39 percent of total loans in 1996) as well as medium and long term loans (for capital improvements such as land improvement and development in rainfed areas, farm mechanization). Loans from the ACC were granted at discounted interest rates and free of commission and fees (ibid.). In Yemen, the development of groundwater abstraction was also fuelled by loans from the Cooperative and Agricultural Credit Bank for the purchase of pumps at interest rates of 9 to 11 percent (compared to 20 percent interest rates in the market) (Ward 1998), as well as subsidies for importing pumps or free pump installation via donor-funded projects since the 1970s (FMWEY 2015). In the Tensift region, Morocco, the state encouraged groundwater abstraction in the 1980s via credits and subsidies for irrigation and exempted farmers from import taxes for drilling material (Tanouti and Molle 2013).

Energy subsidies are also a popular incentive for agriculture with 15 out of 19 countries. In Syria, the development of groundwater abstraction helped by subsidies for fuel and production inputs in the 1970s and 1980s led to the promotion of a 'water-intensive' agricultural sector produced a situation whereby the ruling Ba'th party, with its historical ties to rural areas and the agriculture sector, saw agrarian socialism as the key to social and political mobilization and legitimization (Barnes 2009; Hinnebusch 2011). Barriers to imports are another potential policy tool to support agriculture and irrigation. The concern for internal food production and food security can have negative impacts on groundwater resources as seen in Saudi Arabia after the 1970s when the country supported agricultural expansion through sector-support policies such as free-interest loans, prices incentives to crop or subsidies for irrigation technology (Abderrahman 2005). Agricultural expansion in Saudi Arabia was initiated in the early 1970s by agriculture-sector support policies "as part of a comprehensive import substitution model of development aimed at ensuring self-sufficiency, gaining food security and improving the livelihoods and prosperity of rural communities" (Ouda 2014: 2).

In countries such as Algeria and Tunisia, governments have not pursued a logic of resource conservation but rather one of support and incentives for its abstraction and use (Faysse 2011). In Yemen, World Bank development projects in the 1970s helped develop incipient modern groundwater abstraction technology in the country and later, bank loans for drilling wells and

⁵⁵ See Annex 1 for more information on this project and its implementation problems.

government subsidies for the private sector to import groundwater abstraction technology fueled well drilling in the country.⁵⁶

Table 8. Incentives for irrigation in Arab countries

<i>Countries</i>	<i>Barriers to imports</i>	<i>Domestic price support</i>	<i>Subsidized credit</i>	<i>Energy subsidies</i>
Algeria	Yes	Yes	Yes	Yes
Bahrain	No	No	Yes	Yes
Djibouti	Yes	-	-	-
Egypt	Yes	Yes	Yes	Yes
Iran	Yes	Yes	Yes	Yes
Iraq	No	Yes	Yes	Yes
Jordan	Yes	Yes	Yes	Yes
Kuwait	No	No	Yes	Yes
Lebanon	Yes	Yes	No	Yes
Libya	Yes	Yes	Yes	Yes
Morocco	Yes	Yes	No	No
Oman	No	Yes	Yes	Yes
Qatar	No	No	Yes	Yes
Saudi Arabia	Yes	Yes	Yes	Yes
Syria	Yes	Yes	Yes	Yes
Tunisia	Yes	Yes	Yes	No
UAE	No	Yes	Yes	No
West Bank-Gaza	Yes	No	No	No
Yemen	Yes	Yes	Yes	Yes

Source: World Bank 2007.

2.3.5 The state, vested interests, and groundwater management

2.3.5.1 Power dynamics, inequality, and groundwater governance

Regulation and the enforcement of rules to stop groundwater overdraft might work on paper but when it comes to real implementation, vested interests, the reality on the ground, or a serious lack of political commitment created by weakened or co-opted institutions can hinder the implementation of these rules. In Jordan for example, as Richards wrote (1993: 1), “all government decisions must be viewed through the lens of His Majesty, who must balance contentious internal and external forces”, with agriculture being viewed as “a source of patronage for key constituencies whose support is essential to achieve domestic stability/foreign policy goals, or as a source of income for the population.” In this context, farmers provide important support for the King on different policy issues (e.g. many of the landowners in the Jordan valley are from the Adwani tribe, whose members are well-represented in the Army and government bureaucracy) (Richards 1993).

⁵⁶ In 1973 for example, the Tihama Development Project in the Tihama Coastal Plain (with a total cost of 17.5 million USD) included a feasibility study to expand irrigation in 60,000 new hectares with surface and groundwater, the drilling of 60 wells, with 50 developed for irrigation and sold to farmers through credit extended by an agricultural credit institution or cash sales (World Bank 1973). A project in 1976 in Wadi Hadramawt also included a feasibility study for the development of groundwater in order to establish if present extractions at the time (around 128 Mm³) and expected future ones (up to 160 Mm³) were within the safe yield limits of the aquifer (World Bank 1976).

For Zeitoun et al. (2012), the tragedy of the commons surrounding the over-abstraction of groundwater unfolds unevenly for water and groundwater users, as the more powerful actors might see benefits in the 'race to the bottom', since they have access to "the ears of the policymakers" who can grant them privileged access to funds or in cases allows them to circumvent legislation (to get exceptional well licenses, for example). This obviously reflects more pervasive and deeper socio-political connections between elites and policy-makers, connecting networks of power, patronage, rent-seekers and social and economic capital. These aspects of power asymmetries are therefore, for these authors, of key importance when studying water management policies and water access.

Defining power as 'the ability to influence outcomes', Zeitoun et al. (2012) understand that actors' vested interests in support or opposition to the political status quo are driven by access to economic resources, status and networks of political power. In the case of Yemen, implementation of water management policies is hindered by tensions at the political level derived from "the contest between well-established traditional authorities on the one hand, and the rules and organs of the young Yemeni state on the other" (Zeitoun et al. 2012: 57). As a document of the World Bank put it mildly, despite "improvements in its control institutions" and the 2007 anticorruption law and subsequent action plan, "perceptions about corruption in Yemen remain unfavourable" (Abu-Taleb and Calkins 2009: 195). As Ward et al. (2007) found, the ownership of water resources in Yemen is correlated with high income. Poor farmers on the contrary typically have to share water or buy it, or can only rely on rainwater for agriculture. The poor usually cannot afford to purchase diesel for the pumps, and the costs of drilling a well are too high.

Incidents in the Ta'iz governorate in Yemen in the 1990s prove how difficult the accommodation between state intervention and local interest groups can be. In this region, state driven prospective drilling projects and groundwater abstraction for drinking in urban areas by the NWSA affected the perennial flow of the wadi in Al Hayma-Habir (Handley 2001). The resistance of local rural residents and farmers, facing the army, shows the ability of these communities to resist weak state rule. The imprisonment of sheiks refusing to co-operate with the drilling projects and to protect the drillers ended with three sheiks being imprisoned until they signed the agreement (ibid.). The lack of trust and conflict with the government was further increased when the government failed to deliver part of the compensations promised to the rural communities (ibid.). At that point, the army was sent and was received with women throwing stones and trying to take their guns. Further compensation packages through World Bank projects appeased the villagers as they included the provision of water supplies to villages with 25 percent of the total yield of the three wells drilled by the NWSA (ibid.). As a result, the politics of groundwater management and reallocation in this area are enmeshed with local interests, dominated by clan associations, and manipulated by local political actors to their own ends (ibid.). Additionally, the perception by local communities that the informal modes of governance are more legitimate than more centralized forms of government and rule undermine and add to the weaknesses of the state (ibid.).

Issues of inequality also exist amongst farmers abstracting groundwater as not all of them have the same level of access to capital and the same amount of resources to bypass existing institutional control mechanisms (ibid.). As emphasized by Zeitoun et al. (2012: 55), previous research on water management politics (especially on water demand management) has found that the established political apparatus typically favours male-dominated structures or the wealthy "and is perpetuated by the fact that water resource management institutions also lack much of the ability and legitimacy required to implement change that some in local communities – and external donors – would like to see". For these authors the implementation

problem of water management policy lies in the power asymmetries and entrenched interests of water stakeholder groups.

As Kuper et al. (2012) have studied in the Tadla scheme in Morocco, differences in the access to competitive markets and subsidies from the state between large irrigated farms and small farms increase inequality (Kuper et al. 2012). These differences are further exacerbated by disparities in access to economic capital and wealth: farmers with financial means are able to use alternative water sources and dig wells in order to free themselves from the constraints of water turns imposed by surface water regulations (Van Steenberg and El Haouari 2010). Large farms also appear to be competitive but are in fact benefitting from state subsidies and state redistribution mechanisms. Small farms on the contrary suffer from the reduction of the presence of the state, having to put up with surface water reduction and to invest in order to continue farming and improve their productivity (Kuper et al. 2012).

Inequality is also found in Yemen when it comes to accessing and benefiting from diesel subsidies (Al-Weshali et al. 2015). As these authors point out, well-off farmers benefit disproportionately from diesel subsidies as they consume more energy than poorer households, and also as they consume more energy-intensive products (ibid.). An intricate web of corruption and vested interests benefits from the allocation of subsidies for diesel, transportation of fuel and re-shipping and export to other countries (as far as Southern Africa) (FMWEY 2015). Overall, studies have shown that the richest 20 percent of households benefits from 40 percent of fuel subsidies as opposed to the bottom 40 percent of households being able to access only 25 percent of the subsidy (IMF 2013). Access to diesel by those in need is also affected by the shortage (in production and supply) and exacerbated by diesel smuggling to neighbouring countries (Al-Weshali et al. 2015).

As Ghazouani et al. (2012a) have pointed out in the oasis of Fatnassa, Tunisia, conjunctive water use is another factor contributing to undermine social cohesiveness. Farmers, when facing insufficient and uncertain supply, look for other water sources from which they can pump or abstract (e.g. waterways, wetlands, or groundwater). Most large-scale irrigation schemes such as in Morocco (Tadla) are peppered with wells and access to tubewells and boreholes can provide farmers with means to obviate or bypass collective action and obtain additional water individually (ibid.).

In the El Guerdane area in Morocco, beneficiaries of this project had to finance the procurement and installation of drip irrigation and the river basin agency refunded 60 percent of the costs. Critical studies of this project have revealed the involvement of the royal family in this project and the strategic use of water reallocation to strengthen a private sector dominated by the king and his entourage. Local farmers were marginalized during the application process as well as their uneven access to natural resources (Houdret 2012).

As the example of Israel shows, vested interests by farmers and the need for more water caused policy impasses and the paralysis of the legislative and policy process (Feitelson 2006). This situation was further exacerbated when in the 1990s during a series of drought years, the water commissioners tried to avert political losses by allowing the over-abstraction of groundwater from aquifers rather than establishing water allocation cut-backs. The development of new sources of water was fought by the Treasury in Israel which, worried about the heavy costs of increasing wastewater treatment and seawater desalination, prevented the capital outlays necessary until full cost pricing was implemented. Such approach was however fought in parliament by the agricultural lobby which tried to prevent an increase in water rates, as it needed the approval of parliamentary committees where agricultural interests are disproportionately represented (ibid.).

Water sector reforms in Lebanon initiated in the 1950s aimed at centralizing water supply failed partly due to the failure of the public sector and state agencies during the civil war. This failure caused further wide-spread water sector reforms in 2000 focusing on improving governance, efficiency of delivery, cost recovery within integrated water management approach (Allès and Brochier-Puig 2013). These reforms also included an attempt of a new 'territorialization' of water management by the state intended to establish a process of control of resources, users, and their relations (ibid.). Despite the fact that these reforms were translated into new administrative boundaries and the creation of four regional areas in the country, local water management realities in the north and local political interests clashed with such centralizing attempts (Allès and Brochier-Puig 2013; Ghiotti and Riachi 2013). Additionally, local management and power interests of wealthy families are also at play in the northern regions, creating a feudal-like type of government, far from national policy guidelines coming from Beirut (Allès and Brochier-Puig 2013).

Box 4. Local institutions and communities in Jordan

Despite contemporary changes in values, the mechanisms of tribal relationships have remained part of Jordanian social and political life for decades. For Jordan, contemporary and dominant metaphors of social and political life cut across many domains of culture and levels of society and make it impossible to separate public and private spheres, as kinship cannot be separated from politics. Indigenous patterns of cooperation and conflict resolution are protected and co-opted by centralizing state structures and a monarchy that needs allies. However, the lack of provision of social welfare services has compelled citizens to resort to local institutions, local brokers or community leaders/elders “whose positions are conceived to allow them to demand resources from the state” (Bouziane 2010: 37).

Tribal conflict management and resolution procedures were done via open community forums seeking reconciliation. With the development of a more capitalistic and market-based society in Jordan, these traditional institutional arrangements have evolved towards patron-client relationships across informal social networks. The grass-roots level and the variety of processes, understandings, and everyday practices fostering trust and cooperation between individuals have been relegated in favour of more economic and monetary-based exchanges. However, the rise of community members with economic, social, and cultural capital (e.g. merchants, high-ranking employees, new technocrats) has questioned the authority and role of the middle strongmen (e.g. community and tribal leaders) and their hierarchies. Local institutions and traditional structures such as the guesthouse, which used to represent an archetypical type of public space and common social institution, have however changed as more and more rural communities started being connected via the simultaneous spread of transportation, education, migration, and communication.

Source: Antoun 2000; Bouziane 2010; El-Said and Harrigan 2009.

2.3.5.2 Corruption and rent-seeking

Rent-seeking strategies by actors involved in water management can open the doors to opportunistic behaviour. Corruption, the ‘shadow of the political will’ in agricultural water management, is in many places pervasive (Huppert 2013; Wade 1982). This, in turn, limits the effectiveness of state policies and regulation and leads to the seemingly contradiction of an apparent strong state relying at the same time on coercive force and informal networks of

favours and customs which can limit the implementation of regulation and legislation.⁵⁷ As Regner and Wolff (2000: 11) wrote for Jordan, decades of distributing power for different groups and elites attached to the Hashemite royal family “led to the emergence of successive coherent, closed and competing social groups, such as trans-jordanian major landowners, Palestinian wholesalers, or Bedouin military”. Landholdings are also almost entirely in the hands of traditional families having held in the past top government positions (Regner 1996 in Regner and Wolff 2000). The commercialisation of agriculture products at the national level in Amman is controlled by a reduced niche of dealers, regarded as having great political influence (ibid.).

In Syria, corruption of enforcement officers also undermines the application of rules on the ground. As described by Wendle (2016), well drillers had connections and trusted contacts with local government officials on whom they can count “to look the other way” if they bent the rules (Wendle 2016: 44). This was enabled by bribes so that they can drill wells without government interference “if you bring the money, you get the permissions you need fast [...], if you don’t have the money, you can wait three to five months. You have to have friends” (Wendle 2016: 46).

In Yemen, corruption of official elites can paralyse policy or divert resources towards local interests as described in detail in Annex 1 and in the following section. Zeitoun et al. (2012) found that the group of actors supporting water management policy reform in Yemen includes those with less influence over its implementation, while those opposing water demand management are the most influential. The lack of bargaining power of less influential actors compromises their access to decision-making processes and informal networks of policy implementation. The influence of large farmers is also exerted vis-à-vis the decision makers through chains of personal or tribal relationships with ministry officials (ibid.). The authors suggest the potential positive impacts on these vested interests and policy iron triangles of ‘overlapping’ groups and “the importance of long-term strategies that can both erode positions and capitalize on change-moments” (Zeitoun et al. 2012: 61).

2.3.5.3 Groundwater, power, and vested interests in Yemen

As indicated by Zeitoun (2009), tensions underlying water management and water politics in Yemen are derived from the contest between established traditional authorities and a relatively young Yemen state trying to establish itself and find its own legitimacy amongst the country’s various tribal systems and allegiances. Forces external to the formal branches of government and various vested interests affect the development of national politics, such as families controlling the bulk of commerce and the tacit coalitions between sheikhs and local security officials and representatives (ibid.).

For Van Steenberg et al. (2012), the autocratic and elitist political system in Yemen has always intervened to extend patronage to all elites in the country.⁵⁸ Moreover, newly formed

⁵⁷ The role of donors can also exacerbate this process, where, with aid funds and projects can be misused in the absence of proper state regulation (Maipose 2000 in Hanafi and Tabar 2004) in contexts of state formation or transitional states. Funds and aid for the Palestinian territories used to strengthen structures of power, clientelism, the rise of an economic and political elite, and corruption, are a prime example of this process as examined by Khan et al. (2004). The case of Tunisia is paradigmatic, as companies associated to the deposed president Ben Ali benefited from tax evasion schemes and lax regulation, capturing resources in highly state-regulated sectors (e.g. telecommunications, transportation, real estate), and accounted to 3 percent of all private sector outputs in the country (Rijkers et al. 2014; 2015).

⁵⁸ Corruption in Yemen is considered to be “the main point of business rather than its murky illegal underside” (Bafana 2012: 1. This represents a prevalent system of patronage, networks of influence, political, economic and social power happening at a large scale (grand corruption) as well as at the small scale (petty corruption) (Robinson et al. 2006). Corruption can take many forms and variations, mainly enabled through ‘wasta’ (or connections) with people well

institutions in Yemen such as the NWRA and especially new water user associations have legitimacy problems as their bargaining power and rate of approval is closely linked to specific individuals and their leadership and their ability to solve technical issues and prove themselves organizationally competent (FMWEY 2015; Zeitoun 2009). Additionally, in Yemen, the NWRA's mandate is disconnected from the country's water resource management reality. The assumption is that the state can be in control of groundwater (through a top-down paternalist approach) but in reality the lack of enforcement, state and public-sector weakness and the role of local communities in water management undermine NWRA's goals and ability to act (Ward 2015). Thus, the issue of a legitimacy clash between these two types of structures, old and traditional ones and new ones, is relevant as the new structures can be easily put aside and overruled by the pre-existing ones.

In the past, groundwater access in Yemen also played a role in integrating tribal elites into the government's 'formal ruling establishment' (Moore 2011). In many tribal rural areas, tubewells came to be seen as a sign of wealth and prestige and financing groundwater abstraction amongst tribal elites became an effective patronage mechanisms. Wells were used as political gifts through which local leaders could be co-opted into power. Multilateral donors such as the World Bank financed groundwater abstraction projects, encouraging the Yemeni government to adopt groundwater abstraction as a key development strategy (Ward 2000 in Moore 2011).

Restrictive land use norms strengthen however the power position of rural elites. Under the post-1976 legal regime, well-owners could charge high fees from well-users and access to water use was restructured to individuals having paid for the equipment of the well. At the time, a new system of economic relation was established between wealthier landlords and sharecroppers whereby the landlord would invest in the cost of pumping and provide the seeds and animal power, and the sharecropper or tenant would only retain 25 percent of the product (Viziterv-Vituri 1971 in Moore 2011). This increase in revenues via investment in groundwater abstraction encouraged those with capital to invest in farming and groundwater wells.

Additionally, the high productivity levels of qat cultivation also meant that large sums of capital were being invested in keeping and expanding the business via large-scale irrigation projects. Vested interests in the qat production sector allowed producers to undermine attempts to regulate its production and enjoy a laissez-faire policy from the state, whilst strengthening the role of elites benefiting from the industry (Ward 2000 in Moore 2011). In the Taiz governorate, the state drilling campaign in the 1980s for NWSA in Lower Al-Hayma benefited the local sheikh, as he agreed to the drilling and managed to get three deeper drilled wells out of the deal to supply his successors' luscious qat plantation (Handley 2001).

2.4 Public policy outcomes and user responses to groundwater depletion

2.4.1 Expansion, coping with groundwater depletion, or exiting the system

Facing groundwater depletion and the race to the bottom, farming communities, the state, and groundwater users have come up with solutions to compensate for the loss of the resource. Conjunctive surface-groundwater in large scale irrigated areas such as the Tadla in Morocco or

positioned within the establishment. Examples of corrupt deals include oil imports and exports, diesel subsidies appropriations and diesel re-export, goods' import and exporting licenses and commercial networks importing and supplying basic goods (Bafana 2012; Salisbury 2011). Even though corruption is "the glue that keeps things in place" (Robinson et al. 2006: 6), the 'unpredictable corruption' found in Yemen according to a former Minister of Water and Environment (FMWEY 2015), represents an obstacle which is crippling the system as businesses and investors will have expectations on how to 'work the system' but will easily find that "the mood of the decision-maker has changed" and then will have to replan (ibid.). See Annex 1 for further details.

the Nile Delta in Egypt gives farmers more flexibility. Intensifying rainfed crop production and crop diversification as well as the expansion of groundwater-based agriculture into new areas with more resource potential such as desert lands in the Western Desert of Egypt are also strategies to cope with groundwater depletion by expanding agriculture and resource use, the race to the bottom by resource appropriation potentially leading to groundwater depletion.

Access to capital is however essential to determine the type of strategy followed by groundwater users (Faysse et al. 2011). The development of modern agriculture and new farm holdings in El Ghrouss (Biskra wilaya, in the Ziban oases region in the Algerian Sahara) in the 1980s was driven not only by the access to deep groundwater but also by a necessity to develop social and economic upward mobility in a deprived area through new investments by farmers (i.e. greenhouse horticulture) and also guaranteed old-age post-labour retirement by cultivating date palms as perennial crops (Amichi et al. 2015). By sharing land and water through contractual arrangements, landowners give access to agriculture, production factors and capital to tenants and wage labourers who then, after around 10-15 years of cultivation, will move to new uncultivated lands where they can become in turn landowners (ibid.). These dynamics remain successful and continue to be sustained due to the fact that groundwater and land remain available.

In Morocco, Algeria, and Tunisia, researchers have identified two types of strategies adopted by farmers to address the impacts of groundwater over-abstraction (Berahmani et al. 2012; Faysse et al. 2011). Farmers can adopt 'chasing strategies', which consist in investing in drilling technology to obtain sufficient groundwater to maintain the farmer's production system (e.g. buying a more powerful pump or deepening the well). This type of strategy is individualistic and could be characterized in some instances as an 'exit' type of strategy, whereby groundwater users would decide to exit a system of shared norms and regulation (e.g. if they are members of a communally-managed irrigation system like a GDA in Tunisia) and establish their own wells and technology in order to maximize their own profit and revenues from their crops (Shah 2009). Other more radical 'exit strategies' observed in the region consist in stopping irrigation and groundwater-fed agriculture altogether, and fallowing/renting out/selling the land plot (e.g. in Haouaria, Cap Bon, Tunisia).

In the coastal area of Chaouia in Morocco, farmers have had to adapt to water shortages since the 1980s by deepening their boreholes or by bringing water to their farm from wells drilled in other areas, as well as renting land upstream in the same area (Faysse et al. 2011). Bekkar et al. (2009) have called this type of strategy 'offensive', as farmers aim at maximizing their economic profits by obtaining continuous access to groundwater through individual tubewells. In the irrigated area of Tadla, Morocco, groundwater abstraction dynamics changed from being a mere supplement to surface, after the first boreholes were drilled in the 1980s, water deficits to determining agricultural development (Hammani and Kuper 2008).

Faysse et al. (2011) has identified that groundwater users in Tunisia find ways to cope with change and vulnerability by seeking adaptation mechanisms for cropping systems, irrigation technology, or more broadly household livelihoods. In the Cap Bon, some farmers have been shifting to less water intensive crops or even rainfed agriculture due to a lack of groundwater (e.g. in the Haouaria region). Farmer groups managing groundwater-fed irrigation systems in the Nadhour region in Tunisia have agreed to stop supplying water to farmers outside the official boundaries of the scheme as well as to cap the irrigated area allowed for each farmer in order to reduce pressure in the water system (Faysse et al. 2011). These agreements however have not been able to overcome a lack of coordination between farmers as to the diversification of crops or to establish efficient irrigation dates and times amongst them (ibid.). With a similar approach,

Bekkar et al. (2009) have called these strategies 'defensive strategies' aimed at either maintaining existing farming levels or simply maintaining groundwater access through existing individual or collective wells.

In Yemen, according to Al-Weshali et al. (2015), due to changes in diesel subsidies after 2011 and shortages due to lack of supply and conflict, some farmers in poorly endowed households had to abandon agriculture, whereas others had to adapt their cropping patterns, abandoning farming of irrigated crops and started practicing deficit irrigation for fruits and vegetables. According to a survey by the authors, diesel consumption was halved in these cases, but so was crop yield (dropping by 40 to 60 percent in surveyed regions) (ibid.). Other strategies followed by farmers in Yemen include purchasing water from neighbouring farmers with deeper wells to supplement irrigation of high value crops or buying water from water tankers (the profitability of the irrigated crops with water purchased, qat in many instances, justifies irrigation by tanker) (Ward 2015).

2.4.2 Cooperation and conflicts between users and with the state

Farmer perceptions towards regulation of groundwater management vary from country to country and from area to area. In Morocco, surveys carried out by Faysse et al. (2011) have shown that only half of the farmers in the Souss and Saiss areas mentioned state controls as a possible solution to groundwater over-abstraction whilst only 8 percent in Berrchid and none in Chaouia have mentioned this possibility. In Tunisia, around 15 percent of interviewed farmers mentioned stricter control of illegal boreholes (ibid.).

Some of the contents of the 1995 Water Law in Morocco emphasize implementation problems for the various agreements and measures aimed at solving the situation of over-abstraction of the aquifer. The lack of mediation between the users and individual farmers and the River Basin Authorities makes the dialogue challenging and translates into a lack of effective participation in the process by the users who, ultimately will have to follow the rules. Additionally, the various arbitration instances regarding the development and implementation of the river basin master plans are centralized at the ministry level and do not allow for the participation of the regions involved (BRLI and Agro-Concept 2012).

According to Hammani et al. (2009) the type and characteristics of the development of groundwater abstraction are partly to blame for such perceptions. In Tadla (Morocco) and Mitidja West (Algeria) groundwater use and abstraction are mostly diffuse and most tubewells are illicit and non-regulated, communities lack of management structures, so it is difficult for stakeholders to have an integrated vision of the dynamics of both the groundwater use and the aquifer (Hammani et al. 2009).

Local institutional solutions found by farmers in Morocco and Algeria are often successful but are also volatile, ad hoc, and responsive to environmental and structural drivers (changes in rainfall patterns, changes in central politics driving farmers to establish informal arrangements amongst them). They are also linked to proximity (neighbours or family links) which means they cannot be officially recognized. Errahj et al. (2009) found that more formal types of institutional innovations (land markets, capitalist and mutualist arrangements for accessing groundwater) need to be formally and officially recognized in order to avoid a dualist existence: on the one hand they can exist as illegal and not sanctioned by the state and within an insecure context of informal relations, but on the other hand the results of informal user coordination are ultimately sanctioned by the state and by markets (as agricultural crop production sold).

Tensions between communities and the state can also give way to processes of community organization and participation. In Tunisia, in spite of the state's aim to increase decentralization

of water resources across the country, the development of community participation practices in Gabes is the result of continued sanctions by the state and disagreement of farmers (Leghrissi 2012). The conflict between users and the state arose following the limitation of abstractions after the establishment of a prohibition perimeter banning groundwater abstraction in Gabes (starting in March 1987) (ibid.). An overwhelming majority of farmers were against the ban and against the state, refusing access to farm plots to public officials wanting to control illegal drilling. Further government decrees during this period did not curb the will of farmers to continue drilling boreholes and abstracting groundwater (ibid.).

As a result of such impasse, the state consequently changed its approach and adopted a collaborative strategy in order to raise awareness about the importance of compromising with the state in view of a solution beneficial for both parties. Irrigators as a result of their involvement wanted to have the right to access the aquifer (ibid.). As studied by Leghrissi (2012), these meetings led to the establishment of a community group in charge of the joint management and protection of the El Bssisi-Wadi Al Akarit aquifer. The process of community participation in the GDA of Bssisi in the governorate of Gabes follows therefore this conflict between users and the state. Direct consultation is made impossible because of the distrust between farmers and the state. It is the president who is delegated to deal with the state. Therefore, a double system of participation and communication actually takes place: first the consultation and participation system at the community level and in a second instance, the transmission of the results of this process by the president to higher levels of authority (ibid.). In other parts of Tunisia such as in oases or in Central Tunisia however, the lack of success of collective action within the GDAs is due, according to Riaux et al. (2015), to water access inequalities. The role of the state policy intervention resulted in the loss of capacities of traditional communities to organize themselves by disrupting hierarchies of access to water, changing inequities socially accepted within the community to intolerable and illegal inequalities (ibid.).

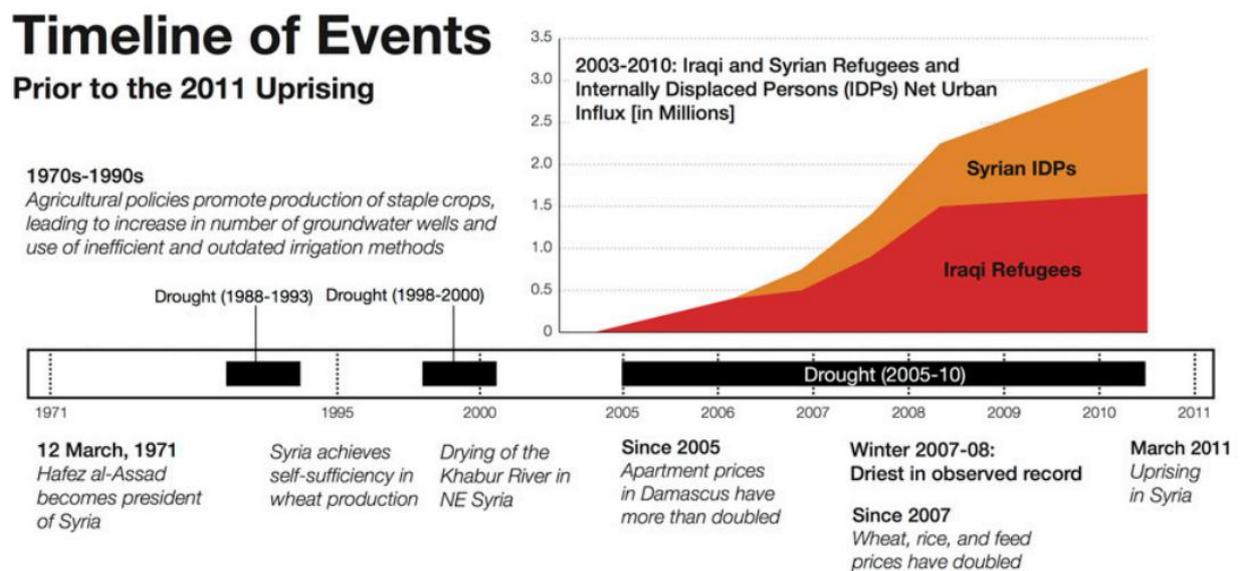
In the Highlands of Jordan, the Ministry of Water and Irrigation, with financial support from the German Cooperation Agency (GIZ) and also French funding, has attempted to integrate and bring together 60 different stakeholders (agricultural water users, government institutions, NGOs, and research institutions) in a joint water forum (the Highlands Water Forum, HWF) aiming to implement a multi-organisational dialogue mechanism for the area (Mesnil et al. 2012). Even though Mesnil et al. (2012) consider that the Forum's bottom-up approach provides the necessary incentives and transparency for donors and participants, continuing wasteful behaviours by groundwater users have been attributed to the fact that the process bypasses "political networks to which rural farmers belong" (Yorke 2013: 106). The fact that the Forum's Secretariat is based at the Ministry of Water and Irrigation and officially mandated by the Prime Minister would denote a predominantly top-down approach vis-à-vis the participation of stakeholders and the process of cooperation between users and the state.

Yemen has had to face many challenges in the past which have undermined the state's capacities to directly control the use of its natural resources. Additionally, perverse incentives and a weak system of rule of law affected by years of internal conflict are constantly challenging the state's capacities and legitimacy vis-à-vis groundwater management. Tensions between farmers and the state also arose in Yemen due to the reduction of diesel subsidies leading to fuel price increases in 2011 (Al-Weshali et al. 2015). This crisis of unprecedented severity was, according to Al-Weshali et al. (ibid.), partly unleashed and exacerbated by the political and social unrest hitting Yemen following the Arab spring events across the region. Tensions have also arisen in Yemen between the state and communities due to inappropriate technology imposed on rural communities (e.g. well fields for urban water supply outside community boundaries),

with in many instances no community consultation, and inflexible approach of public agencies (Ward 2015).

The added issue of the country’s cultural and economic dependency for qat only adds to the problem. Furthermore, legal pluralism complicates the implementation of water policies, weakened further by a phenomenon of a ‘weak state/strong society’ (Migdal 1988 in Handley 2001). This legal pluralism involves the local rule of the customary laws and courts (via local sheikhs). According to Islamic law in Yemen, water contained in wells is considered to be the property of the well owner. Legal incentives linking water ownership to land ownership have also sustained the expansion of drilling and groundwater pumping (Handley 2001).

Figure 43. Timeline of events in Syria



Source: Kelley et al. 2015.

An extreme case of conflict between users and the state is Syria. Coupled with the cancellation of diesel and fertilizer subsidies, continuous years of drought (the last one spanning from 2006 to 2010, the worst one on record) (Kelley et al. 2015) reduced crop yields by 32 percent in irrigated areas and up to 70 percent in rain-fed areas whilst wheat and barley production dropped by 47 and 67 percent respectively, forcing Syria to import wheat for the first time in 15 years (Saade-Sbeih 2011) and increasing food prices (prices of wheat, rice, and feed prices for livestock more than doubled between 2007 and 2008) (Kelley et al. 2015). This also caused farmers to massively abandon their land and migrate to urban areas, causing a humanitarian situation in the north-east of Syria, with as much as 300,000 people migrants according to UN estimates living in makeshift illegal camps (de Châtel 2014). Other estimates account for 1.5 million people displaced from rural areas to urban centres because of the drought (Kelley et al. 2015) (Figure 43). These processes, playing a direct role in the deterioration of Syria’s economic conditions, have been quoted as part of the drivers of the current conflict in Syria (de Châtel 2014; Gleick 2014; Kelley et al. 2015). Widespread social tensions in the country in 2011 forced the government to revise its diesel subsidy policy and decrease the price of diesel down to 15 pounds per litre (Saade-Sbeih 2011). Thus, water has become a contributing cause to the conflict, part of a multitude of factors – political, social, and national (Beck 2014).

3 Community groundwater management in the Arab World

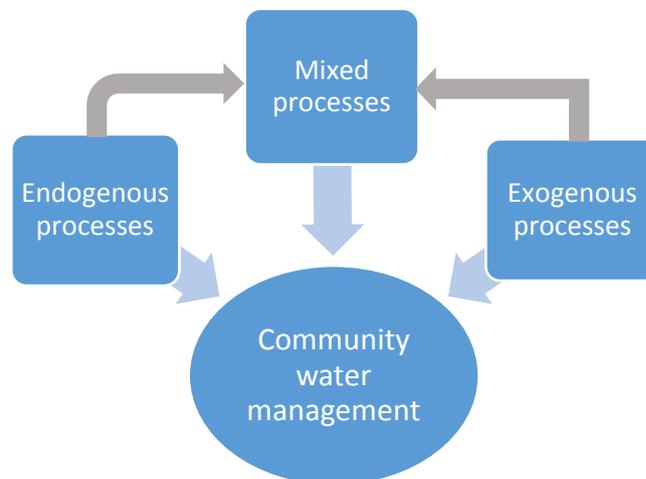
The Middle East and North Africa region is famous for its long standing experience with water systems managed by communities and farmer groups. The formation and articulation of these systems around collective rules can however be internally driven (endogenous process) or can be externally initiated or fostered (exogenous process) (Figure 44).

Endogenous processes of community management can be found in areas in Algeria, Morocco, or Tunisia, where oases and small-scale irrigation areas (Faysse et al. 2011) are based on springs, qanat, or small river diversions. There, Ghazouani et al. (2012b) have observed the existence of collective wells and cost-sharing agreements, developed as a response to high drilling costs. Through such arrangements well owners can sell water to other users or, if the well has more than one owner they can establish rules for water allocation or community members can be appointed as supervisors or coordinators for the allocation and management operations (ibid.). In the Maghreb as a whole however, these irrigation projects with community groundwater management systems are usually concentrated in a limited number of small areas (Faysse et al. 2011; Van Steenberghe 2006). Farmers in the Tadla area Morocco and in the Mitidja plains in Algeria have developed informal arrangements internally to obtain access and jointly manage wells within large scale public irrigation schemes. Hammani et al. (2009) found that access to groundwater by individuals and collectively in the Tadla Area in Morocco and Mitidja West in Algeria partly depends on informal arrangements spurring out of public irrigation schemes.

Exogenous processes of community management show a varying degree of state involvement such as the setup of collective forms of groundwater management by law in Morocco. In Morocco however, collective deep-well projects have been attempted for small-scale irrigation systems but the promotion of cooperative associations and management organizations by the state has not fully worked due to its top-down implementation and insufficient funds allocated (Houdret 2006 in Ghazouani et al. 2012b). The role of communities in groundwater management can also be developed via state devolution, whereby small scale irrigation systems with collective wells are rehabilitated and the infrastructure and management of the system transferred to a new community organization in charge of its operation, typically a water user association, as has happened in Tunisia with the GDAs (Ghazouani et al. 2012a).

Community involvement in groundwater management can also display a combination of exogenous and endogenous characteristics. In Yemen for example, following donor demands, the state has attempted to develop water user associations and river basin management. This new institutional set up tried however to replace or incorporate traditional community management structures with varying degrees of success. In Tunisia, communities with established traditional management of irrigation structures and groundwater allocation in oases have had to adopt state-imposed management structures (GDAs) following specific decentralisation policies.

Figure 44. Processes of community groundwater management



Source: Authors.

3.1 Traditional groundwater management structures in the Arab world

As seen previously in this study, several countries have a history and continue to rely in some instances on traditional groundwater management structures. The use of traditional groundwater management systems in the Arab world demonstrates that communities have the capacity to manage and share groundwater orderly and cooperatively. Although these structures make use of groundwater as a resource for irrigation, the use of traditional groundwater collection systems is different from the generalized characteristics of modern groundwater abstraction systems and limited to small communities or oases. These structures are widespread across the world and known with different names: *khettaras* in Morocco, *foggara* in Algeria, *karez* in Central Asia, and *aflaj* in Oman (Bosi 2009; Lightfoot 1996). Community arrangements and mutual help institutions (Shah 2009) in place dominate these traditional systems rather than the individualistic and anarchic proliferation of groundwater wells. Despite these differences, references to these traditional mechanisms highlight a rich variety of modes of cooperation within the region, showing how communities can organize themselves and manage the use of natural resources. Due to their hybrid features as a groundwater extraction technique which also distributes water via surface channels, qanats are also part of a complex social and environmental structure (Bosi 2009).

3.2 Community management of wells in Moroccan and Tunisian oases

Nowhere in the MENA region is the relationship between water and humans more critical than in an oasis. With space being so contained and confined, oases represent a microcosm of adaptation, change and sustainability in a constant balance between the desert, water, and human activities. Oases are also artificial places, created by irrigated agriculture and mixed farming and require the presence of people with technological knowledge, culture and socio-economic tools to develop hydraulic structures such as wells, channels, and dams. Labour force, available land are crucial to sustain human activities but water remains essential to sustain life in the oasis (Battesti 2012).

Khettaras in the Toghga valley in South-East Morocco are part of the 'social capital' of the community and, despite recent changes in the oasis society (e.g. unemployment, rural exodus), these systems remain the geographical and symbolic centres of the three douars (village) studied by Rondier (2012). Daily life is marked by irrigation and the authority of the village

councils and elders over irrigation issues remains. Traditional ruling bodies retain considerable weight in the management of water and an important symbolic role due to their seniority and legitimacy.

These institutions are however experiencing challenges as they are having problems in adapting to local changes affecting oasis societies, since strict rules exclude farmers not originating from the villages from accessing ancestral water rights (ibid.). A program of participatory irrigation management created three different water user associations in 1997, with some of them more active and successful than others, managing in total 1,400 hectares out of 1,960 and gathering 617 farmers out of 955 (ibid.). In two villages, these user associations have been replaced by development associations, gathering most of the funds in the village and being able to mediate between the state and users to raise funds for projects.

Similar stories are to be found in the Tensift in Morocco, where the first victims of newly drilled groundwater wells in the 1980s were the traditional khattaras. More than 500 were to be found there in 1974 but apparently only one survives nowadays (Tanouti and Molle 2013). Farmers themselves drilled the wells affecting their own traditional irrigation systems, degrading these structures as well as the palm grove (ibid.).

3.3 Community management in Yemen and its limits

With declining groundwater tables, some communities in Yemen have autonomously responded to the challenge by implementing local rules that aimed to reduce conflict and provided more reliable and equitable access to water. In these communities, groundwater user associations can contribute to improving groundwater management. Recent research has identified 24 locations in Yemen where local management has been developed in order to improve community groundwater use (Taher et al. 2012). Likewise, Bruns and Taher (2009) describe how some communities have begun to regulate groundwater abstraction by, for instance, restricting well drilling (in many cases to protect domestic water supply, which is a priority often motivating local initiatives). These local initiatives arise due to, in part, the fact that formal rules aiming to control and reduce groundwater abstraction are not applied at the local level (in spite of national legislation and efforts from formal institutions and courts) (ibid.).⁵⁹

The development of locally and community-based groundwater governance in Yemen seeks to prevent harm to existing users, most notably by developing and enforcing rules restricting well spacing and banning export of water from the abstraction area via tankers (Van Steenberg et al. 2012). Via community negotiation, these local rules have also helped close disputed wells, invest in groundwater recharge, or develop a pipeline network system connecting separate wells (Taher et al. 2012). Some of these customary rules have been drafted centuries ago and, although they can be specific to the type of water source (spate, groundwater, surface water), they are generally consistent with Islamic law and approved and upheld by local sheikhs (Ward 2009).

The different types of groundwater management systems studied by Taher et al. (2012) include informal community norms, local leadership, and user associations, all of them in use in different contexts and sustaining local groundwater management (Bruns and Taher 2009; Van Steenberg et al. 2012; Taher et al. 2012). Taher et al. (2012) also established that the type of rules used by these communities would either aim at preserving common interests or aim to preserve individual interests enforced by either informal norms, leadership, or a water user association. The rules found by these authors were:

⁵⁹ See Annex 1 for further details on community rules for groundwater management in Yemen and its limits.

- Restrict/ban well drilling
- Well sharing
- Well spacing
- Prohibiting well development in sensitive areas
- User cooperative consent to drill wells following consultation by the NWRA
- Ban on tankers
- Well-depth limit
- Spring protection by zoning
- Ban on qat irrigation
- Closure of disputed wells
- Agreement on reservoir operation
- Authorization of new agricultural wells if they also serve drinking water
- Joint user association to regulate new well development
- Non-well owners to share in existing wells

However, in spite of Yemen's experience in traditional water and groundwater management systems, its rehabilitation has not been addressed properly. According to Alhamdi (2012), "the government has not capitalized on traditional water management systems in Yemen and has established an enabling corrupt environment for free-riders, those who actually either take public land in the upper reaches of the wadis or take private land and divert the water from the wadi for new developments, depriving poor farmers downstream". Additionally, this strong community-based management of water has not been able to preserve groundwater resources according to Taher et al. (2012), as in many instances these traditional practices are used to essentially reduce conflict by providing a more reliable and equitable access to water.

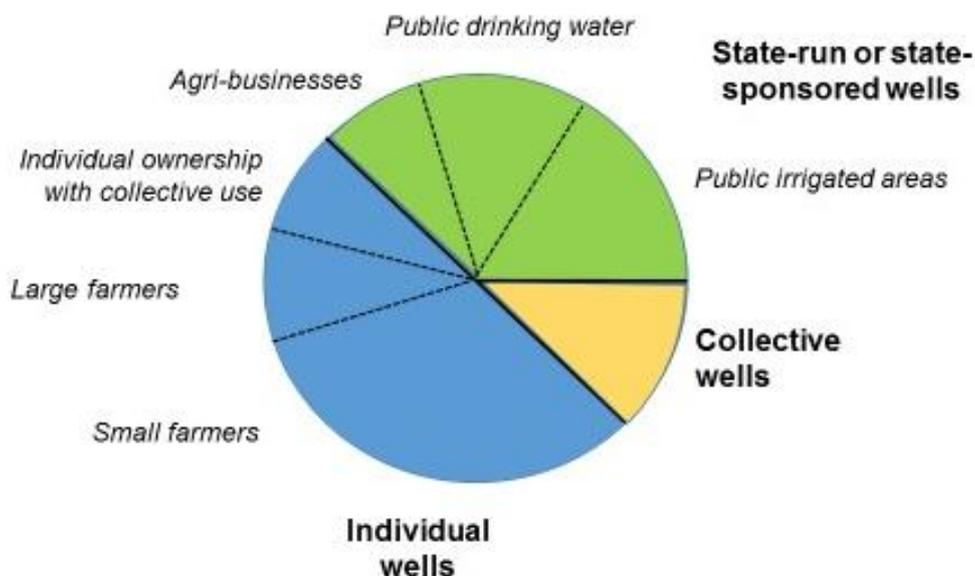
Conflicts continue in Yemen despite the intervention of traditional methods of conflict resolution and the role of tribes and sheikhs in mediation. Also, traditional social structures have been eroded and weakened over the past decades due to the boom of individual well-fuelled irrigation, putting in question these inherited communal norms and values and the authority of traditional authorities (i.e. sheikhs) (FMWEY 2015). The generational gap with the youth represents a challenge to the traditional tribal system and its weakening role as these younger generations can violate traditions and rules (Al-Dawsari 2012). Additionally, the use of the tribal system through government manipulation for political gains has also undermined its roots and respectability within the community as they ended up being seen as serving their own self-interest (ibid.). The links with the government of some tribal leaders through participation in networks of influence (as they accepted official posts in the military or government, financial allocations, bribes, etc.) ensured the consolidation of power in tribal areas (ibid.).

Additionally, land purchases by rich farmers (not always from the same region) and the high revenues derived from qat and corrupt practices have contributed to the shift of the power balance towards rich landowners, and split society in some areas between new land owners and traditional tribal and communal structures (ibid.). This process, according to a former Minister of Water and Environment (FMWEY 2015) happened as traditional land owners controlling land in the wadis were affected by wells drilled around these areas by landless rich investors drilling wells and selling water (ibid.). As springs and spate irrigation in these wadis began to recede due to dropping water table levels, new lands were being irrigated outside the wadis (it is in these areas where qat cultivation boomed as the areas outside the wadis were more suitable for qat). As a result, traditionally controlled lands in wadis lost value due to the lack of water, erosion caused by development projects and roads and the established landowning families lost power against the newly enriched qat growers (ibid.).

4 A typology of wells in the Arab World

Based on the above study of groundwater management, regulation, and governance in the Arab world, Figure 45 and Table 9 present a typology of different types of wells found in the region. The types of wells presented reflect the different management articulations, be it by individuals, communities of users, or the state via different mechanisms of intervention, highlighted in this study. Figure 46 broadly illustrates the evolution in time of these different types of wells.

Figure 45. A simplified groundwater well typology for the Arab World



Note: the sections in the pie chart are supposed to give an indication of the relative number of of each type of well but are not an accurate representation of the real numbers of wells for each type.

Source: Authors.

Individual wells abstracting groundwater are pervasive across the region. These wells are used privately and even though in most cases state regulation requires permits or licenses for these wells, many users abstracting groundwater have not such required permits. The 'atomization' of this phenomenon, linked to the rapid spread of cheap technology, the presence of relatively shallow groundwater, and also in many cases enabling financial deals for farmers or agricultural incentives, have driven a large-scale agricultural revolution in many parts of the region. Many areas have experienced this phenomenon, from the Tadla plain in Morocco, through Sidi Bouzid in Tunisia, the Mitidja Plain in Algeria, wells used by farmers in the Nile Delta in Egypt, to the Azraq basin in Jordan and the Beqaa valley in Lebanon. In this category we can find small farm holders with no more than 1-2 hectares (Cap Bon, Tunisia) and also large private land owners with important investments in high-tech irrigation technology and large pumps (e.g. Souss, Morocco; Western Desert, Egypt; Mafraq, Jordan).

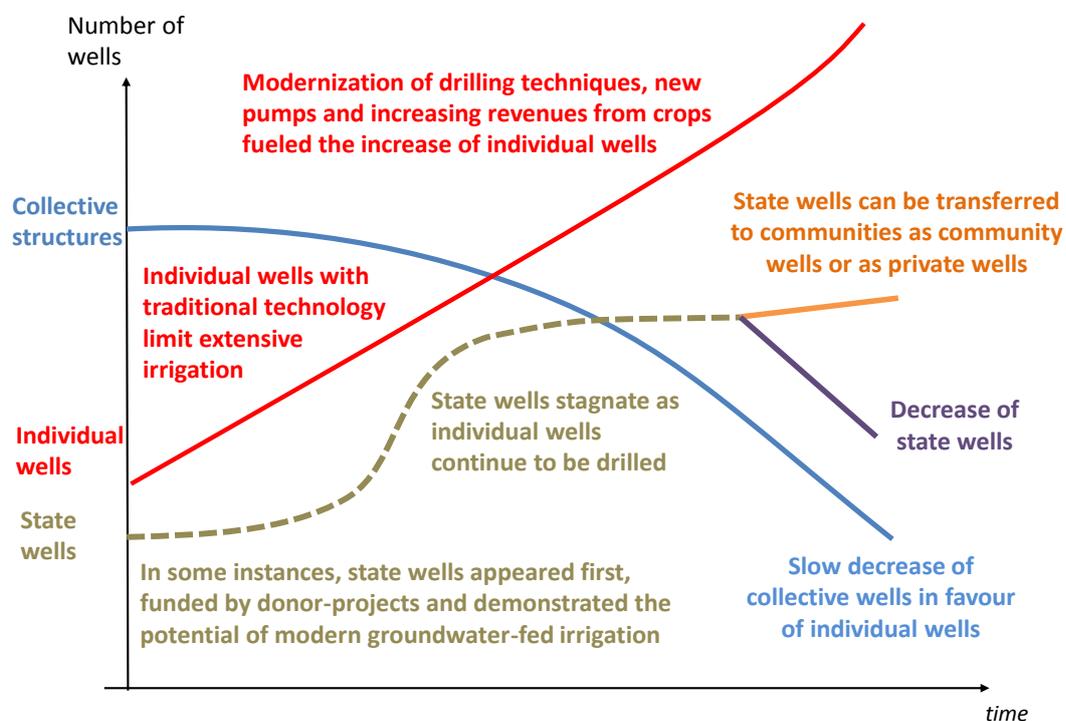
Users with individual wells have also established relations with other users in need of water, giving way to exchange agreements for special services. Users can sell groundwater to users without the capital to invest in a well, such as in Lebanon, where tenants can also rent individual wells along with land from owners. Some types of owner-driven wells also guarantee access to groundwater to other users through different types of exchanges, be it capitalistic with money exchange or mutual following religious or other motivations as sometimes seen in the Nile delta

(El Agha et al. 2015a, 2015b). These exchanges however not always allow management as the asset – i.e. the well, in general continues to be owned privately.

Another type of well found in the region is the collective and communally managed well. These are structures drilled collectively by a group of users or also by the state. Community-driven wells are a mechanism that guarantees access and also can allow the collective management of the resource. Users engage in different types of social arrangements in order to regulate access and management of the resource to a whole or just a portion of a community (mutual help via traditional rules like for the qanats or via newly voted rules in newly created user cooperatives in Yemen). These types of wells, their management, and ways to regulate access have adopted various forms depending on the location and context they are found in. The management regime can be based on free access and solidarity, with the owner displaying goodwill towards fellow groundwater users, or based on strict access rules based on tradition or on capitalistic arrangements and agreements between the community and external users. In some cases, these collective wells have been inherited from public irrigation schemes through a process of ‘disengagement’ from these public irrigated areas, transferring the ownership and management of these wells to private owners (e.g. in the Mitidja plain, Algeria).

Due to its long history, the region has also several characteristic groundwater management structures that have evolved through the centuries and have, in some cases, survived until these days (Figure 46). The traditional qanats found across the region have survived in some countries such as Oman, or in some oases in Morocco. These structures and the management regimes that evolved around the use of the resource ensure water allocation for all users whilst integrating a series of rules and institutions maintaining the equitable use of the resource. In some instances however, these structures have been affected or have disappeared due to the effects of groundwater over-abstraction by private users pumping at greater depths with deep borewells and lowering the water table.

Figure 46. General evolution of well use for groundwater abstraction



Source: Authors.

The state can also be involved in groundwater abstraction in different ways. In places such as Tunisia, where due to a lack of surface water resources, public irrigated areas built by the state in the 1960s and 1970s have relied on groundwater, the state has delegated to water user associations its management (with ministerial supervision). State-run groundwater schemes include large and strategic abstraction schemes such as the Great Man-Made River in Libya, state-supported private agri-businesses in Saudi Arabia, or groundwater well fields for agriculture drilled in large land reclamation projects in Egypt's Western Desert.

Another type of groundwater use in the region is the *conjunctive use* of surface and groundwater for agriculture. In this case, either groundwater or surface water can be used as complementary resources when the other one fails. This is a phenomenon observed in all public schemes in Morocco (and in Tadla in particular), and in the Gharb valley in Syria, where farmers depending on surface water delivered through canals have also turned to groundwater wells. These wells supplement surface water irrigation to different degrees and allow security of supply and therefore security for crop cultivation for farmers. The central part of the Nile Delta in Egypt has seen this phenomenon appear since the early 2000s. In some instances, the opposite situation has been observed, whereby surface water irrigation can complement groundwater wells. This can happen in state-sponsored irrigation areas using groundwater (such as in Tunisia), or in areas with private groundwater abstraction in El Guerdane, Morocco where the state has built large surface water irrigation infrastructure to prevent further reduction of groundwater reserves due to over-abstraction by individual users.

Table 9. A general typology of wells in the Arab World

		<i>Typology</i>		<i>Examples</i>
Groundwater	<i>Individual wells</i>	Individual ownership and use (small and large farmers)		Pervasive in the region
		Individual ownership with collective use (solidarity and exchange arrangements)		Beqaa valley – Lebanon Tadla – Morocco
	<i>Collective wells (with collective ownership and/or collective use)</i>	<i>Owner driven</i>	Solidarity/goodwill	Egypt – Delta
			Capitalistic agreements	Beqaa valley – Lebanon Tadla – Morocco
		<i>Collective wells</i>	With arrangements (mutualistic, capitalistic, traditional)	Wadi Dhelaa, Sana’a – Yemen Tadla – Morocco Oases – Tunisia, Morocco, Mitidja, Algeria
			With collective structures (qanats/khettaras)	Morocco Algeria Oman Syria
	<i>State driven</i>	Transferred (state to community)	Tunisia, GDAs Biskra – Algeria	
	<i>State initiated or sponsored wells</i>	Public irrigated areas		Kairouan, Haouaria – Tunisia Souss - Morocco Libya
		Agri-businesses		Saudi Arabia, Egypt, Jordan, Morocco
		Public drinking water supply (well fields)		Azraq – Jordan Bahrain Libya
State or local administration management		Lebanon (municipal drinking water provision)		
Conjunctive use surface-groundwater	<i>Wells supplementing/replacing surface irrigation</i>	State-controlled		Souss – Morocco Mitidja – Algeria (past)
		Individuals/group		Tadla – Morocco Nile Delta – Egypt Beqaa plain - Lebanon
	<i>Surface irrigation supplementing groundwater wells</i>	State-controlled		Cap Bon - Tunisia
		Individuals		Beqaa plain - Lebanon
		Private companies		Guerdane – Morocco

Source: Authors.

5 Trajectories of conjunctive surface and groundwater interaction

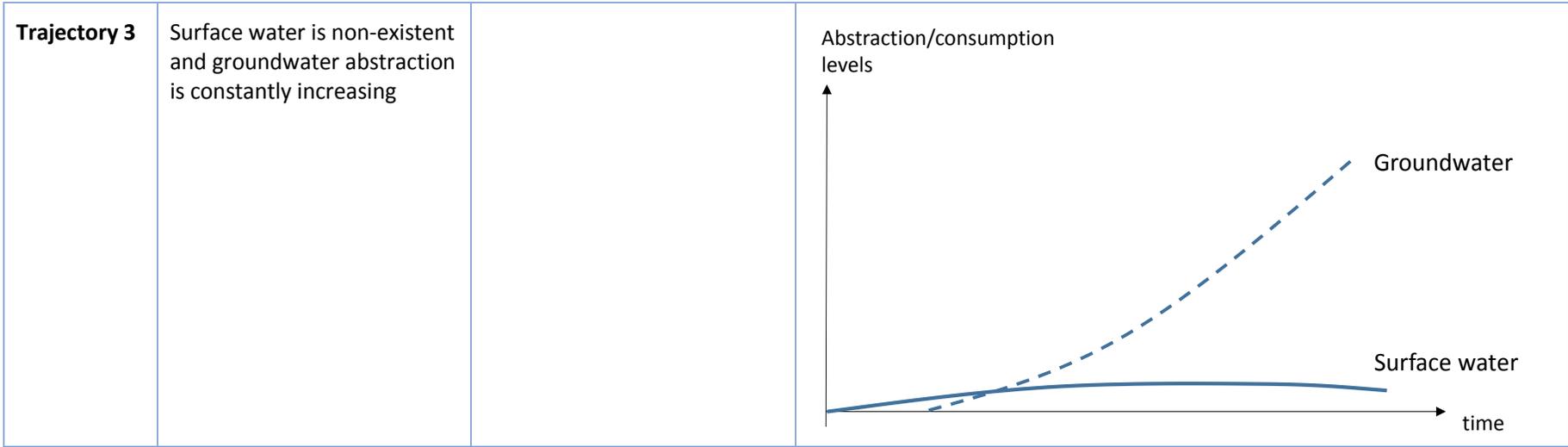
As presented above in some of the case studies, groundwater can also be developed and abstracted conjunctively with surface water. In this section we present a general typology of aquifer and groundwater development trajectories based on the previous analysis. These trajectories are generic cases aimed to reflect and illustrate the evolution of groundwater abstraction and its interaction with surface water. The constant search to secure availability and access to water resources in the MENA region has led users, communities, and governments to maximize the appropriation of water and reduce the risk caused by decreasing levels (stored or accessible). Throughout the different case studies analysed and as the trajectories show, these two sources of water supply (be it for irrigation, drinking water, or industrial uses) have been developed in parallel, in constant interaction and in constant use (and sometimes in competition).

The concept of 'trajectories' mirrors Molle and Wester's (2009) concept of 'river basin trajectories' in as much as it also looks at the "long-term interactions between societies and their environments, with a focus on the development and management of water and associated land resources" (Molle 2003). Surface and groundwater trajectories focus however more specifically on the particular resource appropriation and development dynamics concerning the use of surface water and abstraction of groundwater in irrigated systems. A particular groundwater trajectory encompasses the different processes involved in the lifting and abstraction of groundwater by communities with the medium to longer term potential to deplete the resource. A surface water trajectory indicates the evolution of the use of the resource, either as a primary source of water for agriculture or as complementary to groundwater.

As seen in this analysis, the use and depletion of groundwater is linked to the interaction between availability of the resource and capacity and ability to access it. In most irrigated systems (except in cases where abstraction taps into fossil groundwater as the sole resource like in the desert), the development paths of surface and groundwater development are interrelated as they originate both out of the local intervention and abstraction of users who are in need of the resource and will require tapping into either or both of them depending on the level of accessibility, financial resources and incentives. One must therefore carefully analyse how the paths of the different surface water and under-ground flows are interrelated and how any local intervention that modifies the quantity, quality or timing of one of these flows impacts the whole system (Molle and Mamanpoush 2012).

Table 10. Surface and groundwater trajectories

Trajectories	Description	Cases	Depiction
Trajectory 1	Surface water is insufficient, groundwater helps compensate and find water security in access.	Morocco, Tadla; Egypt, Nile Delta; Lebanon, Beqaa: Litani with wells; Syria, Gharb	
Trajectory 2	Surface water shifts around the tendency of groundwater increase to avoid the 'crash' and can help to stabilize increase in groundwater abstraction. Groundwater abstraction levels may decrease due to depletion or poor quality	Tunisia, Cap bon, Guerdane; Bahrain; Egypt, West Delta	



Source: Authors.

6 References

- Abderrahman, W.A. 2005 Groundwater management for sustainable development of urban and rural areas in extremely arid regions: a case study, *Water Resources Development*, 21(3), 403-412.
- Abderrahman, W.A. 2006 "Saudi Arabia Aquifers", in Foster, S., and D.P. Loucks (eds.) Non-renewable groundwater resources: a guidebook on socially-sustainable management for water-policy makers, IHP-VI Series on Groundwater No.10, Paris: UNESCO, 63-67.
- Abu Zeid, M. 1992 Water resources assessment for Egypt, *International Journal of Water Resources Development*, 8(2), 76-86.
- Abu-Taleb, M., and R. Calkins 2009 "Governance in Yemen's water sector: lessons from the design of an anticorruption action plan", in Jagannathan, N.V., Mohamed, A.S., and A. Kremer (eds.) *Water in the Arab World: management perspectives and innovations*, Washington DC: The World Bank, 191-205.
- Adnane, M. 1989 Communication sur : « Le régime juridique de l'eau au Maroc », Centre National de Documentation, No. 9341, 90-1524, <http://archives.cnd.hcp.ma/uploads/news/90-1524.pdf> (Accessed 3rd March 2014).
- Adriansen, H.K. 2009 Land reclamation in Egypt: a study of life in the new lands, *Geoforum*, 40, 664-674.
- AGIRE 2011 *Elaboration et mise en œuvre d'un contrat de nappe : concept et processus*, Contrat de nappes de la Tadla – Journée de démarrage, Beni Mellal, 23 Juin 2011, Power point presentation.
- Ahmed, S., Zayat, E.L., and M.H. Ali 2011 Well field design in a highly fractured aquifer system: a case study of the Egypt's Siwa Oasis, *International Journal of Water Resources and Arid Environments*, 1(6), 483-489.
- Akhan, M.M. 2014 Yemen Country Report. Developing and Implementing Mitigation and Preparedness for Water Scarcity and Drought (WS&D) Management Plans. Zaragoza, Spain. Powerpoint.
- Al Atiri, R. 2005 Farmers participation in the management of public irrigation schemes in Tunisia, FAO.
- Al Atiri, R. 2007 Evolution institutionnelle et règlementaire de la gestion de l'eau en Tunisie : vers une participation accrue des usagers de l'eau. In, Bouarfa, S., Kuper, M., and A. Debbarh (eds.) *L'avenir de l'agriculture irriguée en Méditerranée. Nouveaux arrangements institutionnels pour une gestion de la demande en eau*, Actes du Séminaire Wademed, Cahors, France, 6-7 November 2006, Cirad, Montpellier.
- Al Insari, M.S. 2013 The water demand management in the Kingdom of Bahrain, *International Journal of Engineering and Advanced Technology*, 2(5), 544-554.
- Al Mes'han, O. 2011 *Development of a decision support system (DSS) for Azraq Oasis*, Final Technical Report, Azraq Oasis Restoration Project, National Center for Research and Development, BADIA Research Program.
- Al Naber, M. 2015 *Groundwater and farming systems in Azraq, Jordan*, USAID Groundwater Governance in the Arab World, Internal Report, Cairo: IWMI.
- Al Sulaimani, Z.B.K., Helmi, T., and H. Nash 2007 The social importance and continuity of falaj use in Northern Oman, *International History Seminar on Irrigation and Drainage*, Tehran-Iran, May 2-5.
- Albarazi, G. 2014 Is Syria's water institution capable of addressing current and future challenges? An exploration of Syria's water policy, administration, and law, MSc Thesis, Unpublished, University of Oxford.
- Al-Dawsary, N. 2012 *Tribal governance and stability in Yemen*, The Carnegie Papers, Carnegie Endowment for International Peace, Washington, DC.
- Alderwish, M.A., AlKhribash, S.B., and Mushied, M.H. 2014 *Review of Yemen's control of groundwater extraction regime: situation and options*, International Research Journal of Earth Sciences, 2(3), 7-16.
- Algérie. 2005. Loi n°05-12 du 28 Jomada Ethania 1426 correspondant au 4 août 2005 relative à l'eau. Journal Officiel de la République Algérienne.

- Alhamdi, M. 2012 'Water scarcity and the need for policy redirection in Yemen', in Yemen in Transition: Challenges and Opportunities, October 19-20, 2012, Harvard University, Video recording, <http://vimeo.com/52884952> (Accessed 6th April 2014).
- Alim, Y. 2012. Ressources en eau : les forages illicites mis à l'index. El Watan, 28 - 11 - 2012. <http://www.djazairiess.com/fr/elwatan/393821>
- Alkebsi, A., and C. Boucek 2010 "Corruption in Yemen: screening of destructive beast", Carnegie Endowment for International Peace, <http://carnegieendowment.org/2010/09/30/corruption-in-yemen-screening-of-destructive-beast> (Accessed 6th August 2015).
- Allan, J.A. 2001 The Middle East water question: hydropolitics and the global economy, London, New York: I.B.Tauris.
- Allan J.A.T. 2007 "Rural economic transitions: groundwater use in the Middle East and its environmental consequences", in Giordano, M., and K.G. Villholth (eds.) *The agricultural groundwater revolution: opportunities and threats to development*, Wallingford, UK: CABI, 63-78.
- Allès, C., and J. Brochier-Puig 2013 Entre centralisation et appropriation locale. Une réforme de l'eau sous tension au Liban-Nord (Akkar), *Etudes Rurales*, 192, 97-115.
- Al-Marshudi, A.S. 2008 Economic instruments for water management in the Sultanate of Oman, *Water International*, 33(3), 361-368.
- Al-Muslimi, F. 2013 "Tribes still rule Yemen", October 10th, 2010, Al Monitor, <http://www.al-monitor.com/pulse/originals/2013/10/yemen-tribes-revolution-politics-saleh.html> (Accessed 6th August 2015).
- Al Naber, M. 2016 Jordan – Azraq Basin Case Study. Groundwater governance in the Arab World. USAID/IWMI Project Publication. Report no.11.
- Al Naber, M. and Molle, F. 2016 The politics of accessing desert land in Jordan. *Land Use Policy* 59: 492–503.
- Al Naber, M. and Molle, F. 2017a Controlling groundwater overabstraction: policies vs. local practices in Jordan Highlands. *Water Policy* (in press).
- Al Naber, M. and Molle, F. 2017b Water and sand: is groundwater-based farming in Jordan's desert sustainable? *Groundwater for Sustainable Development* (forthcoming).
- Al-Said, F.A., Ashfaq, M., Al-Barhi, M., Hanjra, M.A., and I.A. Khan 2012 Water productivity of vegetables under modern irrigation methods in Oman, *Irrigation and Drainage*, 61, 477-489.
- Al-Saidi, M. 2014 'Measurement of decentralisation and commercialisation reforms in the Yemeni urban water and sanitation sector and evaluation of current institutional change', in 'Social water studies in the MENA region' Conference, Abstract proceedings, German Jordanian University Campus, 28-29 September 2014, Madaba, Jordan.
- Al-Sakkaf, R., Zhou, Y., and M.J. Hall 1999 A strategy for controlling groundwater depletion in the Sa'dah plain, Yemen, *Water Resources Development*, 15(3), 349-365.
- Al-Weshali, A., Bamaga, O., Borgia, C., van Steenberg, F., Al-Aulaqi, N., and A. Babaqi 2015 Diesel subsidies and Yemen politics: Post-2011 crises and their impact on groundwater use and agriculture, *Water Alternatives*, 8(2), 215-236.
- Al-Yazidi, N. 2015 *Groundwater governance in Yemen – An analysis*, IWMI Project Internal Report, March 2015.
- Al-Zubari, W.K., and I.J. Lori 2006 Management and sustainability of groundwater resources in Bahrain, *Water Policy*, 8, 127-145.
- Al-Zubari, W. 2012 'Groundwater governance in the Kingdom of Bahrain', PowerPoint Presentation, Regional Consultation on 'Groundwater governance in the Arab World', 8-10 October 2012, Amman.
- Al-Zubari, W.K. 2014 Synthesis report on groundwater governance regional diagnosis in the Arab Region. Groundwater Governance - A Global Framework for Action. GEF and FAO.
- Al-Zubari, W.K. 2016 Personal communication.

Al-Zuwaini, L. 2012 *The rule of law in Yemen: prospects and challenges*, Rule of Law Quick Scan Yemen, Hiil Rule of Law Quick Scan Series, The Hague, The Netherlands: Hiil.

Amichi, F. 2015. Personal communication.

Amichi, H., Bouarfa, S., Kuper, M., Ducourtieux, O., Imache, A., Fusillier, J.L., Bazin, G., Hartani, T., and F. Chehat 2012 How does unequal access to groundwater contribute to marginalization of small farmers? The case of public lands in Algeria, *Irrigation and Drainage*, 34-44.

Amichi, F., Bouarfa, S., Lejars, C., Kuper, M., Hartani, T., Daoudi, A., Amichi, H., and M. Belhamra 2015 Des serres et des hommes : des exploitations motrices de l'expansion territoriale et de l'ascension socioprofessionnelle sur un front pionnier de l'agriculture saharienne en Algérie, *Cahiers d'Agriculture*, 24, 11-19.

Amichi, H., Mayaux, P.-L., and S. Bouarfa 2015 Encourager la subversion : recomposition de l'État et décollectivisation des terres publiques dans le Bas-Chéouli, Algérie », *Politique africaine*, 137, 71-93.

Amin, I.F. 2002 *Groundwater mining in the Tripoli area, Lebanon*, in "Hydrogeology in developing countries: opportunities and challenges", The Geological Society of America 2002 Denver Annual Meeting, October 27-30, 2002, https://gsa.confex.com/gsa/2002AM/finalprogram/abstract_43379.htm (Accessed 4th September 2014).

Antoun, R.T. 2000 Civil society, tribal process, and change in Jordan: an anthropological view, *International Journal of Middle East Studies*, 32(4), 441-463.

Apaydin, A. 2011. Groundwater legislation in Turkey: problems of conception and application. *Water International*, Vol. 36, No. 3, pp. 314–327.

Assadollahi, S.A., 2009 *Groundwater resources management in Iran*, <http://cgwb.gov.in/documents/papers/incidpapers/Paper%20%20-Assadollahi.pdf> (Accessed 9th November 2015).

AUC 2009 *Community-based integrated water management in Farafra Oasis, Egypt, Final Technical Report*, Desert Development Centre, The American University in Cairo.

Aw-Hassan, A., Rida, F., Telleria, R., and A. Bruggeman 2014 The impact of food and agricultural policies on groundwater use in Syria, *Journal of Hydrology*, 513, 204-215.

Ayubi, N.N. 1995 *Over-stating the Arab State: politics and society in the Middle East*, London: IB Tauris Publishers.

Bachta, M.S., Zaibet, L., and L. Albouchi 2005 Impact assessment of water resources development in the Merguellil basin: Kairouan, Tunisia, Internal Report, INAT, IRD, IWMI.

Bafana, H. 2012 "Case samples: corruption methodology in Yemen", <http://blog.haykal.sg/the-yemen/13-case-samples-corruption-methodology-in-yemen> (Accessed 6th August 2015).

Barham, N. 2014 "The sociopolitical aspects of water scarcity in Jordan", *Conference on 'Social water studies in the MENA region – State of the art and perspectives'*, German Jordanian University Campus, 28-29 September 2014, Madaba, Jordan.

Barnes, J. 2009 Managing the Waters of Ba'th Country: The Power and Politics of Syria's Water Scarcity, *Geopolitics*, 14(3), 510-530.

Barnes, J. 2012 Pumping possibility: agricultural expansion through desert reclamation in Egypt, *Social Studies of Science*, 42(4), 517-538.

Battesti, V. 2012 "The power of disappearance: water in the Jerid Region of Tunisia" in Johnston, B.R. (ed.) *Water, cultural diversity, and global environmental change*, Paris, France, Dordrecht, The Netherlands: UNESCO-IHP, Kluwer, 77-96.

Battesti, V. 2013 Des ressources et des appropriations: retour, apres la revolution, dans les oasis du Jerid (Tunisie) , *Etudes Rurales*, 192(2), 153-175.

Beadnell, H.J.L. 1909 An Egyptian oasis. An account of the oasis of Kharga in the Libyan Desert, with special reference to its history, physical geography, and water supply, London: John Murray.

- Beck, A. 2014 Drought, dams, and survival: linking water to conflict and cooperation in Syria's civil war, *International Affairs Forum*, 1-12.
- Bekkar, Y., Kuper, M., Errahj, M., Faysse, N., and M. Gafsi 2009 On the difficulty of managing an invisible resource: farmers' strategies and perceptions of groundwater use, field evidence from Morocco, *Irrigation and Drainage*, 58, 252-263.
- Belghazi, S. 2003 Local governance, development and service delivery, Thematic paper for workshop D, Arab States Local Governance Forum, Sana'a, Yemen, December 6-9 2003, Regional Bureau of Arab States, UNDP, Lebanese Center for Policy Studies, <http://www.cespi.it/STOCCHIERO/Ascod-Marocco/Saad%20Belghadi.pdf> (Accessed 15th October 2014).
- Bellal, S.A., Mokrane, S., Ghodbani, T. and O. Dari 2015 Ressources, usagers et gestionnaires de l'eau en zone semi-aride : Le cas de la wilaya d'Oran (ouest algérien), *Territoire en mouvement Revue de géographie et aménagement*. <http://tem.revues.org/2859>, (Accessed 9th November 2015).
- Ben Hamouda, M.F. 2008 Approche hydrogéochimique et isotopique des systèmes aquifères côtiers du Cap Bon : cas des nappes de la côte orientale d'el Haouari, Tunisie, PhD thesis, Institut National Agronomique de Tunisie.
- Ben Hounet, Y., Casciarri, B., Dupret, B., Ireton, F., and A. Wilson 2011 Pratiques de l'appropriation foncière en contexte musulman, *Transcontinentales*, 7, 2-11.
- Benabdelfadel, A. 2012 Protection des ressources en eau souterraines au Maroc (contrat de nappe), Secrétariat d'Etat auprès du Ministère de l'Energie, des Mines, de l'Eau et de l'Environnement, Charge de l'Eau et de l'Environnement – Département de l'Eau, Royaume du Maroc, <http://www.solutionsforwater.org/wp-content/uploads/2012/01/Contrat-de-nappe-Maroc.ppt> (Accessed 4th September 2014).
- Benblidia, M. 2011 L'efficacité d'utilisation de l'eau et approche économique, Etude nationale, Algérie, Sophia Antipolis : Plan Bleu.
- Bencherifa, A., and H. Popp 1992 L'oasis de Figuig: persistance et changement, Rabat: Passau.
- Benchokroun, T. 2008 Convention-cadre pour la préservation et le développement des ressources en eau du bassin hydraulique du Souss-Massa, *Revue HTE*, 140, Septembre 2008.
- Ben-Meir, Y. 2014 'Decentralizing municipalities in Morocco and Arab Spring Countries', *Morocco World News*, Friday 18th July 2014, <http://www.morocworldnews.com/2014/07/134870/decentralizing-municipalities-in-morocco-and-arab-spring-countries/> (Accessed 15th October 2014).
- Bensman, J. 1987 Mediterranean and total bureaucracies: some additions to the Weberian theory of bureaucracy, *Politics, Culture, and Society*, 1(1), 62-78.
- Berahmani, A., Faysse, N., Errahj, M., and M. Gafsi 2012 Chasing water: diverging farmers' strategies to cope with the groundwater crisis in the coastal Chaouia region in Morocco, *Irrigation and Drainage*, 61, 673-681.
- Bergh, S.I., and M. Jari 2010 Introduction to the Special Journal Issue: Spaces for Change? Decentralisation, participation and local governance in the Middle East/North Africa Region, *Journal of Economic and Social Research*, 12(1), 1-7.
- Bloomberg 2015 "Saudi wells running dry – of water – spell end of desert wheat", November 4th 2015, <http://www.bloomberg.com/news/articles/2015-11-04/saudi-wells-running-dry-of-water-spell-end-of-desert-wheat> (Accessed 6th December 2015).
- Bosi, L. 2009 Social-ecological change and adaptation in a traditional irrigation system: the case of falaj Hassas (Oman), MSc Thesis, School of Geography: University of Oxford.
- Boujnikh, M. 2008 Evolution des paysages irrigués dans le Souss oriental (Maroc) – de la khattara à la motopompe, des terroirs faïd aux grands périmètres irrigués (le cas des Ouled-Berrhil, province de Taroudant), PhD Thesis, University of Nancy 2.
- Bouri, S., and H. Ben Dhia 2010 A thirty-year artificial recharge experiment in a coastal aquifer in an arid zone: the Teboulba aquifer system (Tunisian Sahel), *Comptes Rendus Geoscience*, 342, 60-74.
- Bouziane, M. 2010 The state from below: local governance practices in Jordan, *Journal of Economic and Social Research*, 12(1), 33-61.

BRLI, Agro Concept 2012 Gestion de la demande en eau dans les pays méditerranéens : gestion de la demande en eau – étude de cas du Maroc, Décembre 2012.

Brun, S. 2006 De l'erg à la forêt. Dynamique des unités paysagères d'un boisement en région littorale. Forêt des dunes de Menzel Belgacem, Cap Bon, Tunisie, PhD Thesis, Université de Paris IV – Paris Sorbonne.

Bruns, B., and T. Taher 2009 Yemen Water User Association Study: Findings and Recommendations for a Problem-Solving Approach, Sana'a: Groundwater and Soil Conservation Project, <http://www.yemenwater.org/wp-content/uploads/2013/05/Yemen-Water-User-Assosiation-Study.pdf> (Accessed 29th December 2013).

Burchi, S., and A. D'Andrea 2003 *Preparing national regulations for water resources management. Principles and Practice*, FAO Legislative Study No.80, Rome: Food and Agriculture Organization of the United Nations.

Burdon, D.J., Mazloum, S., and C. Safadi 1954 Groundwater in Syria, *Bulletin de l'Association Internationale d'Hydrologie Scientifique*, 37, 377-388.

Çakmak, E.H. 2010. *Agricultural Water Pricing: Turkey*. Paris: OECD.

Canesse, A.A. 2009 Gestion des ressources naturelles et système institutionnel de gouvernance en Tunisie, *Maghreb-Machrek*, 202, 49-64.

Canesse A.A. 2010a « Les Groupements de développement agricole en Tunisie : entrepreneurs locaux ou relais administratifs ? » in, Denieul P.N., and M. Madoui (dir.) *Entrepreneurs maghrébins. Terrains en développement*, Paris : Karthala, 243-255.

Canesse, A.A. 2010b Rural “participation” and its framework in Tunisia, *Journal of Economic and Social Research*, 12(1), 63-88.

Caponera, D. 1992 *Principles of water Law and administration, national and international*. Balkema, Rotterdam.

Carapico, S. 2002 Foreign aid for promoting democracy in the Arab World, *Middle East Journal*, 56(3), 379-395.

Chebaane, M., El-Naser, H., Fitch, J., Hijazi, A., and A. Jabbarin 2004 Participatory groundwater management in Jordan: development and analysis of options, *Hydrogeology Journal*, 12, 14-32.

Cherif, S., El Ayni, F., Jrad, A., Trabelsi-Ayadi, M. 2013 Aquifer recharge by treated wastewaters: Korba case study (Tunisia), *Sustainable Sanitation Practice*, 14(1), 41-48.

Chowdhury, S., and M. Al-Zarhani 2013 Implications of climate change on water resources in Saudi Arabia, *Arabian Journal of Science and Engineering*, 38(8), 1959-1971.

Clarke, F.E. 1979 *The corrosive well waters of Egypt's Western desert*, Contributions to the Hydrology of Africa and the Mediterranean Region, Geological Survey Water-Supply Paper 1757-O, Washington DC: United States Geological Survey.

Code des Eaux, 1975. Code des Eaux 1975, Tunisie.

Coskun, A.A. 2003. Water Law - The Current State of Regulation in Turkey. *Water International*, Volume 28, Number 1, Pages 70-78.

Coyne et Bellier, Tractebel Engineering SUEZ, and KEMA 2012 Draft Final Feasibility Study Report, Summary, Red Sea-Dead Sea Water Conveyance Study Program, http://siteresources.worldbank.org/EXTREDESEADSEA/Resources/FS_July_2012_English.pdf (Accessed 15th September 2014).

Custodio, E. 2010 “Intensive groundwater development: a water cycle transformation, a social revolution, a management challenge”, in Martinez-Cortina, L., Garrido, A., and E. Lopez-Gunn (eds.) *Re-thinking water and food security: fourth Botin Foundation Water Workshop*, Fundacion Botin, CRC Press, 259-298.

Dawoud, M., and S.S. Ismail 2013 Saturated and unsaturated River Nile/groundwater aquifer interaction systems in the Nile valley, Egypt, *Arabian Journal of Geosciences*, 6, 2119-2130.

de Châtel, F. 2014 The Role of Drought and Climate Change in the Syrian Uprising: Untangling the Triggers of the Revolution, *Middle Eastern Studies*, 50(4), 521-535.

Del Vecchio, K. 2013 Une politique contractuelle sans contrôle? La régulation des ressources en eau souterraine dans la plaine du Saiss au Maroc, Mémoire de Master 2, Université Lumière Lyon 2, Sciences Po Lyon.

Demilecamps, C. 2010 *Farming in the desert: analysis of the agricultural situation in Azraq Basin*, German-Jordanian Programme "Management of Water Resources", GIZ.

Doğdu, M.S. 2013. Building Groundwater Governance in a Changing Environment: What Approaches to Adopt. Presentation at Groundwater Governance: A Global Framework for Action"5th Regional Consultation: Europe, Central Asia and North America Region The Hague, The Netherlands, 18-21 March 2013.

Dorman, W.J. 2007 *The politics of neglect: the Egyptian state in Cairo, 1974-98*, PhD Thesis, School of Oriental and African Studies, University of London.

DSI. 2012. DSI and water. www2.dsi.gov.tr/english/water-and-dsi/files/assets/basic-html/page66.html

Egel, D. 2010 *Tribal diversity, political patronage and the Yemeni decentralization experiment*, University of California, Berkley, [http://www.yemenwater.org/wp-content/uploads/2013/03/Egel Tribes.pdf](http://www.yemenwater.org/wp-content/uploads/2013/03/Egel_Tribes.pdf) (Accessed 6th August 2015).

Ehlers, E. and A. Saidi. 1989 "Qanats and pumped wells: The case of Assad'abad, Hamadan", in Beaumont, P., Borine, K., and K. McLachlan (eds.) *Qanat, kariz, and khattara*, London: School of Oriental and African Studies, 89-112.

El-Agha, D., Closas, A. and Molle, F. 2015a Survey of groundwater use in the central part of the Nile Delta. Water and Salt Management in the Nile delta Project Report No. 6. IWMI, WMRI: Cairo, 2015.

El-Agha, D., Closas, A. and Molle, F. 2015b Dynamics of groundwater use in the central part of the Nile Delta. Dry Land Systems Report, IWMI, WMRI: Cairo, 2015.

El Arabi, N.E., and M.A. Dawoud 2012 Groundwater aquifer recharge with treated wastewater in Egypt: technical, environmental, economical and regulatory considerations, *Desalination and Water Treatment*, 47(1-3), 266-278.

El Bastawesy, M., Ramadan Ali, R., Faid, A., and M. El Osta 2013 Assessment of waterlogging in agricultural megaprojects in the closed drainage basins of the Western Desert of Egypt, *Hydrology and Earth System Sciences*, 17, 1493-1501.

El Hedi Louati, M., and J. Bucknall 2009 "Tunisia's experience in water resource mobilization and management", in Jagannathan, N.V., Mohamed, A.S., and A. Kremer (eds.) *Water in the Arab World: management perspectives and innovations*, Washington DC: The World Bank, 157-180.

El Jamali, H. 2013 Community-based water management: the oasis of Figuig, Morocco, recent extensions and transformation, *International Journal of Environmental Monitoring and Analysis*, 1(5), 213-229.

El Kashouty, M., and A. Abdel-Lattif 2011 Multivariate statistical analyses of the groundwater system in Darb El-Arbaein, Southwestern Desert, Egypt, *Arabian Journal of Geosciences*, 4, 1117-1130.

El Moujabber, M., Bou Samra, B., Darwish, T., and T. Atallah 2006 Comparison of different indicators for groundwater contamination by seawater intrusion on the Lebanese Coast, *Water Resources Management*, 20, 161-180.

El Naqa, A. 2011 Study of salt water intrusion in the Upper Aquifer in Azraq Basin, Final Report, IUCN.

El Tahlawi, M.R., Farrag, A.A., and S.S. Ahmed 2008 Groundwater of Egypt: "an environmental overview", *Environmental Geology*, 55, 639-652.

El-Gohary, F. 2010 Incorporation of environmental dimension in integrated water resources management, Water Governance Program in the Arab States, Cairo: UNDP.

El-Naqa, A., Al-Momani, M., Kilani, S., and N. Hammouri 2007 Groundwater deterioration of shallow groundwater aquifers due to overexploitation in northeast Jordan, *Clean* 2007, 35(2), 156-166.

El-Naqa, A., and Al-Shayeb, A. 2009 Groundwater protection and management strategy in Jordan, *Water Resources Management*, 23, 2379-2394.

El-Said, H, and J. Harrigan 2009 “You reap what you plant”: social networks in the Arab world – The Hashemite Kingdom of Jordan, *World Development*, 37(7), 1235-1249.

Elshorst, H., and D. O’Leary 2005 Corruption in the Water Sector: opportunities for addressing a pervasive problem, Seminar ‘Meeting international water targets without fighting corruption?’, World Water Week, Stockholm, August 21-27, 2005, [http://www.swedishwaterhouse.se/swh/resources/20051010170953Corruption in the water sector Elshorst.pdf](http://www.swedishwaterhouse.se/swh/resources/20051010170953Corruption_in_the_water_sector_Elshorst.pdf) (accessed 1st October 2014).

ERM, BRL ingenierie, and ECO Consult 2012 Preliminary Draft Environmental and Social Assessment (ESA) – Executive Summary, Red Sea-Dead Sea Water Conveyance Study Environmental and Social Assessment, http://siteresources.worldbank.org/INTREDESEADSEA/Resources/Environmental_and_Social_Assessment_Summary_EN.pdf (Accessed 15th September 2014).

Errahj, M., Kuper, M., Faysse, N., and M. Djebbara 2009 Finding a way to legality, local coordination modes and public policies in large-scale irrigation schemes in Algeria and Morocco, *Irrigation and Drainage*, 51(2), 289-302.

EuropeAid 2015 *Pre-feasibility study for new programmes in application of irrigation based on groundwater in Western Egypt, Baseline report*, EuropeAid/132633/SER/Multi.

Ezzat, M.A. 1976 *Exploitation of ground water – Kharga Oasis*, Ground water series in the Arab Republic of Egypt, Exploitation of ground water in El –Wadi El-Gedid Project Area (new Valley), Ministry of Irrigation, Cairo, Egypt.

FAO 2008a *Etude de cas du Maroc*, Etude sur la gestion des eaux souterraines dans les pays pilotes du Proche Orient, Bureau régional de la FAO pour le Proche-Orient.

FAO 2008b *Rapport Algérie*, Etude sur la gestion des eaux souterraines dans les pays pilotes du Proche-Orient, Bureau régional de la FAO pour le Proche-Orient.

FAO 2008c *Groundwater management in Libya*, Food and Agriculture Organization.

FAO 2009a *Groundwater management in Saudi Arabia*, Rome: Food and Agriculture Organization of the United Nations.

FAO 2009b *Groundwater management in Yemen, Draft Synthesis Report*, Rome: Food and Agriculture Organization of the United Nations.

FAO 2009c *Groundwater management in Oman, Draft Synthesis Report*, Rome: Food and Agriculture Organization of the United Nations.

FAO 2009d *Groundwater Management in Iran, Draft Synthesis Report*, Rome: Food and Agriculture Organisation of the United Nations.

FAO 2009e *Groundwater Management in Tunisia, Draft Synthesis Report*, Rome: Food and Agriculture Organisation of the United Nations.

FAO 2015 *Towards a regional collaborative strategy on sustainable agricultural water management and food security in the Near East and North Africa Region*, Main Report, Second Edition, Rome: FAO.

Fayrap, A.; Sargin, A.H. 2015. Agricultural groundwater management in Turkey. Paper presented at the 26th Euro-Mediterranean Regional Conference and Workshops « Innovate to improve Irrigation performances », 12-15 October 2015, Montpellier, France. International Commission on Irrigation and Drainage

Faysse, N., Hartani, T., Frija, A., Marlet, S., Tazekrit, I., Zairi, C., and A. Challouf 2011 Usage agricole des eaux souterraines et initiatives de gestion au Magreb: défis et opportunités pour un usage durable des aquifères, AfDB-BAfD Note Economique.

Faysse, N. and O. Petit 2012 Convergent readings of groundwater governance? Engaging exchanges between different research perspectives, *Irrigation and Drainage*, 61(S:1), 106-114.

Faysse, N., El Amrani, M., El Aydi, S., and A. Lahlou 2012 Formulation and implementation of policies to deal with groundwater overuse in Morocco: which supporting coalitions?, *Irrigation and Drainage*, 61(S1), 126-134.

- Feitelson, E. 2006 Impediments to the management of shared aquifers: a political economy perspective, *Hydrogeology Journal*, 14, 319-329.
- Ferragina, E., and F. Greco 2008 The Disi project: an internal/external analysis, *Water International*, 33(4), 451-463.
- Feuillette, S. 2001 Vers une gestion de la demande sur une nappe en accès libre : exploration des interactions ressource usages par les systèmes multi-agents. Application a la nappe de Kairouan, Tunisie Centrale, Phd Thesis, Université Montpellier II.
- FMWEY, 2015. Former Minister of Water and Environment of Yemen, personal communication, 4th August 2015.
- Fragaszy, S. 2014 Personal communication.
- Fragaszy, S., and A. Closas 2016 Cultivating the desert: irrigation expansion and groundwater abstraction in Northern State, Sudan, *Water Alternatives*, 9(1), 139-161.
- Frija, A., Chebil, A., Speelman, S., and N. Faysse 2014 A critical assessment of groundwater governance in Tunisia, *Water Policy*, 16, 358-373.
- Gana, A. 2009. Dynamiques institutionnelles et irrigation en Tunisie : les conditions d'une gestion participative de l'eau agricole. Powerpoint.
- Garduño, H., and S. Foster 2010 Sustainable groundwater irrigation: approaches to reconciling demand with resources, Strategic Overview Series, No.4, GWMATE, The World Bank.
- Gatter, P. 2008 "Financial mechanisms of decentralization and the taxation of qat", in Nefissa, S.B., Grabundzija, M., and J. Lambert (dir.) *Societe civile, associations et pouvoir local au Yemen*, Centre Français d'Archeologie et de Sciences Sociales de Sanaa, Fondation Fiedrich Ebert, Sanaa.
- Gatter, P. 2012 *Politics of qat: the role of a drug in ruling Yemen*, Wiesbaden, Germany: Dr. Ludwig Reichert Verlag.
- Gatter, P. 2013 *Politics of qat in Yemen*, Yemen: Challenges for the Future International Conference, 11th and 12th of January 2013, SOAS University, London, UK.
- Gaub, E. 2008 *La gestion des eaux souterraines en Tunisie*, Bureau regional de la FAO pour le Proche-Orient, Food and Agriculture Organization.
- Geroudet, C. 2004 Démographie et histoire agraire du bassin versant du Merguellil, Tunisie centrale, Partie II : Politiques agricoles et structures foncières, Internal Report, INA, IWMI, IRD.
- Ghazouani, W., Marlet, S., Mekki, I., Harrington, L. W., and A. Vidal 2012a Farmers' practices and community management of irrigation: why do they not match in Fatnassa Oasis?, *Irrigation and Drainage*, 61, 39-51.
- Ghazouani, W., Molle, F., and E. Rap 2012b *Water Users Associations in the NEN Region – IFAD interventions and overall dynamics*. Report submitted to IFAD, International Water Management Institute IWMI.
- Ghazouani, W., and I. Mekki 2015 *Les ressources en eaux souterraines de la plaine de Haouaria : Etat fragile, acteurs multiples et nécessité d'un changement intégré*, « USAID Groundwater Governance in the Arab World » Internal Project Report, Cairo : IWMI.
- Ghiotti, S., and R. Riachi 2013 La gestion de l'eau au Liban: une reforme confisquée ?, *Etudes Rurales*, 192(2), 135-152.
- Giraldi, M. 2012. La gestion collective de l'eau en Tunisie centrale : le territoire irrigué de Kerma (plaine de Kairouan). Mémoire de stage, SupAgro.
- Gleick, P. 2014 Water, drought, climate change, and conflict in Syria, *Weather, Climate, and Society*, in press.
- Goode, D.J., Senior, L.A., Subah, A., and A. Jaber 2013 *Groundwater-level trends and forecasts, and salinity trends in the Azraq, Dead Sea, Hammad, Jordan Side Valleys, Yarmouk, and Zarqa groundwater basins*, Jordan: U.S. Geological Survey Open-File Report 2013-1061, (<http://pubs.usgs.gov/of/2013/1061>, Accessed 31st March 2015).

- Greco, F. 2004 Water securitization in the Middle East: the Unity Dam and the Disi Aquifer, MSc Dissertation, King's College London/SOAS.
- GTZ 2004 *Groundwater Resources*, National Water Master Plan, Ministry of Water and Irrigation, The Hashemite Kingdom of Jordan.
- Gül, A., Rida, F., Aw-Hassan, A., and O. Büyükalaca 2005 Economic analysis of energy use in groundwater irrigation of dry areas: a case study in Syria, *Applied Energy*, 82, 285-299.
- Hadidi, K. 2014 personal communication, Director General of the Water Authority of Jordan.
- Hafez, Z. 2009 The culture of rent, factionalism, and corruption: a political economy of rent in the Arab World, *Contemporary Arab Affairs*, 2(3), 458-480.
- Hajjaj, M.E. and A.H. Hashim 2013 Water security and stability in the Kingdom of Bahrain, *Desalination and Water Treatment*, 51(1-3), 67-74.
- Hamdane, A. 2014a *La gestion des ressources en eau souterraines (nappes et aquifères) comme biens communs : Cas de la Tunisie*, Synthèse régionale sur l'approche économique de la gestion de la demande en eau en Méditerranée, SCET-Tunisie.
- Hamdane, A. 2014b personal communication, Former Director General, Ministry of Agriculture, Tunisia.
- Hamdane, A. 2015. Le contrôle de l'utilisation des eaux souterraines et la gestion participative des nappes. Report to FAO.
- Hammani, A., and M. Kuper 2008 « Caractérisation des pompages des eaux souterraines dans le Tadla, Maroc », in Kuper, M., and A. Zairi (eds.) *Economies d'eau en systèmes irrigués au Maghreb*, Actes du troisième atelier régional du projet Sirma, Nabeul, Tunisie, 4-7 juin 2007.
- Hammani, A., Hartani, T., Kuper, M., and A. Imache 2009 Paving the way for groundwater management: transforming information for crafting management rules, *Irrigation and Drainage*, 58, 240-251.
- Hanafi, S., and L. Tabar 2004 "Donor assistance, rent-seeking and elite formation", in Khan, M.H., Giacaman, G., and I. Amundsen (eds.) *State formation in Palestine*, London, New York: RoutledgeCurzon, 215-238.
- Handley, C. 2001 Water stress: some symptoms and causes. A case study of Ta'iz, Yemen. Aldershot, UK Ashgate.
- Harding King, W.J. 1917 Irrigation in the Dakhla oasis, *The Geographical Journal*, 50(5), 358-364.
- Healy, S., and G. Hill 2010 *Yemen and Somalia: terrorism, shadow networks and the limitations of state-building*, Middle East and North Africa Programme/Africa Programme Briefing Paper MENAP/AFP BP 2010/01, Chatham House, London, UK: Chatham House.
- Hefny, K. and A. Shata 1996 *Strategy for development of deep-lying aquifers in Egyptian desert*, Part II, WRSR Publication Series No.18, Water Resources Strategic Research Activity, Ministry of Public Works and Water Resources, national Water Research Center, Winrock International Institute for Agricultural Development, US Agency for International Development.
- Hellegers, P., Perry, C., Al-Aulaqi, N., Al-Eryani, A.R., and M. Al-Hebshi 2008 *Incentives to reduce groundwater extraction in Yemen*, Report 2008-058, LEI Wageningen UR, The Hague.
- Hill, G., Salisbury, P., Northedge, L., and J. Kinnimont 2013 *Yemen: corruption, capital flight and global drivers of conflict*, Chatham House.
- Hinnebusch, R. 2011 "The Ba'th's agrarian revolution (1963-2000)" in Hinnebusch, R. (ed.) *Agriculture and reform in Syria*, Fife: University of St Andrews Centre for Syrian Studies, 3-14.
- Hjort, K.C., Zakaria, M., and F.I. Salah 1998 *An introduction to Jordan's agriculture sector and agricultural policies*, WTO Accession Unit, Ministry of Industry and Trade, Hashemite Kingdom of Jordan.
- Houdret, A. 2008 Les conflits autour de l'eau au Maroc : origines sociopolitiques et écologiques et perspectives pour transformation des conflits, Résumé français de la Thèse, Phd Thesis, University of Duisburg-Essen and University Paris 8.

- Houdret, A. 2012 The water connection: irrigation, water grabbing and politics in Southern Morocco, *Water Alternatives*, 5(2), 284-303.
- Huppert, W. 2013 Viewpoint – Rent-seeking in agricultural water management: an intentionally neglected core dimension?, *Water Alternatives*, 6(2), 265-275.
- Huppert, W., and B. Wolff 2002 Principal-agent problems in irrigation: inviting rentseeking and corruption, *Quarterly Journal of International Agriculture*, 41(1/2), 179-198.
- IAEA 2012 *Regional strategic action programme for the Nubian Sandstone Aquifer System*, Final Report, 26 January 2012, Vienna, Austria: International Atomic Energy Agency.
- Imache, A. 2008 Construction de la demande en eau agricole au niveau régional en intégrant le comportement des agriculteurs: application aux exploitations agricoles collectives de la Mitidja-ouest (Algérie), PhD Thesis, Institut des Sciences et Industries du Vivant et de l'Environnement (Agro Paris Tech).
- Imache, A., Bouarfa, S., Hartani, T., and M. Kuper 2010 *La Mitidja 20 ans après. Réalités agricoles aux portes d'Alger*, Alger: Editions Alpha.
- Imache, A. 2014 personal communication, LISODE, Montpellier, France.
- IMF 2013 *Case studies on energy subsidies reform: lessons and implications*, Washington DC: International Monetary Fund.
- INECO 2007 *Governance and water management structures in the Mediterranean basin*, National Technical University of Athens, Sixth Framework Programme (2002-2006) European Commission, INCO –CT-2006-517673.
- IRG 2013 *Groundwater modeling within the Upper Litani Basin Report*, Litani River Basin Management Support Program, USAID, <http://www.litani.gov.lb/wp/wp-content/uploads/LRBMS/018-LRBMS-GROUNDWATER%20MODELING%20WITHIN%20THE%20UPPER%20LITANI%20BASIN.pdf> (Accessed 10th September 2014).
- IRG 2014 *Analysis report: socio-economic survey of groundwater wells in Jordan*, Institutional Support and Strengthening Program (ISSP), USAID, Jordan.
- Jaghdani, T.J. 2011 *Demand for Irrigation Water from Depleting Groundwater Resources: An Econometric Approach*, PhD Dissertation thesis, Faculty of Agricultural Sciences, Georg-August-University Göttingen, Germany.
- Janty, G. 2014 *Les enjeux de la préservation et du développement d'un paysage culturel. Le cas de la palmeraie de l'oasis de Figuig (Maroc)*, PhD Thesis, Université Paris Diderot (Paris 7).
- Jilali, A. 2014 Impact of climate change on the Figuig aquifer using a numerical model: Oasis of Eastern Morocco, *Journal of Biology and Earth Sciences*, 4(1), 16-24.
- Jouili, M., Kahouli, I., and M. Elloumi 2013 Appropriation des ressources hydrauliques et processus d'exclusion dans la région de Sidi Bouzid (Tunisie Centrale), *Etudes Rurales*, 192, 117-134.
- Kacem, A.; Daoud, A. and Zouari, K. 2008. Le bassin de Sisseb El Alem (Kairouanais, Tunisie centrale) : importance, caractéristiques des aquifères et éléments pour une meilleure gestion. *Sécheresse* 2008 ; 19 (1) : 55-60.
- Kadi, A., Feuillette, S., Le Goulven, P., and P. Le Grusse 2003 « Modèles d'exploration des dynamiques entre ressources et usages de l'eau pour une gestion intégrée des nappes souterraines. Application à la nappe de Kairouan en Tunisie », *Séminaire PCSI « Gestion intégrée de l'eau au sein d'un bassin versant »*, 2 December 2003, Montpellier.
- Kaptijn, E. 2010 Community and power: irrigation in the Zerqa Triangle, Jordan, *Water History*, 2(2), 145-163.
- Karimi, P., Qureshi, A.S., Bahramloo, R., and D. Molden. 2012 Reducing carbon emissions through improved irrigation and groundwater management: A case study from Iran, *Agricultural Water Management*, 108(2012), 52– 60.
- Karimi, S. 2003 *Qanat, as the symbol of the native Iranians in water harvesting from ground water resources*, 3rd IWHA conference in Alexandria, December 11–14, 2003.

- Katzmair, H. 2009 The social networks of Jordan irrigation farmers – a stakeholder analysis for the groundwater aquifers in the north-eastern highlands of Jordan (Amman-Zarqa and Azraq Basin), Executive Summary, FAS.research, GTZ, <http://highlandwaterforum.files.wordpress.com/2012/08/1-1-social-network-analysis-executive-report.pdf> (Accessed 2nd November 2014).
- Kefi, M., Faysse, N., Le Goulven, P., and M.S. Bachta 2003 « Comportement des irrigants face à des changements d'accès à l'eau dans les périmètres irrigués de la plaine de Kairouan », *Séminaire PCSI « Gestion intégrée de l'eau au sein d'un bassin versant »*, 2 December 2003, Montpellier.
- Kelley, C.P., Mohtadi, S., Cane, M.A., Seager, R., and Y. Kushnir 2015 Climate change in the Fertile Crescent and implications of the recent Syrian drought, *Proceedings of the National Academy of Sciences*, 112(11), 3241-3246.
- Khair, K., Aker, N., Haddad, F., Jurdi, m., and A. Hachach 1994 The environmental impacts of humans on groundwater in Lebanon, *Water, Air and Soil Pollution*, 78(1-2), 37-49.
- Khan, M.H., Giacaman, G., and I. Amundsen (eds.) 2004 *State formation in Palestine*, London, New York: RoutledgeCurzon.
- Khoury, P.S., and J. Kostiner 1990 "Introduction: tribes and the complexities of state formation in the Middle East", in Khoury, P.S., and J. Kostiner (eds) *Tribes and State Formation in the Middle East*, Berkeley: University of California Press, 1-24.
- King, C., and B. Salem 2012 A socio-ecological investigation of options to manage groundwater degradation in the Western Desert, Egypt, *AMBIO*, 41(5), 490-503.
- Klingbeil, R. 2014 'Managed aquifer recharge – aquifer storage and recovery: regional experiences and needs for further cooperation and knowledge exchanges', International Association of Hydrogeologists (IAH), 41st International Congress, 'Groundwater challenges and strategies', Marrakech, Morocco, 15-19 September.
- Korfali, S.I., and M. Jurdi 2010 Deterioration of coastal water aquifers: causes and impacts, *European Water*, 29, 3-10.
- Kuper, M., Hammani, A., Chohin, A., Garin, P., and M. Saaf 2012 When groundwater takes over: linking 40 years of agricultural and groundwater dynamics in a large-scale irrigation scheme in Morocco, *Irrigation and Drainage*, 61(S1), 45-53.
- Lackner, H. 2014 "Water scarcity: why doesn't it get the attention it deserves?", in Lackner, H. (ed.) *Why Yemen matters*, London: Saqi Books, 161-182.
- Lattemann, S., and T. Hopner 2008 Environmental impact and impact assessment of seawater desalination, *Desalination*, 220(1-3), 1-15.
- Le Goulven, P., Leduc, C., Bachta, M.S., and J.C. Poussin 2009 "Sharing scarce resources in a Mediterranean River Basin: Wadi Merguellil in central Tunisia", in Molle, F., and P. Wester (eds.) *River Basin trajectories: societies, environments, and development*, Wallingford: CABI, 147-170.
- Le Visage, S. 2015. Dynamiques de l'irrigation par les eaux souterraines : quels usages, organisations et utilisations autour de la ressource dans la région d'Izmir – Turquie. Mémoire de stage, ISTOM.
- L'Economiste 2014 *Eaux souterraines: les contrats de nappes bientôt généralisés*, Édition N° 4242 du 2014/03/27.
- Leduc, C., Calvez, R., Beji, R., Nazoumou, Y., Lacombe, G., and C. Aouadi 2004 "La modernisation de l'agriculture irriguée dans les pays du Maghreb", Séminaire WADEMED Rabat 19-21 April 2004.
- Leghrissi, H. 2012 Importance des arrangements institutionnels dans la gestion des puits privatifs dans un périmètre irrigué : cas du périmètre Bsissi-Oued El Akarit en Tunisie, MSc Thesis, Supagro Montpellier.
- Lichtenthaler, G. 2014 "Customary conflict resolution in times of extreme water stress: a case study of a document from the Northern Highlands of Yemen", in Lackner, H. (ed.) *Why Yemen matters*, London: Saqi Books, 183-196.
- Lightfoot, D.R. 1996 Syrian qanat Romani: history, ecology, abandonment, *Journal of Arid Environments*, 33, 321-336.

- Mabrouk M. B., Jonoski A., Solomatine D. and S. Uhlenbrook 2013 *A review of seawater intrusion in the Nile Delta groundwater system – the basis for assessing impacts due to climate changes and water resources development*.
- MacAlister, C., Pavelic, P., Tindimugaya, C., Ayenew, T., Ibrahim, M.E., and A.M. Meguid 2012 “Overview of groundwater in the Nile River Basin”, in Awulachew, S.B., Smakhtin, V., Molden, D., and D. Peden (eds.) *The Nile River Basin: water, agriculture, governance, and livelihoods*, Abingdon, UK: Routledge-Earthscan, 186-211.
- Mahmod, W.E., Watanabe, K., and A.A. Zahr-Eldeen 2013 Analysis of groundwater flow in arid areas with limited hydrogeological data using the Grey Model: a case study of the Nubian Sandstone, Kharga oasis, Egypt, *Hydrogeology Journal*, 21, 1021-1034.
- Marina Stephan, R. 2007 Legal framework of groundwater management the Middle East (Israel, Jordan, Lebanon, Syria and the Palestinian Territories)”, in Shuval, H., and H. Dweik (eds.) *Water resources in the Middle East*, Berlin, Heidelberg: Springer, 293-299.
- Marlet, S. 2013 Démarche d’intervention pour l’émancipation et l’amélioration des performances des associations d’irrigants en Tunisie. Powerpoint presentation.
- Masciopinto, C. 2013 Management of aquifer recharge in Lebanon by removing seawater intrusion from coastal aquifers, *Journal of Environmental Management*, 130, 306-312.
- Massuel, S. 2015. Personal communication.
- Massuel, S.; Amichi, F.; Ameer, F.; Calvez, C.; Jenhaoui, Z.; Bouarfa, S.; Kuper, M.; Habaieb, H.; Hartani, T. and Hammani, A. 2017. Considering groundwater use to improve the assessment of groundwater pumping for irrigation in North Africa. *Hydrogeology*.
- Mekki, I., and W. Ghazouani 2012 Case study: Tunisia. Diagnostic sur les Groupement de Developpement Agricole (GDA) concernés par le projet FIDA dans les deux gouvernorats de Siliana et Zaghuan, IWMI Case studies, Internal report.
- Mesnil, A., and N. Habjoka 2012 The Azraq Dilemma: Past, Present and Future Groundwater Management, German-Jordanina Programme “Management of Water Resources”, GIZ.
- Metni, M., El-Fadel, M., Sadek, S., Kayal, R., and D. Lichaa El Khoury 2004 Groundwater resources in Lebanon: a vulnerability assessment, *International Journal of Water Resources Development*, 20(4), 475-492.
- Ministry of Energy and Water 2015 Staff, personal communication, Lebanon, 20th January 2015.
- Mohamed, O.M.A. 2014 ‘Status of groundwater resources governance, Sudan’ in 3rd targeted regional workshop for GEF IW projects in Africa, http://iwlearn.net/abt_iwlearn/events/workshops/the-3rd-african-regional-targeted-workshop-for-gef-iw-projects/presentations/status-of-groundwater-resources-governance-sudan-nubian-sandstone-project/view (Accessed 3rd June 2014).
- Molle, F., Mamanpoush, A., and M. Miranzadeh 2004 *Robbing Yadullah’s water to irrigate Saeid’s garden: Hydrology and water rights in a village of central Iran*, IWMI Research Report No. 80, Colombo: IWMI.
- Moore, S. 2011 Parchedness, politics, and power: the state hydraulic in Yemen, *Journal of Political Ecology*, 18, 39–50.
- Morill, J., and J. Simas 2009 “Comparative analysis of water laws in MNA countries”, in Jagannathan, N.V., Mohamed, A.S., and A. Kremer (eds.) *Water in the Arab World: management perspectives and innovations*, Washington DC: The World Bank, 285-334.
- Mouri, H., and S. Marlet 2007 “De l’association d’intérêt collectif au groupement de développement agricole : le changement institutionnel et son impact sur le fonctionnement des périmètres publics irrigués tunisiens », in Bouarfa, S., Kuper, M., and A. Debbah (eds.) *L’avenir de l’agriculture irriguée en Méditerranée. Nouveaux arrangements institutionnels pour une gestion de la demande en eau*, Actes du séminaire Wademed, Cahors, France, 6-7 novembre 2006, Montpellier : CIRAD.
- MRE 2013 *Plan de gestion intégrée des ressources en eau dans le bassin côtier algérois O2A*, Activités du Résultat 1 – Activité 01.04, Elaboration du Plan de Gestion, Gestion intégrée des ressources en eau dans le bassin hydrographique côtier algérois O2A, Ministère des Ressources en Eau, République Algérienne Démocratique et Populaire.

- MWI 2003 Water Master Plan, Ministry of Water and Irrigation, Jordan.
- MWRI 2005 *National Water Resources Plan for Egypt – 2017*, Ministry of Water Resources and Irrigation, Planning Sector, Arab Republic of Egypt.
- Nassif, M.H. 2015 *Groundwater evolution and transformation of agrarian systems between the 1960s and 2015: a comparison between Terbol, Faour, and Hoshmosh*, USAID Groundwater Governance in the Arab World Project, Internal report, Cairo: IWMI.
- Niayesh, U. 2015 *Recovering Iran's lost groundwater reserves impossible*. Trends News Agency. <http://en.trend.az/iran/society/2395560.html> (Accessed 9th November 2015).
- Nour, S. 1996 Groundwater potential for irrigation in the East Oweinat area, Western Desert, Egypt, *Environmental Geology*, 27, 143-154.
- NWSSIP 2008 *Update of the National Water Sector Strategy and Investment Programme*, the NWSSIP Update, Republic of Yemen, December 17th, 2008.
- Omer, A.M. 2008 Water resources and freshwater ecosystems in Sudan, *Renewable and Sustainable Energy Reviews*, 12, 2066-2091.
- Ouda, O.K.M. 2014 Impacts of agricultural policy on irrigation water demand: a case study of Saudi Arabia, *International Journal of Water Resources Development*, 30(2-3), 282-292.
- Ouelhazi, H., Lachaal, F., Charef, A., Challouf, B., Chaieb, H., and F.J. Horriche 2013 Hydrogeological investigation of groundwater artificial recharge by treated wastewater in semi-arid regions: Korba aquifer (Cap-Bon Tunisia), *Arabian Journal of Geosciences*, September 2013.
- Özdemir G. 2005. Cooperative–shareholder relations in agricultural cooperatives in Turkey. *Journal of Asian Economics*, 16 (2): 315-325.
- Posusney, M.P. 2004 Enduring authoritarianism: Middle East lessons for comparative theory, *Comparative Politics*, 36(2), 127-138.
- Powell, O., and R. Fensham 2015 The history and fate of the Nubian Sandston Aquifer springs in the oasis depressions of the Western Desert, Egypt, *Hydrogeology Journal*, 1-12.
- Philips, S. 2011 *Yemen and the politics of permanent crisis*, The Adelphi Series, The International Institute for Strategic Studies.
- Ramirez, O., Ward, F.A., Al-Tabini, R., and R. Phillips 2011 Efficient water conservation in agriculture for growing urban water demands in Jordan, *Water Policy*, 13(1), 102-124.
- Redecker, G. 2007 *NWSSIP 2005-2009 Two years of achievements ... and an outlook – A donor's perspective*, KfW Office Sana'a, Yemen.
- Regner, J., and B. Wolff 2000 *Rent seeking in irrigated agriculture: institutional problem areas in operation and maintenance*, MAINTAIN Thematic Paper No.9, Division 45, Rural Development, GTZ.
- Riaux, G., Giraldi, M., and H. Nouri 2015 Quand l'histoire orale s'invite dans la gestion de l'eau. l'espace irrigué de Kerma (Tunisie), *Espaces et Societies 2015/1*, 160-161, 155-172.
- Richards, A. 1993 *Bananas and Bedouins: political economy issues in agricultural sector reform in Jordan*, Democratic Institutions Support (DIS) Project, Governance and Democracy Program, Near East Bureau, USAID.
- Richards, A. 2001 Coping with water scarcity: the governance challenge, DESC Water Advisory Group.
- Rignall, K. 2015 The labor of agrodiversity in a Moroccan oasis, *The Journal of Peasant Studies*, in print.
- Rijkers, B., Baghdadi, L., and G. Raballand 2015 *Political connections and tariff evasion: evidence from Tunisia*, Policy Research Working Paper, No. 7336, Washington DC: The World Bank.
- Rijkers, B., Freund, C., and A. Nucifora 2014 *All in the family: state capture in Tunisia*, Policy Research Working Paper, No. 6810, Washington DC: The World Bank.
- Robinson, G.E., Wilcox, O., Carpenter, S., and A.G. Al-Iryani 2006 *Yemen corruption assessment*, USAID-Yemen.

- Rondier, A. 2012 Gestion des Khettara d'Ait Aissa OuBrahim (vallée du Todgha, Maroc) : Territoire, héritage et valorisation, MSc Thesis, Ecole Nationale du Génie de l'Eau et de l'Environnement de Strasbourg.
- Rose, E.P.F. 2012 "Groundwater as a military resource: development of Royal Engineers Boring Sections and British military hydrogeology in World War II", in Rose, E.P.F, and J.D. Mather (eds.) *Military Aspects of Hydrogeology*, Special Publications, 362, London, UK: Geological Society, 105-138.
- Rybakov, V. 2012 Water crisis in Yemen: speculations, realities and mitigation actions (introduction to the upgraded water management), Sana'a, Yemen, <http://www.yemenwater.org/wp-content/uploads/2013/01/Report-victor.pdf> (Accessed 8th March 2016).
- Saade-Sbeih, M. 2011 L'exploitation des eaux souterraines en Syrie centrale : construction de diagnostics et politiques d'intervention, PhD Thesis, Université de Lausanne.
- Saidi, A. 2012 *Première partie : état des lieux consolidé, A.1.4 Elaboration du Plan de Gestion, « Diagnostic – Plan de gestion intégrée des ressources en eau dans le bassin hydrographique Cotier Algérois O2A »*, Ministère des Ressources en Eau, République Algérienne Démocratique et Populaire.
- Salisbury, P. 2011 *Yemen's economy: oil, imports and elites*, Middle East and North Africa Programme Paper MENA PP 2011/02, Chatham House, London, UK: Chatham House.
- Salman, A., Al-Karabileh, E., REgner, H.J., Wolff, H.P., and M. Haddadin 2008 Participatory irrigation water management in the Jordan Valley, *Water Policy*, 10, 305-322.
- Sghaier, M. 2010 *Etude de la gouvernance des ressources naturelles dans les oasis. Cas des oasis en Tunisie*, Union Internationale pour la Conservation de la Nature.
- Shah, T. 2009 Taming the anarchy: groundwater governance in South Asia, Washington DC: RFF Press.
- Shammas, M.I., and G. Jacks 2008 "Management of the Salalah plain aquifer, Oman", in Battacharya, P., Ramanathan, A.L., Mukherjee, A.B., Bundschuh, J., Chandrasekharam, D., and A.K. Keshari (eds.) *Groundwater for sustainable development: problems, perspectives and challenges*, London: Taylor & Francis, 409-421.
- Sims, D. 2015 *Egypt's desert dreams: development or disaster*, Cairo: American University Press.
- Sowers, J.L. 2013 Environmental politics in Egypt: activists, experts, and the state, Abingdon, UK: Routledge.
- Sternberg, T. 2016 Water megaprojects in deserts and drylands, *International Journal of Water Resources Development*, 32(2), 301-320.
- Taher, T., Bruns, B., Bamaga, O., Al-Weshali, A., and F. van Steenberg 2012 Local groundwater governance in Yemen: building on traditions and enabling communities to craft new rules, *Hydrogeology Journal*, 20, 1177-1188.
- Tanouti, O. 2014 Personal communication, 27th May 2014, Agronomist, Ecole Nationale d'Agriculture, Morocco.
- Tanouti, O., and F. Molle 2013 Réappropriations de l'eau dans les bassins versants surexploités: le cas du bassin du Tensift (Maroc), *Etudes Rurales*, 192(2), 79-96.
- Tayeb, M. 2016. Personal communication.
- Taylor, G.C. 1976 *Historical review of the International Water-Resources program of the U.S. Geological Survey 1940-1970*, Geological Survey Professional Paper 911, Washington DC: United States Geological Survey.
- The Hague Institute for Global Justice 2014 *The political economy of water management in Yemen: conflict analysis and recommendations*, Ministry of Foreign Affairs of the Netherlands, The Hague Institute for Global Justice.
- Tibi, B. 1990 "The Simultaneity of the Unsimultaneous: Old Tribes and Imposed Nation-States in the Modern Middle East", in Khoury, P.S., and J. Kostiner (eds) *Tribes and State Formation in the Middle East*, Berkeley: University of California Press. 126-149.
- Transparency International 2008 *Global Corruption Report 2008: Corruption in the water sector*, Cambridge: Cambridge University Press.

Tunisie, 1978. Décret No 78-814 du 1er septembre 1978, fixant les conditions de recherche et d'exploitation des eaux souterraines.

Tunisie, 1997. Décret No 97-2082 du 27 octobre 1997, fixant les conditions d'exercice de l'activité de forages d'eau.

Tutundjian, S. 2012 Third regional consultation: Arab states region, Regional consultation report, Groundwater Governance: A global framework for country action, GEF ID 3726, GEF, The World Bank, UNESCO-IHP, FAO, IAH.

UNDESA 2004 Republic of Yemen, Public Administration Country Profile, Division of Public Administration and Development Management (DPADM), Department of Economic and Social Affairs (DESA), United Nations, <http://unpan1.un.org/intradoc/groups/public/documents/un/unpan023187.pdf> (Accessed 7th March 2016).

UNDP 2013 Water governance in the Arab Region: managing scarcity and securing the future, New York, USA: UNDP.

UNDP 2014 *Assessment of groundwater resources of Lebanon*, Ministry of Energy and Water, UNDP, Lebanon.

UNESCO 2012 *Managing water under uncertainty and risk*, The United Nations World Water Development Report 4, Volume 1, Paris: UNESCO.

UN-ESCWA and BGR 2013 *Inventory of Shared Water Resources in Western Asia*, Beirut: UN-ESCWA (United Nations Economic and Social Commission for Western Asia), BGC (Bundesanstalt für Geowissenschaften und Rohstoffe).

USAID 1999 Policies and procedures for free-flowing groundwater management in Egypt's Western Desert, Report No.16, APRP – Water Policy Activity, Ministry of Public Works and Water Resources, US Agency for International Development.

USAID 2010 *Country profile – Oman*, MENA regional water governance benchmarking project.

USAID 2014 Institutional support & strengthening program socio-economic analysis report impact assessment of groundwater wells in Jordan.

Van der Gun, J.A.M., and A.A. Ahmed 1995 *The water resources of Yemen: a summary and digest of available information*, Report WRAY-35, Ministry of Oil and Mineral Resources, The Republic of Yemen and, Ministry of Foreign Affairs, Kingdom of the Netherlands.

Van Steenbergen, F. 2006 Promoting local management in groundwater, *Hydrogeology Journal*, 14, 380-391.

Van Steenbergen, F., and N. El Naouari 2010 "The blind spot in water governance: conjunctive groundwater use in MENA countries", in Bogdanovich S., and L. Salame (eds.) *Water policy and law in the Mediterranean: an evolving nexus*, Serbia: Faculty of Law Business Academy Novi Sad, 171–189.

Van Steenbergen, F., Bamaga, O.A., and A.M. Al-Weshali 2012 *Groundwater security in Yemen: role and responsibilities of local communities in conserving groundwater*, Embassy of the Kingdom of the Netherlands, Water and Environment Centre, MetaMeta Research.

Van Steenbergen, F., Kumsa, A., and N. Al-Awlaki 2015 Understanding political will in groundwater management: comparing Yemen and Ethiopia, *Water Alternatives*, 8(1), 774-799.

Venot, J.P., and F. Molle 2008 Groundwater depletion in the Jordan Highlands: can pricing policies regulate irrigation water use?, *Water Resources Management*, 22(12), 1925-1941.

Venot, J.P., Molle, F., and Y. Hassan 2007a *Irrigated agriculture, water pricing and water savings in the Lower Jordan River Basin (in Jordan)*, Research Report 18, Comprehensive Assessment of Water Management in Agriculture, Colombo, Sri Lanka: International Water Management Institute (IWMI).

Venot, J.P., Molle, F., and Y. Hassan 2007b "Wells and canals in Jordan: can pricing policies regulate irrigation water use?", in Molle, F., and J. Berkoff (eds.) *Irrigation water pricing: the gap between theory and practice*, Wallingford UK, Cambridge MA: CABI, 233-261.

Wada, Y., van Beek, L.P.H., and M.F.P. Bierkens 2012 Nonsustainable groundwater sustaining irrigation: a global assessment, *Water Resources Research*, 48(6), 1-18.

Wade, R. 1982 The system of administrative and political corruption: canal irrigation in South India, *The Journal of Development Studies*, 18(3), 287-328.

Wagner, W. 2011 *Groundwater in the Arab Middle East*, Heidelberg: Springer.

Walz, J. 2010 Yemen, drugs, and the water table, *The Globalist*, January 13th, 2010, <http://www.theglobalist.com/yemen-drugs-and-the-water-table/> (Accessed 10th April 2014).

Ward, C. 1998 Practical responses to extreme groundwater overdraft in Yemen, International Conference Yemen: the challenge of social, economic, and democratic development, April 1998, University of Exeter, Centre for Arab Gulf Studies.

Ward, C. 2009 "Water conflict in Yemen: the case for strengthening local resolution mechanisms", in Jagannathan, N.V., Mohamed, A.S., and A. Kremer (eds.) *Water in the Arab World: management perspectives and innovations*, Washington DC: The World Bank, 233-267.

Ward, C. 2015 *The water crisis in Yemen: managing extreme water scarcity in the Middle East*, London : IB Tauris.

Ward, C. and P. Gatter 2000 *Qat in Yemen*, The Middle East and North Africa Region, Washington DC: The World Bank.

Ward, C., Beddies, S., Hariri, K., Yaffei, S.O., Sakhody, A., and B. Gerhager 2007 *Yemen's water sector reform program – a poverty and social impact analysis (PSIA)*, GTZ, World Bank, Washington DC.

Wendle, J. 2016 Syria's climate refugees, *Scientific American*, 314(3), 42-47.

Wessels, J. 2012 "Groundwater and Qanats in Syria: leadership, ownership and abandonment", in Johnston, B.R. (ed.) *Water, cultural diversity, and global environmental change*, Paris, France, Dordrecht, The Netherlands: UNESCO-IHP, Kluwer, 149-162.

Wilkinson, J.C. 1977 *Water and tribal settlement in south-east Arabia. A study of the aflaj of Oman*, Oxford: Oxford University Press (re-printed 2013, Hildesheim: Georg Olms Verlag).

Wolf, A.T. 2000 Indigenous approaches to water conflict negotiations and implications for international waters, *International Negotiation*, 5, 357-373.

World Bank 1973 Appraisal of Tihama Development Project, Yemen Arab Republic, 27th of March 1973, Report No. 73a-YAR, Europe, Middle East, and North Africa Region, The World Bank.

World Bank 1974 *Appraisal of the Sana'a Water Supply Project, Yemen Arab Republic*, Report No.287a-YAR, Europe, Middle East, and North Africa Region, The World Bank.

World Bank 1975 *Appraisal of Southern Uplands Rural Development Project, Yemen Arab Republic*, Report No.687-YAR, Europe, Middle East and North Africa, The World Bank.

World Bank 1976 *Appraisal of Wadi Hadramawt Agricultural Project, People's Democratic Republic of Yemen*, 12th January 1976, Report No. 847a-YDR, Europe, Middle East and North Africa, The World Bank.

World Bank 2003 *Republic of Lebanon: policy note on irrigation sector sustainability*, Report No.28766-LE, Agriculture and Rural Development Department, Washington DC: The World Bank.

World Bank 2007 *Making the most of scarcity: accountability for better water management in the Middle East and North Africa*, Washington DC: The World Bank.

World Bank 2009 *Project Appraisal Document on a Proposed Grant to the Republic of Yemen for a Water Sector Support Project*, 28th January 2009, Report No.46801-YE, Washington DC: The World Bank.

World Bank 2011 *Restructuring paper on a proposed project restructuring of Yemen-Water Sector Support Project Grant to the Republic of Yemen*, Report No. 61629, 28th April 2011, Washington DC: The World Bank.

World Bank 2013 *Restructuring paper on a proposed project restructuring of Yemen-Water Sector Support Project (Grant No. IDA H449-RY)*, Report No. 73330-YE, 2nd October 2013, Washington DC: The World Bank.

World Bank 2015 *Implementation Status & Results Report, Seq. No: 13, Yemen-Water Sector Support (P107037)*, Middle East and North Africa, Republic of Yemen, IBRD/IDA, ISR17983, Washington DC: The World Bank.

- Wulfsohn, I. 2013 A dangerous addiction: qat and its draining of Yemen's water, economy, and people, *Middle East Economy*, 3(10), http://www.aftau.org/site/DocServer/lqtisadi_November_2013.pdf?docID=20141 (Accessed 10th April 2014).
- Wuttman, M., Gonon, T., and C. Thiers 2000 The qanats of 'Ayn-Manawir (Kharga oasis, Egypt), *Journal of Achaemenid studies and Researches*, 1.
- Yemen 2002 Law No. (33) for the Year 2002 concerning water.
- Yemen Times, 29th January 2013, "Corruption and inefficiency hinders Yemen's local administration", <http://www.yementimes.com/en/1509/report/1948/Corruption-and-inefficiency-hinders-Yemen%E2%80%99s-local-administration.htm> (Accessed 7th March 2016).
- Yemen Times, 8 May 2014, "Despite new era, anti-corruption agenda struggles in Yemen" <http://www.yementimes.com/en/1779/opinion/3829/Despite-new-era-anti-corruption-agenda-struggles-in-Yemen.htm>, (Accessed 7th March 2016).
- Yercan M.; Atış E. and Salali H.E. 2009. Assessing irrigation performance in the Gediz River Basin of Turkey: water user associations versus cooperatives. *Irrigation Science*, 27 (4): 263-270.
- Yıldız, D. and Uysal, H. 2015. Sustainable Water Management and Irrigation Cooperatives in Turkey.
- Yorke, V. 2013 *Politics matter: Jordan's path to water security lies through political reforms and regional cooperation*, NCCR Trade Working Papers, No.2013/19, April 2013, Swiss National Centre of Competence in Research, http://www.nccr-trade.org/fileadmin/user_upload/nccr-trade.ch/wp5/5.5a/Valerie_Yorke_NCCR_WP_2013_19_v3.pdf (Accessed 15th September 2014).
- Zehtabian, G., Khosravi, H., and M. Ghodsi 2010 "High demand in a land of water scarcity: Iran", Schneier-Madanes, G., and M.F. Courel (eds.) *Water and Sustainability in Arid Regions: Bridging the Gap Between Physical and Social Sciences*, Verlag: Springer Science + Business Media, 75–86.
- Zeitoun, M. 2009 *The political economy of water demand management in Yemen and Jordan: a synthesis of findings*, Water Demand Management Series, Regional Water Demand Initiative in the Middle East and North Africa, IDRC-Canada, CIDA-Canada, IFAD.
- Zeitoun, M., Allan, T., al Aulqi, N., Jabarin, A., and H. Laamrani 2012 Water demand management in Yemen and Jordan: addressing power and interests, *The Geographical Journal*, 178(1), 54-66.
- Zekri, S. 2008 Using economic incentives and regulations to reduce seawater intrusion in the Batinah coastal area of Oman, *Agricultural Water Management*, 95, 243-252.
- Zekri, S. 2009 Controlling groundwater pumping online, *Journal of Environmental Management*, 90, 3581-3588.
- Zekri, S., and A.S. Al-Marshudi 2008 A millenarian water rights system and water markets in Oman, *Water International*, 33(3), 350-360.
- Zeldon, W. 2010. Legislation on Use of Water in Agriculture: Turkey. www.loc.gov/law/help/water-law/turkey.php

7 Annex 1.

DISCLAIMER

USAID suspended programming in Yemen in May 2015 and this complementary annex on Yemen was completed by IWMI staff in Cairo, Egypt. Some of the materials used for this annex are part of an original draft report commissioned to a consultant and submitted by the consultant in April 2015, before USAID suspended its programs in Yemen.

7.1 Groundwater resources in Yemen

Groundwater in Yemen is found throughout a wide range of formations and aquifers have noticeable variations in terms of dimensions and other hydro-geological parameters. Western and southwestern aquifers have limited dimensions while eastern aquifers are considerably larger and deeper. Shallow aquifers are found in alluvial wadi beds with direct seasonal recharge. In the coastal plains, fluvial and marine deposits are combined to form alluvial, Aeolian and clastic rock formations with considerable thickness. In these areas annual recharge usually takes place through seasonal floods. In the southwest and western regions, volcanic sediments and fractured metamorphic and granitic complexes create large diversities in storage and recharge. These aquifers are in general of poor to moderate yield depending on fracture networks while in some places the massif complexes are effectively impermeable to water flow.

Sandstone and carbonate aquifers, mainly of the Tawilah Group, are found in various parts of the country, while the Kholan and Wajid sandstone are found in limited areas like the Sa'dah Basin. The Mukalla sandstone is the most important aquifer in the country where its thickness is reported to be approximately 1,000 metres in the Shabwah area. Carbonate aquifers are found in the west as part of the Amran Group or Amran limestone and the Um-Er-Radhuma limestone in the east of Yemen. These rocks form the so called 'extended Mukalla complex' containing reserves accounting for about 96 percent of the total groundwater stored in the country.

Different geo-chronological events have affected the aquifers' structure, texture, lithology, hence, storage capability and permeability. Primary porosity dominates in the recent and friable sediments, whereas secondary porosity controls flow in the older aquifers. Permeability of the recent sediments in Sana'a is between 300-600 m²/day while in Nissab and Markha of Shabwah governorate permeability is between 200-700 m²/day. In Hadhramaut, the Mukalla sandstone has been measured at 100-500 m²/day while the Wajid sandstone in Sa'dah is reported at 75-125 m²/day and Tawhila formation in Amran Basin at 200-700 m²/day. Volcanic aquifer transmissivity varies between 50-300 m²/day (Rybakov 2012).

Shallow and tertiary sediments as well as fractured volcanic aquifers receive local and seasonal recharge. Regional recharge is thought to take place in the eastern regions where the sedimentary intercalated beds have considerable horizontal and vertical dimensions (Table 12. Comparative of basin recharge estimates). No significant recharge water to the aquifers is transboundary and for the wadis situated in the north and northeast regions (e.g. Marib, Al Jawf and Sa'dah), surface runoff drains north and eastwards to recharge aquifers in Saudi Arabia.

Annual groundwater recharge estimates at the national level were established at 1,000-1,500 Mm³/year and a total withdrawal volume of 2,110 Mm³ (Al-Yazidi 2015; FAO 2009). There is however large disparity in figures (Table 11). One reason for such wide variability in estimates is that hydro-geological studies have been carried out in parts of several basins and areas. These

studies were not designed to provide a comprehensive and integrated basin-level water resources management plan and only meet partial goals in isolated parts of these basins and at different times (Al-Yazidi 2015). The volume of renewable and non-renewable groundwater stored in the different aquifers is estimated at about $10.37 \cdot 10^9$ Mm³. Most of it is fossil water of different quality stored mainly in the Mukalla aquifer system. Average drawdown increases of the static water level in these aquifers is between 1-2 m/year in coastal aquifers (Abyan, Tuban, Tihama) to 3-6 m/year in the highland plains (Sa'dah, Sana'a, Amran).

Table 11. Comparative of groundwater recharge estimates

Basin	Recharge [Mm ³ /year]	Information source
Abyan Delta	59	Italconsult, 1973
	32	Humphreys & Sons, 1977
	105	FAO, 1992
	109	WRAY-34, 1995
	96	Komex, 2002
	300	PTP-II, 2004
Sana'a Basin	56	Mosgiprovodkhoz, 1986
	42	TS-HWC, 1992
	102	Alderwish and Dottridge, 1996
	32	SAWAS, 1996
	53.4	Hydrosult, 2010
Sa'adah Basin	10	WRAY-3, 1985
	3	TS-HWC, 1992
	32	Techniplan, 2004
Amran Basin	9	BGR/GTZ, 1977
	17	DHV, 1993

Source: Rybakov 2012.

Table 12. Comparative of basin recharge estimates

Aquifer complex	Fresh (fossil) groundwater stored Mm ³	Approximate average recharge Mm ³ /Year	Approximate abstraction Mm ³ /Year	Remarks
Tihama Quaternary aquifers	550,000	550	810	Quaternary aquifer
Southern coastal plain (west Mukalla)	70,000	375	225	Several quaternary aquifer units
Extended Mukalla complex	10,000,000	500	575	Quaternary sandstone with interconnected quaternary deposits
Highland plains	50,000	100	500	Various isolated units with variable lithology

Source: Van der Gun and Ahmed 1995.

7.2 Groundwater politics and policies in Yemen

7.2.1 Groundwater development in Yemen before unification in 1990

Historically, the split between northern and southern Yemen introduced a very different way to regulate and control natural resources. A socialist sense of society, organized through state-control and regulation found in southern Yemen was in opposition with the more 'individualistic' ideas found in northern Yemen. Following the introduction of the pump by the British in the South, when the colonial powers left, state-organised irrigation was established after 1967 where "no one was allowed to drill or to own even a well because it was the government" (FMWEY 2015) as opposed to a more 'free market' and individualistic approach in the north. As unification happened "under the ground of free market", the socialist ideas from the south were abandoned, leading to a total collapse of the political and management system in the south (encouraged by the government as it gave loans and credits to farmers to individually develop irrigation), with all the skills and experience from the north "replicated very quickly in the south" (ibid.).

Before Yemen's unification in 1990, the control and monitoring of well drilling were either too strict in the southern governorates of the People's Democratic Republic of Yemen (PDRY), or too loose in the northern governorates of the Yemen Arab Republic (YAR) (Al-Yazidi 2015). At the time, apart from the traditional community rules, some minor and dispersed authority on general water management had been vested to agricultural and domestic water supply agencies.⁶⁰ In the early 1990s and in response to conditions made under World Bank financed projects, such as the Water and Land Conservation Project, a first regulation concerning organization of well drilling emerged through a Ministerial Resolution (ibid.).⁶¹ Implementation of this regulation failed however due to disputes over authority among government agencies that were link to different policy sectors (ibid.).

The modern development of groundwater in Yemen with deep boreholes occurred through donor-funded projects originated in the 1960s and 1970s. Previously, as will be introduced later, groundwater was abstracted through traditional wells. Project documents state that by 1973 there were more than 200 hand-dug wells with pumps and some drilled wells pumping water from the Wadi Zabid Aquifer (World Bank 1973). Dug wells had 2 to 3 meters in diameter and down to 30 meters in depth. It was estimated that by mid-1973 about 300 wells would be in operation, pumping around 60 Mm³ of groundwater, with an annual recharge of 120 Mm³ (ibid.). It was established that though the area had seen a decrease in groundwater levels of 2 to 2.5 meters between 1970 and 1971, further groundwater decline was difficult to estimate. Additionally, increased depression of groundwater would "induce more rapid flow into the area from the east, thus at some level restabilization within average recharge limits will be attained" (World Bank 1973: Annex 4, Page 4). Thus, in view of this, it was considered that dug wells should be replaced with a lesser number of drilled wells (100 to 150 metres deep). The agricultural credit union also provided credits for the purchase and installation of pump-engine sets and on-farm development of the area for irrigation and loans for around 50 wells in Wadi Mawr and 35 in Wadi Zabid (ibid.).

⁶⁰ These were a series of Presidential and Cabinet resolutions concerning establishment and tasks of agricultural development authorities and water supply and sanitation utilities. For instance the Abyan Development Authority in 1974, the Public Drilling Corporation in 1981, the National Water Supply and Sanitation Corporation in 1973, and the Sana'a Protection Zone in 1975.

⁶¹ - Ministerial resolution no. 46 for 1992 concerning regulatory bylaw on well drilling organization

A project in 1976 in Wadi Hadramawt also included a feasibility study for the development of groundwater in order to establish if present extractions at the time (around 128 Mm³) and expected future ones (up to 160 Mm³) were within the safe yield limits of the aquifer (World Bank 1976). The project document stated that there were already around 2,150 open wells with diesel pumpsets, and an additional 81 tubewells in cooperatives and another 21 tubewells on state farms. The total annual abstraction of groundwater in the Wadi was established at 128 Mm³. an average yield of 25 litres per second) on state farms (World Bank 1976).

7.2.2 Groundwater policy and management after 1990

7.2.2.1 The creation of NWRA

Following Yemen's unification in 1990, on the 29th of October 1995, the President of the newly created Republic issued Decree No. 154 on the establishment of the National Water Resources Authority (NWRA). Previously, the responsibility of water resource management had been scattered between different agencies. This new decree merged a series of different departments under the umbrella of the new NWRA (Al-Yazidi 2015). The departments to be attached to the new Authority were: 1) the Technical Secretariat of the Higher Water Council; 2) the General Directorate of Water Resources management in the Ministry of Agriculture and Water Resources (now named the Ministry of Agriculture and Irrigation); 3) the Department of Hydrology in the Mineral Exploration Corporation of the Ministry of Oil and Mineral Wealth; 4) the Water Resources Department in the Water and Sanitation Corporation in the Ministry of Electricity and Water.

Following its creation in 1995, the beginning of NWRA's operations and functioning was delayed for two years until 1997. The implementation of the Decree faced difficulties such as a lack of physical offices and basic facilities and equipment, and no budget. These difficulties were in addition to a resistance from these agencies and ministries to lose part of their staff and mandates to the newly created Authority (ibid). The above-mentioned departments with the exception of the Technical Secretariat of the High Water Council, did not transfer the required staff, office equipment or technical facilities to NWRA, leaving the Authority without operating or implementation capabilities (ibid.). According to The Hague Institute for Global Justice (2014: 79) "water management responsibilities are divided over many authorities with minimum integration and coordination."

Following its creation, NWRA witnessed an expansion of its organisation and administrative network, covering the country through seven regional branches and small local management units. This decentralisation, as will be analysed later, aimed to develop stakeholder participation in water management through the creation of water-basin committees and formal water user associations in 2002 (Van Steenberg and El Naouari 2010). The capabilities of NWRA in performing its duty are controlled by the Cabinet, giving approval prior the implementation of the National Water Plan, the delegation of authority to the Water Basin Management Committees, or the promulgation of standards for water use (Al-Yazidi 2015).

7.2.2.2 NWRA's institutional difficulties and the Water Law of 2002

Despite the increase of activities and reach of the Authority, Al-Yazidi (2015) considers that NWRA has barely addressed the control of groundwater abstraction through the application of licensing and registration of wells as forcefully as it has applied other policies and regulations such as those surrounding drilling rig registration. This is partly due to the fact that, among the

difficulties NWRA has had to face, some of the most pressing ones are a weak organisational network, poor and technical capacities, and a lack of professionalism of its staff.

NWRA has also had to face weak political and social support since the implementation of its mandate would mean the reduction of illegal drilling and groundwater abstraction, which in turn would affect influential leaders and politicians with vested interests in agriculture and the use of groundwater (see further sections). This has translated into a poor implementation of the Water Law on the ground through NWRA, particularly those aspects related to the control of drilling activities and the registration of water rights.

Additionally, NWRA has had to face skeptic voices and opposition from within the government. Before the Water Law was passed, skeptic voices argued that NWRA's authority was not based on any law, therefore refuting its authority and legitimate mandate. Following the Water Law in 2002 (Table 13), detractors said that the articles in the Law about NWRA were unclear and should be expanded into more consolidated and understandable bylaws and regulations. These various implementation problems have been translated into an absence or ineffective enforcement of well licensing and registration by NWRA, which has in turn encouraged the illegal drilling of wells and abstraction of groundwater.

The creation of the Ministry of Water and Environment in 2003 following the Water Law added an additional layer of complexity and conflict vis-à-vis NWRA's competencies and mandate. The Ministry was established to lead and represent the water sector and different environment agencies including NWRA. Subsequently the Water Law was amended in 2006, putting the Ministry in charge, taking parts of NWRA's mandate away from the Authority. The Ministry became therefore the interlocutor of the water sector with the Cabinet. NWRA would direct its proposals not to the Cabinet directly but through the newly created Ministry.

According to Al-Yazidi (2015), prior to the establishment of water basin management committees in Yemen, a considerable proportion of the general public and of water users did not know that a Water Law exists or that there are water resource and irrigation policies. Some politicians and even some judges knew little of nothing about water sector regulations and policies. In a case study mentioned by The Hague Institute for Global Justice (2014: 105), villagers from Shahik and Tan'im villages in the Khalwan area in Sanham district (southeast of Sana'a) know about well spacing standards (set to 500-750 meters) but other than that, "local farmers have no knowledge of the Water Law, neither the role of the ministry of water and environment (MWE), nor the national water resources authority (NWRA)."

In the Sana'a Basin, Tareq Safeah,⁶² lawyer and licensing officer at the NWRA branch, related how the enforcement of the Water Law was limited due to the presence of many constraints (Al-Yazidi 2015). Some of these constraints are related to gaps and omissions in some of the articles of the Law such as the criminalization of illegal well drilling, punished by a small fine. Additionally, the law did not require a drilling license for dug wells shallower than 60 meters depth. This issue increases conflicts especially in areas of natural springs.

Moreover, with the Water Law from 2002 and the requirement to register wells, farmers have been suspicious that registration will gradually lead to metering (Lackner 2014). They are worried that groundwater abstraction rights "might eventually be defined by the amount of land they own and historically cultivate" (Lichtenthaler 2014: 186). In the face of dropping water

⁶² Interviewed on the 06/11/2014 by Al-Yazidi (2015).

table levels, mostly wealthy landowners can afford to drill and deepen their wells. There are therefore social, economic and technical barrier for small landowners to enter the drilling market unless they find ways to form cohesive groups willing to share the investment costs (Lackner 2014). These issues between land and water are more acute as, due to the absence of enforcement of the Water Law in some areas such as the Sa'dah Basin in Northern Yemen, conflicts have shifted to land ownership instead of water rights, access, or illegal drilling. There is also no respect for the minimum distance separation requirements between wells (Al-Yazidi 2015).

Table 13. Yemen's 2002 Water Law selected articles on water and groundwater

Article	Executive procedures
11	Composition and duties of Water Basin and Water Zone Committees, together with their relationship with local authorities.
17- 2	Standards, data and measures for the preparation of Water Plans.
23 -2	Minimum and maximum standards for temporary use of water.
24	Conditions and controls for methods of treating water.
25-4-ii	Controls for co-ordination between Ministry of Agriculture and Irrigation, National Water Resources Authority and other "relevant concerned entities".
26 -7	Qualitative and environmental standards for the treatment and disposal of wastewater.
30	Procedures and controls for constructing water installations, small irrigation structures and excavation of subsidiary canals for harvesting water.
31	Specification of cases where Government can withhold acquired water rights.
34	System and rules for maintenance of a register of acquired rights of benefit from water.
37	Details for the implementation of license (permits) for construction of water installations or water wells.
38-4	Approval of assignment of licenses (permits) to other parties.
42	Registration fees, rules, provision and procedures for permits for contractors and engineering offices involved in well drilling, groundwater exploration, consultancy, studies, water resources works, and distribution of water well water.
46	General Standards and Technical specifications, and rules and procedures for: drilling, water wells, site and general plans for water and irrigation installations, water treatment and desalination plants. Forbidden Wells, streams, creeks and natural springs, drilling equipment essential supplies, drilling substances and well casings, and pumps.
51	Procedures for right of entry of authorized employees to enter property to carry out work associated with the Law, and the compensation in the event of damage resulting.
54 (1)	Standards and specifications related to the disposal of wastes.
54 (3)	Notification of Forbidden Water Zones or Protective Zones where disposal of wastes is Prohibited.
54 (4)(ii)	Conditions and standards of protection (in respect of disposal of wastes) by manufacturing plants before they are allowed to operate.
55	Basic controls and standards/criteria for the execution of studies and research on protecting groundwater aquifers in costal arrears from saline intrusion, and the construction of related installations.

Article	Executive procedures
60	Procedural controls for the construction of pits or pools in rural villages for the disposal sewage.
63	Conditions for staff to be given the status of judicial enforcement for control and inspection of the Law.
73	Rules and procedures related to licenses, permits and approvals required under the Law, and the fees, charges and deposits for these and for the technical services of NWRA.
9	Rules and controls for regulating the collection and use of fees charged by NWRA in respect of: water benefit registration fee, water benefit fee for commercial uses, and protection fee against pollution.
2	Rules and regulations for the collection and use of all charges, bonds, deposits and penalties which shall accrue to NWRA under the Law, or to “relevant concerned entities” for services provided by them under the Law.

Source: Al-Yazidi 2015.

7.2.2.3 NWRA’s enforcement difficulties

NWRA’s main enforcement problems are however systemic, stemming from institutional and political flaws. The difficulties of the agency can be illustrated with the lack of prosecution of illegal drillings in the country. Following The Hague Institute for Global Justice (2014: 5) “almost all of the water-related civil court cases concern illegal drilling cases identified by the branches of the NWRA”. The increase in drilling activities and number of drilling rigs was initially induced by remittances by Yemeni immigrants from Saudi Arabia and the Gulf up until the 1990 Gulf War, followed by a decline and a further gradual increase since 2000 (Al-Yazidi 2015). The spread of the drilling rig and pump technology should be understood within the context of increasing population growth, development of water and sanitation services, unrealizable and unproductive rainfed agriculture and increasing need for irrigated crops and evolution of the cropping patterns (ibid.).

The increase of well drilling has been also encouraged by the availability of uncontrolled drilling rigs (Al-Yazidi 2015). Based on NWRA’s information, there are more than 900 rig platforms in Yemen, of which only 222 have been registered and only 23 have been subject to disciplinary action under the water law and other regulations. According to M. Abdussalam, Director General of the water right and permits department of NWRA, the number of wells drilled and deepened in 2013 are estimated at 5,000 of which permitted wells were only 150, about 3 percent (Al-Yazidi 2015). The violations of illegal drilling that have been caught in the act and submitted to the courts by all NWRA regional branches totalled 570, from which only 4 cases have been sentenced (ibid.). In the Sa’dah Basin in the northern part of the Yemen, officials confirmed that indiscriminate drilling is prevalent in the basin and enforcement of the Water Law is absent (ibid.). The basin faces continuous and random drilling without control and no measures are taken with respect to violations by the Government agencies or the local council, possibly a sign of the weakness of water user groups in the basin.

As seen from above, only very few cases of illegal drilling or illegal wells enter the courts, one the main reasons being “the high reluctance by the district security forces and prosecution to enforce the water law. For example, approximately 29 illegal drilling cases were recorded in the first three months of 2013 in the Sana’a basin. However, only one or two finally entered the court system. The efficiency of the respective NWRA branches plays a vital role in these figures.

For instance, the number of illegal drilling cases recorded by the NWRA Sana'a branch shows a drop between 2010 and 2012. This does not mean that the illegal drilling have declined, but rather that the monitoring activities were very limited during that period due to the financial limitation and instability at that time" (The Hague Institute for Global Justice 2014: 183).

Conflict resolution in the Ta'izz area also shows how political connections can help some users favour their cause and how the NWRA and the implementation of rules are subject to many pressures (including corruption and patronage as will be further developed). A subject in Khadeer District, Tai'zz, took his dispute "to higher political levels and managed to obtain letters from the Governor of Ta'izz, the Minister of Water and Environment, the Presidential Office Manager, the head of Appeals court in Ta'izz, and the Attorney General. All those letters were addressed to the head of NWRA in Sana'a asking him to 'refrain from opening new water conflicts' in the case of Halhalah conflict. According to Person 94, the NWRA's action had stirred the conflict. These actions make it clear that Person 94 is a powerful man with lots of connections; he managed to obtain court rulings in a very limited time (5 court rulings in 2 years), which is pretty unusual in Yemen" (The Hague Institute for Global Justice 2014: 152).⁶³ Person 94 had also been accused by the Qassemes of bribing the judge, security, and persecution of NWRA officials in Tai'zz.

In this conflict, "inconsistent and conflicting approaches of the two NWRA offices to address the dispute highlight the lack of institutionality and coordination within NWRA itself." (The Hague Institute for Global Justice 2014: 150). In the Tai'zz area, having reviewed several cases of water conflicts, The Hague report concludes that "the NWRA in Tai'zz does not seem to have much power or capacity to intervene".

7.2.3 Groundwater management and Yemeni politics after the 2011 revolution

Yemen's political structure after the 2011 revolution, although in flux, was not substantially altered and remained largely intact throughout the transition period two years later (Hill et al. 2013). "By signing the GCC deal 'the elite families agreed on a powersharing deal, sanctioned and refereed by the international community'. As Saleh handed over formal power to Hadi in November 2011, he was still the fulcrum for military, economic, political and, to an extent, tribal power" (Hill et al. 2013: 27). During the transitional period, the government in place was "largely made up of Saleh-era ministers and officials, including members of the opposition who previously served in government" (ibid.). Also, the restructuring of the military and security sectors remained opaque, excluding civil society and opposition groups (Hill et al. 2013).

Additionally, as The Hague Institute for Global Justice (2014: 116) points out, "in the power vacuum created by the 2011 revolution, new leaders have appeared, who wielded power by virtue of their link with new political parties. They could obtain power in the field of water, by becoming the hears of the newly established donor-funded, water associations" (The Hague Institute for Global Justice 2014: 116)

⁶³ This conflict arose because of qat. Person 94 had been overconsuming well water to irrigate qat farms outside the area. The Qassemes family, living in the same community, indicated that the overconsumption of water had left their wells dry (leading to insufficient water for domestic use and agriculture). During the dispute the Qassemes family drilled two wells, one higher up Person 94's well, and one close to it. Person 94 won five court cases against the Qassemes. NWRA branch in Ta'izz was involved which issued a report favourable to Person 94. The Qassemes then requested the intervention of NWRA's central office in Sana'a (The Hague Institute for Global Justice 2014).

As a result, a new layer of members of the elite was established on top of the last one, with the implication that “the substructure of the Saleh-era political economy remains largely in place. Most of the ‘commanding heights’ of the economy are still in the hands of the same clique, with only minor reshuffling. The rotation of cabinet ministers and military commanders represents a rebalancing of rival factions in the established elite. Elite behaviour over the course of the transition suggests that the former members of the Saleh regime remain largely self-interested, and are participants not just in the internationally brokered transition process but also in other, murkier, negotiations and conflicts” (Hill et al. 2013: 29).

This ‘failed transition’ and the struggles by the interim government to push political reforms faced resistance from incumbent and old elite interests. The political decisions over water management (and Yemen’s political economy for that matter) remained in the hands of local tribal leaders, with a small elite at the top of around 10 families with close ties to the deposed president, remaining mostly intact, “thus ensuring that a status quo in the division of power between the powerful and wealthy elite and the powerless poor” (The Hague Institute for Global Justice 2014: 85).

These changes in the political environment of Yemen have increased legitimacy problems found in Yemen’s political system. “For 33 years, president Saleh strengthened his power by strategically using ‘divide and rule tactics’ to weaken possible opposition. He created a complex system of nepotism and patronage, in which checks and balances could not be properly enforced (e.g. courts were structurally under-financed). These organisations were affected in one way or another by elites that possessed power due to do their proximity to the regime” (The Hague Institute for Global Justice 2014: 2).

Following the 2011 revolution in Yemen the internal security situation has deteriorated, drifting into an international armed conflict in March 2015 with the participation of Saudi Arabia. The lack of change at the political level in Yemen described above came in parallel with a general weakening of both traditional and governmental authorities. “As an interviewee observed, ‘nowadays the law of the forest reigns, we are living in a jungle!’” (The Hague Institute for Global Justice 2014: 134). This process of state weakening will be further developed in latter sections. According to Nabil Al-Barq,⁶⁴ Judicial Officer and Illegal drilling monitor agent for NWRA, Sana’a Basin Branch, this deterioration of security has led to problems with the field teams monitoring illegal drilling, encroached by gunmen. After being reported, these threats were not followed and no serious punitive actions were taken against the gunmen by the police or public prosecutors.

There is also a reported complacency by water law enforcers to stop illegal drilling rigs from being moved and to arrest offenders (Al-Yazidi 2015). There is also inability to collect the necessary information related to water law violations and prove them due to the presence of gunmen or other tribal forces, leading to the rejection of cases against water law violations by prosecutors due to lack of proof. When a trial actually happens, there is also limited awareness of the Water Bylaw, which results in weak judicial rulings against violators (ibid.).

With the conflict in Yemen, shortage of diesel has affected agriculture and farmers’ livelihoods. In the Khalwan area in the Sanham District, “large problems exist, as everywhere in Yemen, with obtaining diesel fuel for the pumps. Electrical pumps cannot be used because the electricity supply is unreliable. People usually wait at fuel stations for one or two days to get diesel.

⁶⁴ Interviewed on the 09/11/2014 by Al-Yazidi (2015).

Whereas the normal diesel price is 10,000 rials it may increase up to 40,000 rials on the black market, with the risk that the diesel is diluted with water (and consequently damaging the pump's engines)." (The Hague Institute for Global Justice 2014: 105). In another village in the Sana'a basin, Arrowdah, "costs of drilling a well and installing the necessary pumps and infrastructure sometimes amount to 20 million ryal (68,000 euro), which means that farmers have to participate in collective financing in order to drill a well. Normally these participants divide the water between them according to fixed percentages based on the share each one paid in buying the equipment." (The Hague Institute for Global Justice 2014: 110).⁶⁵

7.2.4 Legal pluralism and water management

It is worth noting at this point that the system of modern water rights in Yemen was founded on principles of justice and equality to secure the right of all resource-based members of society to benefit from common natural resources (Al-Yazidi 2015). Evidences of regulated customary water rights, applied until now, show that local communities have had the awareness about efficient use and conservation of water in order to regulate these systems collectively.⁶⁶ Under an urgency to survive, local communities developed value-based rules to acclimate with their social and natural environment to safeguard the water resources and avoid, mitigate and conciliate conflicts over water rights (Al-Yazidi 2015). This led to simple but morally persistent and hereditary water management values, rooted in the collective consciousness of the rural society to comprise an essential part of its culture (ibid.). These water rights values, as with other values, have more recently been oriented to align with the principles and norms of Islamic law or *Sharia*. Some rules of the water rights are unwritten but they are protected by the legitimate values of the tribal customs.

Following Weiss (2015), many of the causes of Yemen's poor groundwater management are linked to the problem of ill-defined water rights. This problem stems from a patchwork of contradictory and overlapping legal standards and the "disjointed nature of the legal system governing water resource rights and allocations" (Weiss 2015: 18). The legal pluralism found in Yemen, between traditional rules, Civil Law, and the Constitution, regarding the codification of groundwater as private property provides the departing legal imbroglio (Weiss 2015). For The Hague Institute for Global Justice (2014: 2) "the legal system is pluriform and disjointed; contradictions exist between the various sources of law and legal references (formal law, traditional law, agricultural traditions), as well as within the formal body of law. There are contradictions between, on the one hand, the civil code and the traditional rights (which are broadly in line) and the constitution and the water law."

The legal nature of groundwater appropriation is not appropriately codified and the Constitution and the Civil Code are in clear disagreement (as the Civil Code is based on the *sharia* – or Islamic law). "Ownership according to the water law can be based on permits given by the Authority but also on the basis of traditional rights. The water law includes a number of provisions and regulations to determine the requirements. Therefore, with the adoption of the water law attempts were made to build a bridge between state legislation and traditional rights by trying to make traditional rights susceptible to state regulation" (The Hague Institute for Global Justice 2014: 94).

⁶⁵ The impact of diesel shortages on agriculture will be revisited later as there are large vested interests involved in diesel sales and diesel smuggling in Yemen.

⁶⁶ This will be further explored in latter sections.

Yemen's water management system has therefore to reconcile on the one hand the respect of tribal traditions that in turn should not violate the Sharia provisions and on the other democratic values enshrined in the new legal texts and regulations of the modern civil state. The complexity of this combination is represented in the tribal-religious-military ruling powers, where each plays its part in shaping the water-political scene including adverse impacts of implementation of the water regulations. Judgements and court rulings can seem arbitrary as either of the legal systems is used. Farmers and officials stated that people in Sa'dah basin resorted to provisions of Islamic Sharia or custom to resolve their disputes (Al-Yazidi 2015). The adversaries go to leaders whom they believe know the provisions of Islamic Sharia and ask him to intervene and resolve the dispute, or to wider conciliation in hard to resolve cases. This may be taking the case to those in political control in Sa'dah basin, who then send one of the leaders to adjudicate the case, either according to Islamic law, or where issues have clear provisions in custom, judged accordingly. Fragmentation brings therefore "contradictions between approaches in the regulatory framework, which is likely to decrease the possibility to resolve conflicts in practice" (The Hague Institute for Global Justice 2014: 2).

This results in a very slow legal and judicial process whenever cases are brought to the court. As an example, in land ownership cases, "[w]hilst customary structures previously oversaw land ownership and transfers, their authority has weakened so much that claimants now extensively use the courts to formalise land ownership and address competing claims. Estimates of the caseload in primary courts over land and property vary from 50% (YAVA) to a staggering 80% (World Bank). It is not unusual for such cases to drag on for ten or more years. In the meantime, claimants often resort to violence to keep or attain control over the property" (Al-Zuwaini 2012: 76).

The legal system is also compromised, apart from the above-mentioned issues of legal pluralism, by the existing system of patronage which increases its lack of legitimacy and trust. "Several studies claim that corruption is so endemic that court cases are commonly resolved only through bribing judges and court staff. Clerks reportedly overcharge on filing fees, and extract bribes for processing routine court documents. If the bribe is not forthcoming, the papers might not be served, the file may be lost, or the case might never appear before a judge. In courts with multiple judges or chambers, litigants bribe clerks to assign their cases to 'friendly' judges" (Al-Zuwaini 2012: 68). As The Hague Institute for Global Justice (2014: 2) puts it, "public confidence in the fairness of the courts and the waning of traditional leadership which has been compromised by the political developments over the last 10 to 20 years, e.g. due to complex nepotism and a system of patronage."

7.2.5 Failed decentralisation through local councils and water basin committees

Yemen's legislation and policies have been affected by local, national and international experiences, which have required compromises in order to adapt them to the existing mandates of the different government authorities (Al-Yazidi 2015). The intention was to facilitate agreement among as many stakeholders as possible including donors for adaptable water resources management concepts and approaches. Regulations and policies were developed on paper but their application, however, is still hesitant. The deficiencies of government authorities have made them incapable to apply the water resources management principles enshrined in the different new regulations (Al-Yazidi 2015).

As described by Dr. Al-Ghaith in the Yemen Times (2013), "the local governance has failed to achieve its ends because the aim of establishing local rule in Yemen was not actually

implemented with the interest of Yemen's districts and areas in mind. The aim was to only keep the citizens busy with something unreal and now this has become an obstacle to people's access to service." Corruption has also affected the mechanisms of local government as the majority of members who presented candidatures for the local elections were corrupted figures and "[l]ocal councils have become just a tool in the hand of the regime to pass decisions without being accountable for the consequences" (ibid.). Professor Al-Ghaith concluded that "the local elections which was held in 2006 were just a farce in which only corrupt figures climbed up the ladder and thus expanded the corruption circle", adding that "the problem does not lie in the idea of the local council, but it is in the method of its election, its work ethic, and using it as cards to get western support for power clinging."

The water law emphasizes the restoration of participation found in local communities in order to shape water resources management. Although this concept had proved to be efficient throughout history at the community level, local community rule had been weakened over the years. The role of the local community elders, societal figures and tribal Sheikhs in neutral arbitration and solving water right-related conflicts has been adversely affected under the influence of political partisanship, religious affiliations, and corruption (Al-Yazidi 2015).⁶⁷

During the development of water policies and regulations, the role of local councils with regard to water governance was perceived as crucial (ibid.). Local councils were delegated considerable authority that could be used to launch a decentralized and participatory management system. According to the Local Authority Law from 1999⁶⁸ and the Water Law along with several related Cabinet Decrees, the councils were assumed to participate in policy-making, planning and monitoring of well drilling and drilling firms and setting up of protection zones. Their responsibility is to supervise, follow-up and monitor the implementation of regulations, policies and plans made by the basin committee. Local councils are concerned because all the water basins are shared between different governorates under the administrative control of local councils. The councils are also concerned with water basin-wide development interventions that have to be coordinated based on integrated management concepts.

However, many of the councils are still too weak administratively and resource-wise to play their role and water issues are still not part of the councils' serious concerns. Most of the councils' water management-related technical and financial capacities either do not exist or are very poor and they cannot exercise their role as government authorities do not pay attention to monitoring and supervision of local councils (Al-Yazidi 2015). The participation of local councils in water basin committees is mostly donor driven than self-initiative, and dependent on responsible staff being assigned as governors. In the Ta'iz area in Yemen for instance, there is evidence of leadership leading the change. It has been reported that the chairman of NWRA has encouraged local people to support rural-urban water transfers. The set up would benefit farmers as they would get a greater financial reward for the water. This representative however has pushed for change whilst having an understanding of the local situation and local politics which has given him credit amongst community members. He had also built up good relations with local politicians and tribal leaders and started a public awareness campaign about water scarcity (Zeitoun 2009).

⁶⁷ These issues will be further detailed in a latter section.

⁶⁸ The Local Authority Law of 1999 presented the model for national decentralization, calling for municipal elections, held for the first time in February 2001. It also restructured the distribution of budgetary resources between local and central governments (UNDESA 2004).

Of the five established water basin committees in Sa'dah, Amran, Sana'a and Tuban and Abyan water basins, Abyan basin committee is doing relatively well within its command area with the different stakeholders represented in its membership, according to Al-Yazidi (2015). This success has been backed however by heavy central and local support, and international donor financing. In general however, water basin committees are affected by weak government rule and local council authorities and lack of awareness of the local communities (ibid.). Additionally, while the Water Law and related regulations significantly opened the door to decentralized and participatory management, governmental agencies are reluctant to delegate serious decentralised authority to local levels. According to Al-Yazidi (2015), this incomplete implementation of existing regulations and policies is a problem that mostly lies in the inefficiency of the government administration and lack of a supportive political will. Decisions at the local level are also affected by local politics as decisions are made by influential community members. Even so, these decisions rarely go beyond the meeting room, since nobody is able to enforce or implement them, especially when it comes to touching existing benefits of bigger and better-off water users and influential Sheikhs.

Decentralised agencies also struggle financially. Although considerable funds have been spent, project-based support is scattered over many water-basins in isolated interventions that cannot reach most of the water users (Al-Yazidi 2015). Accordingly, the established user associations and groups are isolated, with their capacities linked to their own ability to generate income, and they often stop functioning after the project ends. Gamil Al Darrab of the Local Corporation for Water Supply and Sanitation office, established in 1991, said that their office is badly affected (ibid.). The proportion of what is collected from the bills is only 30 percent because people do not pay, creating an amount of debt for the Corporation of around YR147 million from un-paid bills from users and YR 13 million from the government (ibid.). Eng. Yahya Al Sharafi, Director General of the National Water Resources Authority Branch Office (NWRA-branch), stated that work in the branch almost stopped except that employees attend every day (ibid.). This results into a lack of operating expenses, with only one employee being paid a salary (the Director General himself) while the rest of the employees are contractors, many of whom did not receive the contractual salaries for the last 12 months (ibid.).

In 2004, the Sa'dah Water Basin Committee was established with support from the German development bank, KfW. After its mandate and membership composition was legalized, the committee had a successful functioning for three years (Al-Yazidi 2015). By July 2007, the KfW support had come to end. The NWRA branch office, acting as a technical secretariat in coordination with the local council, took the responsibility for continuation of the committee operation. Sadly however, both NWRA and the local council failed to allocate the operational budget for the committee while simultaneously losing coordination with the stakeholders. The result was that the committee stopped working and the situation returned back to where it was before the intervention (ibid.).

The creation of water user associations was also driven by the reduction of groundwater levels due to drinking water project with transfer to urban areas (e.g. Taiz urban area) (FMWEY 2015). Through donor-driven funds, these user associations were created so that they could benefit from specific development projects and funds to improve local access to water resources (FMWEY 2015; Lackner 2014). Given the disruption of local traditions, the development of water user associations was actually a way to reinforce local rule (as it was under traditional rule), "a desperate way to organize the community to learn from their tradition, which is already weak, to include the groundwater. Which is a very good idea but it had very little chance of success

because traditions were already weakened and the task of controlling groundwater is much more political than what you can do it” (FMWEY 2015).

Water user associations in Yemen also suffered from top-down hierarchical problems, with a lack of power-sharing and a centralized functioning mode (The Hague Institute for Global Justice 2014). Moreover, “[p]olitical actors would siphon funds away and legalize illegal practices and would easily capture these weak organizations. Rather than being a mechanisms for broader empowerment, the WUAs in Wadi Siham became an instrument of the elite for funds capture. Especially during and after the revolution, water user associations have become a receptacle for arms and weapons purchased with external support. This way they converted into yet another system by which powerful stakeholders can exert their vested interests in the face of a weakened governmental authority and at the detriment of others” (The Hague Institute for Global Justice 2014: 136).

7.2.6 The role of the international community in water management in Yemen

Following up on the previous sections where the role of the international community was highlighted as crucial in some cases to maintain the country’s efforts towards decentralisation and even more so in funding the first projects aiming to develop modern groundwater abstraction, this section further develops its role. Donor aid in the form of external grants “increased from around 1% of GDP in previous years to about 6% of GDP in 2012, according to the IMF. However, overall levels of foreign aid have been overshadowed by high volumes of capital flight: Yemen ranked fifth among Least Developed Countries surveyed for capital flight between 1990 and 2008. Illicit financial flows on this scale are incentivized by the global issue of international tax havens,” (Hill et al. 2013: viii).

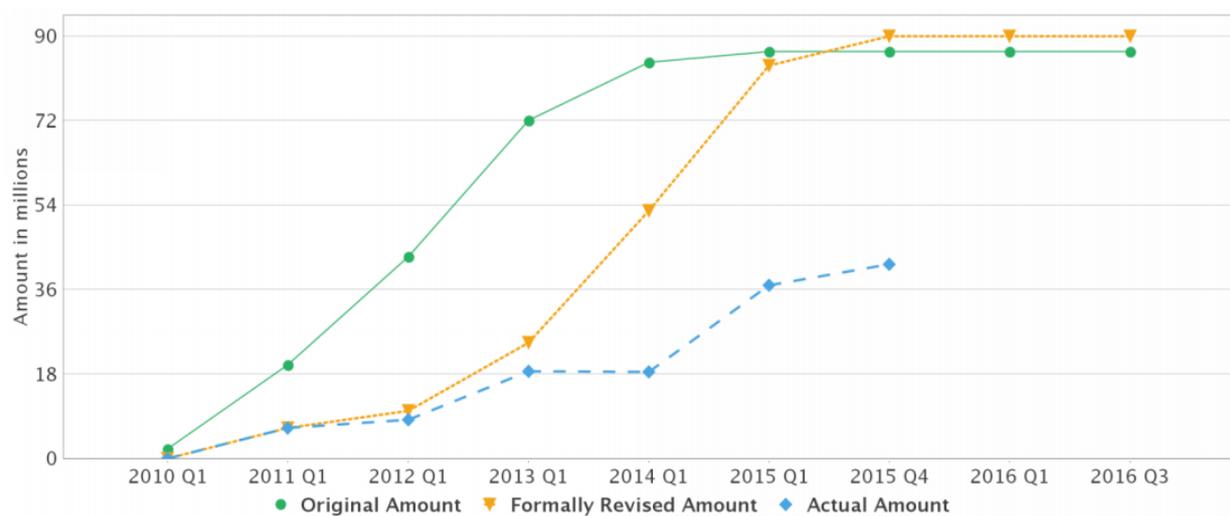
Despite the organisational reform pushed forward by the Water Law and following regulations, government agencies in Yemen failed to find a way to work together and to agree. The fragmentation of organisations within the government regarding water management conveyed a bad image to stakeholders and donors. This has led to a pattern of isolated interventions by donors, both in duration and locations, limiting the practical implementation of regulations and policies (Al-Yazidi 2015).

Another consequence of internationally-funded project in Yemen has been, as seen by the TDA [Tihama Development Authority] in the Hudaydah governorate that “internationally funded water projects in Yemen have had the unintended consequence of reinforcing local power centres and contributing indirectly to the situation of chaos and insecurity” (The Hague Institute for Global Justice 2014: 137).

During its first year of implementation, one of the latest World Bank loans for Yemen suffered significant delays due to complicated domestic procedures and procurement bottlenecks arising from procedural difficulties and poor due diligence from corrupt practices in bidding and allocation of contracts. The assessment in the initial project document for the Water Sector reform project qualified the overall risk for procurement as substantial, with many agencies lacking capacity to administer international competitive bids, keep records, need for formal and on-the-job training for entry and high-level procurement professionals, lacking capacity to produce good quality bid evaluation reports, and with too many units/committees/departments involved in the procurement implementation phase (World Bank 2009).

“[D]ifferences in understanding among development partners regarding the nature of the financing, capacity constraints at several levels and a lack of close supervision from relevant Government agencies” also limited the start of the project (World Bank 2013: 1).⁶⁹ As a result, all disbursements were suspended in July 2011 but reinstated in January 2012. As of September 2013, the project had only disbursed 21 percent and committed only 50 percent of the grant proceeds. The project also encountered problems regarding the implementation by the NWRA due to a lack of “timely responses” from the Ministry of Finance regarding the release of funds, as well as “frequent changes to, and limited competence of, staff seconded from the MOF [Ministry of Finance]” (World Bank 2011: 5). Additionally, the implementation of this specific component was hindered due to the “inadequate readiness of some sub-components and weak coordination among various Government agencies dealing with anti-corruption issues” as part of the implementation of the Anti-Corruption Action Plan prepared to be laid out as part of the Water sector reform financing (World Bank 2013: 2).

Figure 47. Cumulative disbursement for Yemen’s water sector support project committed amount (original and actual amounts)



Source: World Bank 2015.

7.3 Groundwater, power, and vested interests in Yemen

Yemen is traditionally known for its tribal structure and over the years, a system of political alliances, vested interests, and networks of power and patronage was developed between the political elites and the tribal leaders. Also, due to the autocratic nature of the state, the basis for decision-making in the country is very narrow and centralised (Van Steenberg et al. 2015). This limits, according to these authors, the span of attention and interest decision makers and politicians pay to the water crisis in the country, as they are more interested in political issues directly affecting their hold on power (ibid.). Also, the fact that groundwater management is a very much local issue escapes the national political arena and falls in the lap of local elites supporting the central government (ibid.). According to Al-Zuwaini (2012: 54) “[a]bout 70% of the MPs reportedly are tribal leaders who maintain their loyalties to their own tribe. Also,

⁶⁹ The country’s development loan consisted of various funding mechanisms such as direct World Bank/IDA funds, and various trust funds from Germany, and the Netherlands (known as the Donor Core Group) (World Bank 2009).

security sector and military posts are commonly used to garner tribal support, while strong business leaders and Islamists often vie for other crucial positions.”

In Yemen, tribal groups believed that the government would seize and irrigate land belonging to them, seen by the state as common property land and therefore not owned by anyone in particular and prone to exploitation. Many tribal communities dug their own wells in empty patches of land so that the government could not expropriate them (Moore 2011). As a result, groundwater abstraction development became to be identified in many areas with the growth of the state which in turn had the effect of triggering the individualistic development of wells by Yemeni communities seeking independence from the government (ibid.).

7.3.1 Corruption, political power networks, and vested interests in Yemen

7.3.1.1 Generalized corruption, business, and politics

Vested interests in politics and agriculture represent one of the largest obstacles to effective groundwater management and regulation in Yemen. Corruption and rent-seeking have been prevalent in Yemen, enabled by a system of patronage and networks of power and influence reaching all the way to the previously deposed president, Saleh. Business deals at the local level are usually enabled by middlemen (or ‘introducers’) in Yemen or also intermediary Yemeni firms acting as ‘agents’ who will take commissions (for speedy arrangements, favourable terms, and contacts with high government officials) (Bafana 2012). Bills for contracts awarded can include ‘gift costs’ paid to government officials. Introducers are usually high-level tribal, military or government figures or people with strong tribal, military, or government connections. Inflated cost claims are a regular mechanism to obtain additional rents from contracts (ibid.). As a result, the iron-triangle of ‘tribe/military/government’ is, according to the Yemeni legal expert Bafana, a critical factor in Yemen’s business which, in addition, cripples the country’s economy by diverting funds to these networks (Alkebsi and Boucek 2010; Bafana 2012).

International development projects (in the water sector for example) are not exempt of corruption, and there have been instances of opaque procurement practices to award construction projects to 2-3 companies which were not qualified to handle project budgets from international development funds (for 130 million in the water sector for example in 2006) and which had close ties with the government (one was owned by a minister, another was an obvious ‘front’) (FMWEY 2015).

The fact that Yemen has increasingly been depending on oil and gas production and export⁷⁰ to generate revenues, accumulate foreign currency reserves and fund subsidies as well as underwrite other costs, has exposed even more so the intricacies and levels of corruption and elite appropriation of rents in the country (Salisbury 2011).⁷¹ The export of oil and diesel across the Gulf and also southwards to African countries is carried out by these elites and also by smugglers managing distribution networks for drugs and weapons (FMWEY 2015; Healy and Gill 2010). The networks of power and influence allowing the commercialization of subsidized diesel represent “a black hole of corruption” as a former Minister of Water and Environment put it (FMWEY 2015), diverging around 80 percent of subsidies “to 15 people [...] mainly military

⁷⁰ Between 2000 and 2009 the hydrocarbons sector accounted for 20-30 percent of the country’s GDP, 80-90 percent of its exports and 70-80 percent of government revenues (Salisbury 2011).

⁷¹ These corruption networks involve the highest levels of government. The president at the time, Saleh, reputedly had a business partner who was the sole private distributor of oil derivatives both to government facilities and to private businesses (Salisbury 2011).

people, some investors” and also ‘front’ companies for bigger investors (ibid.). According to The Hague Institute for Global Justice (2014: 59), “the patronage system was built on rents from oil exports and access to the newly liberalized economy: around ten key families and business groups with close ties to Saleh controlled more than 80 percent of imports, manufacturing, processing, banking, telecommunications and the transport of goods.”

Corruption and political power is also facilitated by the tribal system in Yemen. The strong influence of the tribal system in the country’s politics arises from the corruption and weakness of state institutions, starting in the 1960s and 1970s when official institutions were weakened by a lack of resources (Robinson et al. 2006). This tribal system is seen as “second-best substitutes for an absent state or weak state” (Corstange 2008 in Al-Dawsari 2012) as these tribes provide social order outside the formal system, as well as channel rents and influence across political and geographical scales.⁷² The system is therefore characterised, according to Robinson et al. (2006: v), as being in “precarious balance between tribe and state”. The presence of this tribal system is also felt in the country’s formal institutions. Sheikhs have continued to have control of the parliament since the Yemeni Revolution in 1969, with never less than 50 percent of parliament seats in the hands of tribal leaders (Al Muslimi 2013). According to a former Minister of Water and Environment (2015, pers. com.), the high leadership of the country and land owners “are one and the same”. It is, as he says, “much more than a relationship, it is organic, a part of the whole. The people who were in control of the situation were the sheikhs and the army people” while “technocrats and technical people were only tools to be used when it suits the actual power players” (FMWEY 2015).

Influence by powerful tribal leaders was also maintained through financial aid included in the government’s annual budgets (with payments for salaries through the Ministry of Tribal Affairs to nearly 6,000 tribal sheikhs throughout the country) (Egel 2010). The relationship between tribes and government is also very organic and contributing to social stability, with tribes in some cases providing basic services for the government such as negotiations with rebel or terrorist groups, traditional dispute resolution in rural areas through consensus building and maintaining relationships (including also water resource conflicts between communities or villages) or also ensuring the security of government officials and buildings during rebel assaults on towns (Al-Dawsari 2012).

This corruption-greased investment environment has been encouraged by opportunistic parties that have seized power positions to grow quick profits depending on scarce natural resources (Al-Yazidi 2015). The Al-Gur area in Al-Hudaidah⁷³ coastal strip represents an example of how such powers are exploiting groundwater for export fruit growing. This has been accompanied by indifference of the general public of farmers in that area who have nothing to do under increasing poverty, inherited tribal-based disparity and weak awareness. Regardless of the social justice or sustainable development issues, financial and political faces of power are combined and lead to ‘resource capture’ by influential stakeholders (Zeitoun 2009).

⁷² In 2012 the Prime Minister opened a dispute with the sheikhs as he announced that these financial donations were allocated to buy their loyalty and would be stopped. 400 sheikhs openly protested and requested a non-biased treatment from the Prime Minister, following the President’s more moderate approach to their role and influence in politics. Yemen Times, “Disputes between Yemeni government and tribal leaders over budget”, August 5th, 2012, <http://www.yementimes.com/en/1571/news/823/Disputes-between-Yemeni-government-and-tribal-leaders-over-budget.htm> (Accessed 6th August 2015).

⁷³ Originating from Al-Yazidi (2015) with original data from a field visit to Al-Gur area in 1999.

7.3.1.2 Corruption and patronage networks at the top level

The former political regime in Yemen encouraged and nurtured political and social conflict, counter-acting the law and self-destructively weakening state governance (Al-Yazidi 2015). The former president played the role of Yemen's sheikh, commander-in-chief of the armed forces, head of the Supreme Judicial Council and the head of the ruling party beside his position as president of the state. In each position, Saleh interfered in all matters and behaved arbitrarily to events rather than based on a defined development strategy or envisioned political approach (ibid.). In order to stay in charge, power and wealth were distributed among elites and influential tribal and military positions once they pledged support and alliance. The multiplicity of favours granted ankylosed management and political structures with multiple levels of government. As quoted by the president in an interview in 1986: "The State is part of the tribes, and our Yemeni people is a collection of tribes. Our towns and countryside are all tribes. All the official and popular apparatuses of the state are formed from the tribes [...]" (Al-Zwaini 2012: 59).

Philips (2011) describes the patronage system around president Saleh as an "informal and fluid web of power created by President Saleh to consolidate his family's power" and can be "best described as a series of concentric circles with the president at their centre" (Figure 48).⁷⁴ The deposed president had made himself the ultimate arbiter, "approving all major deals and production-sharing agreements with the international oil companies that had been awarded concessions in Yemen. A government monopoly, Yemen Petroleum Company, dominated the import and distribution of petroleum products, and delegated monopoly privileges to two major operators, Tawfiq Abdulraheem and Ahmed al-Iessi. Both men had close ties to Saleh and Ali Mohsin (who himself profited from an effective monopoly over the import of goods by oil firms through his firm Dhakwan Petroleum and Mineral Services" (Hill et al. 2013: 21).^{75, 76}

At the same time, as Hill et al. (2013: 18) write, "[m]arriage and blood relations underpinned the early power structures of Saleh's regime, with his tribe, the Sanhan, coming to dominate the armed forces [...]. The regime's access to hard and soft power was amplified by a tacit power-sharing agreement with the Hashid, Yemen's most important tribal confederation, of which the Sanhan are a part, and which was headed at the time by Sheikh Abdullah al-Ahmar" (Hill et al. 2013: 18). As part of this intricate system of patronage and family connections, the military also played an important role for the allocation of power, patronage, and rent, "with 'ghost' soldiers, weapon-, fuel- and people-smuggling all providing lucrative revenue sources for ranking officers and their business partners" (Hill et al. 2013: 21). In the Yemen Arab Republic during Saleh's rule from 1978 until the unification, "[w]hile democratic institutions were accepted in principle, military and tribal figures such as sheikhs held veto rights, treated offices as personal fiefdoms that could be passed on to their offspring, and successfully avoided playing by the rules" (The Hague Institute for Global Justice 2014: 58).

⁷⁴ Philips, S. 2011 "Chapter Five: the regime", <https://www.iiss.org/en/publications/adelphi/by%20year/2011-2c64/yemen-and-the-politics-of-permanent-crisis-fc0f/ap420-07-chapter-5-c122> (Accessed 31st August 2015).

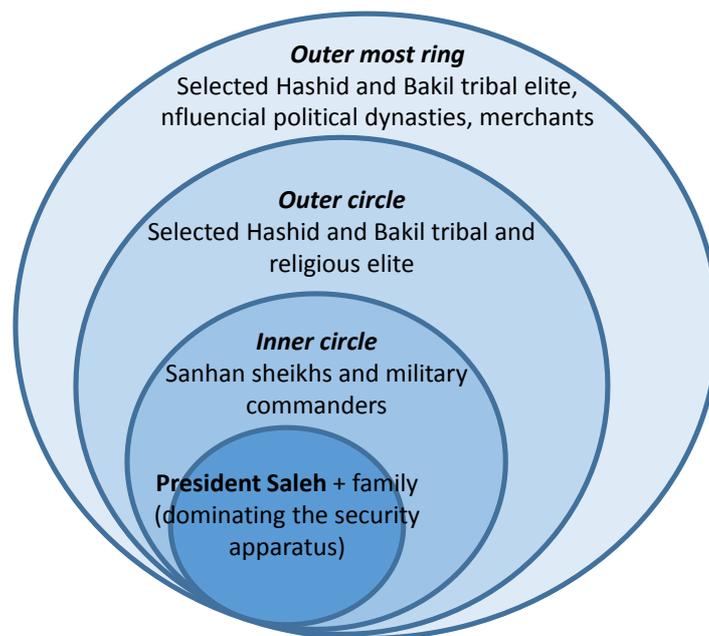
⁷⁵ According to Hill et al. (2013: 21), "Saleh also allocated state-subsidized fuel products on a quota basis to his relatives and political allies, who were free to charge a substantial mark-up to wholesale domestic buyers, or trade their allocated quota overseas at international market prices. The president also allowed selected businessmen to claim subsidies on non-existent fuel imports, on the basis of falsified import documents, a practice that was to prove hugely costly to the state."

⁷⁶ It was estimated by the World Bank that the subsidies only reached 19 percent of its target in Yemen while 81 percent of all subsidies in the country were going only to 15 people, involved in businesses such as re-selling and re-exporting diesel (FMWEY 2015).

The existence of patronage and corruption had, as a direct impact, the formation of rent-seeking groups, “which do not always take measures in the interest of the society at large, but with personal gains in mind. Over time, the powerful coalitions of rent-seeking groups become greedier and demand an even larger influence over national economic policies to consolidate their advantage” (The Hague Institute for Global Justice 2014: 59). Additionally, “family members and other affiliates are often appointed to positions despite a lack of qualifications. In terms of water management, nepotism, patronage and corruption may lead to a sub-optimal use of water and subsequently poor development outcomes in terms of economic growth or poverty reduction” (ibid.).

Moreover, the structures of nepotism and corruption will, according to The Hague Institute for Global Justice (ibid.), “have likely resulted in a general distrust by civil society in the formal institutions relevant to the use of water as well as water-related disputes” given the fact that many sheikhs are financially supported by the government through a non-transparent process according to their relevance to the regime (Philips 2011 in The Hague Institute for Global Justice 2014: 60). This affects, as will be presented later, traditional institutions of conflict resolution arising from water management within and between communities.

Figure 48. Power circles and nepotism structure in Yemen during Saleh’s rule



Source: Based on Philips 2011 and The Hague Institute for Global Justice 2014.

7.3.1.3 Corruption networks after 2011

The influence of these de-facto powers increased after the country’s unification when dramatic changes occurred in terms of the departure from state and semi state economy to economic liberation and a relatively open market (Al-Yazidi 2015). This change was driven by political propaganda visualizing welfare and prosperity to come from the transformation, while lacking not only a development vision and risk assessment but also political commitment. In Yemen the prevailing tribal-based social stratifications, agriculture-based economy and primitive and weak centralized state did not help building an adequate economized infrastructure and institutionalized superstructure for smooth transformation.

Despite the political changes of 2011 the difference between the new and old forms of the ruling system are barely noticeable. The reformed system still represents the extension of the former one carrying with it the problems inherited from the past misleading politics and indifferent management style. Power and wealth are still distributed among political - tribal – military triangle points resembling a kind of feudalism-like system or oligarchic regime.

According to The Hague Institute for Global Justice (2014: 60), after 2011 “the same groups retain control over most of Yemen’s resources while relying on patronage networks and dominating decision-making in the government, military, and political parties.” The Yemen Times (2014) suggested in an article that Saleh’s overthrow had dismantled the old patronage system but created “a plethora of opportunities for new actors to exploit, increasing the competition.” Under the old regime, “bribery was more standardized—there was a limit to how much a soldier would demand,” After his deposition, “with no central authority, each group has its own price.” Staff continue to be hired on the basis of their relations to local rulers who allocated positions “without regard for qualified individuals who wish to apply to the positions.” In that example mentioned in the Marib province, east of Sana’a, “[m]any of the employees either do not exist or do not show up to work. The latter collect their pay cheques without earning them, while the sheikh collects the pay cheques of the former ‘ghost workers’. By the time each employee takes his share of the budget provided by the Ministry of Health, there’s hardly anything left to buy medicine or maintain the facility.”

7.3.2 Qat, politics, and groundwater in Yemen⁷⁷

In Yemen, the cultivation and commercialization of qat represents a very important sector for the country’s economy with 12 percent of the agricultural area in the country and making more than 40 percent of the agricultural GDP and around 6 percent of Yemen’s total GDP. The vested interests in this industry are therefore important, so is the use of groundwater for cultivating this special type of crop. Many farmers and intermediaries depend on its cultivation and commercialisation, a challenge when it comes to control and potentially reduce groundwater use for qat cultivation. In terms of water consumption, it has been estimated that qat accounts for a third of Yemen’s current water consumption (Walz 2010; Wulfsohn 2013), representing 50 percent of the irrigated area in the country (FAO 2009).

Qat production increased from only 7,000 hectares in 1970 to over 150,000 hectares in 2009 and the crop is grown by 43.6 percent of Yemen’s agricultural landholders (with 85 percent of production found in the highlands, concentrated mainly in five governorates) (Al-Weshali et al. 2015). According to the Ministry of Agriculture, in 2012 qat production area had reached 158,546 hectares with a 2.12 percent expansion annually (Al-Yazidi 2015). Assuming that groundwater is used as a supplementary source and that qat consumes 5,000 m³/hectare/year, its total consumption will tend to be about 21 percent of the total agricultural water consumption and 31% of the renewable resources (ibid.).

It has been estimated that over 6.7 million people depend directly or indirectly on qat cultivation and trade (34.2 percent of Yemen’s population). After the 1970s, a rapid increase in incomes; an increase in crop profitability; the introduction of tubewells; and the improvement of transport networks allowed for qat to be massively produced, transported and sold across the country. It is also believed that the government policy on diesel subsidies is one of the reasons that stimulated large-scale groundwater pumping to irrigate, amongst other crops, qat

⁷⁷ Section based on Gatter (2013) unless indicated otherwise.

(Al-Weshali et al. 2015). Quick revenues generated by qat also act as incentives for farmers to continue drilling wells and for drilling rig owners to offer beneficial financial schemes to repay for the investment (usually as part of the revenues generated by the first qat crop once it has been harvested) (FMWEY 2015).

Qat is produced mainly in mountainous areas (above 800 meters) and 44 percent of land plots growing qat are irrigated with pumps and even tanker trucks, although in the central highlands this is nearly 100 percent due to lower rainfall (Figure 49). Qat irrigation and household drinking water needs have become in some areas direct competitors and instances of violence and conflict amongst farmers are not rare. These conflicts can also involve the state and they can be violent in some cases.^{78, 79} The high cost of qat drains economic resources from the household budget which are spent to buy qat instead of basic products (e.g. food) (reportedly some 72 percent of men and 33 percent of women chew qat). High prices for qat and subsidies allowed for a booming expansion of the cultivated area. Moreover, its high productivity ensured the best financial return for farmers at 50-90 US cents/m³ against a cost of water that rarely exceeds 10 US cents/m³ (RIs 15/m³) (data from 2000).

Taxation over qat is low as the state does not have the means to establish a well-functioning tax collection system. Road checkpoints are supposed to control and limit the transport of qat but corruption of officers is widespread and for a few bags of qat they let drivers pass. These are however limited in areas outside the main capital and in some cases whole areas were exempted from the Qat tax as a means of patronage of the Salih regime (in the Hamdan area, home to many military officers, or Salih's original tribal area). For those governorates taxing qat (with more or less success), this crop alone represents more than three quarters of their tax income (up to 68 percent of the tax revenue in Zakat). Conflict has also affected revenues from qat for the central government. In the area of the Sa'da governorate, revenue from qat taxation stopped pretty much at the same time as the 6th war in the Houthi Conflict. Until then the government was able to maintain the checkpoints and thus ensure a flow of cash from tax revenues.

The use of tubewell technology to tap groundwater in Sa'da's arid central plateau and basin zone in the north east of Yemen has driven intensive agriculture since the 1970s. Qat production as well as fruit benefited from diesel subsidies making irrigation highly profitable as well as a newly paved road between Sa'da and Sana'a (Yemen's capital) and the government's ban on fruit and vegetable imports in 1984.

In 2003, 30.9 percent of Sa'da landholders owned irrigation pumps (whilst the national average was just over 10 percent). The Sa'da governorate is made up of smallholders with 43.9 percent of them owning less than half a hectare of land for cultivation. In 2003 qat was grown in 39.7 percent of farm plots in the governorate, representing 27.3 percent of the population in Sa'da (a

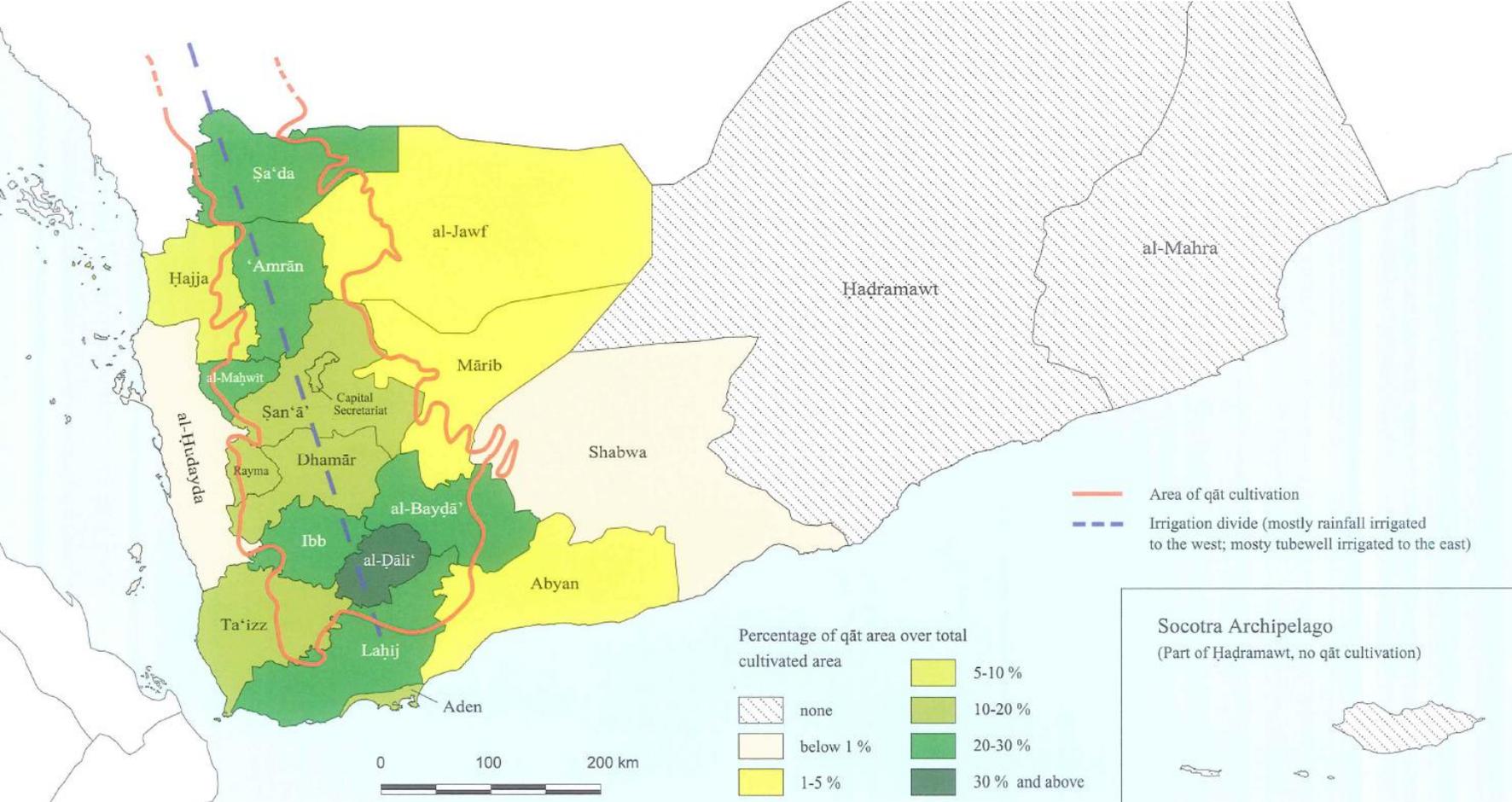
⁷⁸ According to the Yemen Times, a confrontation between qat farmers and government forces broke out on the 30th of September 2013 in Wadi Al-Ghail in Ibb governorate after the state-run Public Electricity Corporation started digging a well in the area. A shooting followed between military forces and farmers after an attack on the corporation employees. Military vehicles arrived at the scene to confront the qat farmers fearing for their livelihoods believing that the new drilled well which will be used to abstract groundwater for approximately 60,000 residents will negatively impact the availability of groundwater for their crops. Yemen Times 2013, <http://www.yementimes.com/en/1716/news/2955/Water-scarcity-and-qat-irrigation-led-to-clashes-in-ibb-and-Taiz.htm>, (Accessed 12th January 2014).

⁷⁹ According to the government, there would be up to 4,000 casualties per year due to conflicts in Yemen over water (<http://www.scidev.net/global/water/news/water-death-yemen-conflict.html>) (Accessed 29th June 2015).

high disparity within the governorate meant that some districts were more dependent than others on qat, with the Haydan district cultivating qat in 50.1 percent of its farming surface).

The history of Sa'da governorate has been conflict-prone, with five wars with rebel groups against the central government between 2005 and 2010. This however did not stop the government from collecting taxes on qat consumption through the conflict. According to Handley (2001), taxes (zakat) on crops are paid to the government via the local leadership. In 2003, the year before the hostilities against the central government started, qat cultivated area in the Sa'da governorate represented 5.1 percent of total qat cultivation area in Yemen and yet only 1.1 percent of the country's total qat consumption taxes were collected there. The reported lack of tax leverage by the government in that area can be linked to the traditional low control levels over tribal lands where qat markets were set up thus avoiding government's checkpoints, and the fact that qat was mostly exported to other parts of Yemen and Saudi Arabia whilst the government tax is on consumption.

Figure 49. Share of qat cultivation in agriculture areas in Yemen



Source: Gatter 2013.

7.4 Community and groundwater management in Yemen

7.4.1 Community management rules

Community rules allow for allocation of groundwater, access and compensation mechanisms to be established between groundwater users (Bruns and Taher 2009; Taher et al. 2012; Van Steenberg et al. 2012). An ample selection of types of rules is found in the literature and also reviewed in this report, including rules for banning well drilling, well spacing, spring protection by zoning, closure of disputed wells, agreements on reservoir operation, and joint user associations to regulate new well development. In the Ta'iz governorate, Yemen, well owners contravening spatial proximity rules to other wells can compensate their neighbours by supplying water if the neighbouring well is affected or by agreeing to cease pumping if a certain water level is reached (Handley 2001). These agreements are done via informal local structures of negotiation (with the intermediate of the sheikh) as the claiming owner knows that the government courts are likely to 'lean' to the highest bidder and take time in the resolution of the matter. The local sheikh is therefore privileged, provided that the two parties trust him to give a fair jurisdiction (ibid.). Observations made by this author about the process of local mediation and negotiation suggest that "the more local (bottom-up) the process of arbitration (that is, local customary law, court location and arbitrator), the more likely and acceptable solution will be found and law enforcement will be possible" (Handley 2001: 166).

Although not as tribal as in the north of Yemen, sheikhs in the Ta'iz governorate are typically a senior community member who is elected by the local families on the basis of his knowledge of customary law. These institutional figures are 'the local political reality' (ibid.) and cannot be bypassed at any stage of water management. These figures have also a strong presence in the capital in the form of parliamentary members (mostly sheikhs and land lords and very few professional politicians) (FMWEY 2015). In some areas of the country however, farmers did not find any interest in becoming members of a user association as this could be far away; they were too old; they did not like the responsibilities associated with becoming a member; they had no time; registration to become a member had not started yet; or becoming a member was costly and reserved to limited number of community members (especially sheiks and village leaders) (FMWEY 2015). Likewise, farmers in Sana'a and Taiz already discussed their problems with the neighbours and therefore did not see the point in becoming members of a user association (Hellegers et al. 2008).

7.4.2 Conflict resolution mechanisms

Water conflicts are rarely brought to civil court. This is due to the fact that "faith in the fairness of the courts is limited, due to corruption and the politicization of officials. In addition, although traditional arbitration is also costly to conflicting parties, the cost of settling a conflict through judicial means is in many cases considered to be too high, which prevents people from seeking justice through the legal system. Consequently, most of the cases are resolved within the local communities according to local traditions, as these are familiar to and relatively more affordable for a large group of people" (The Hague Institute for Global Justice 2014: 5).

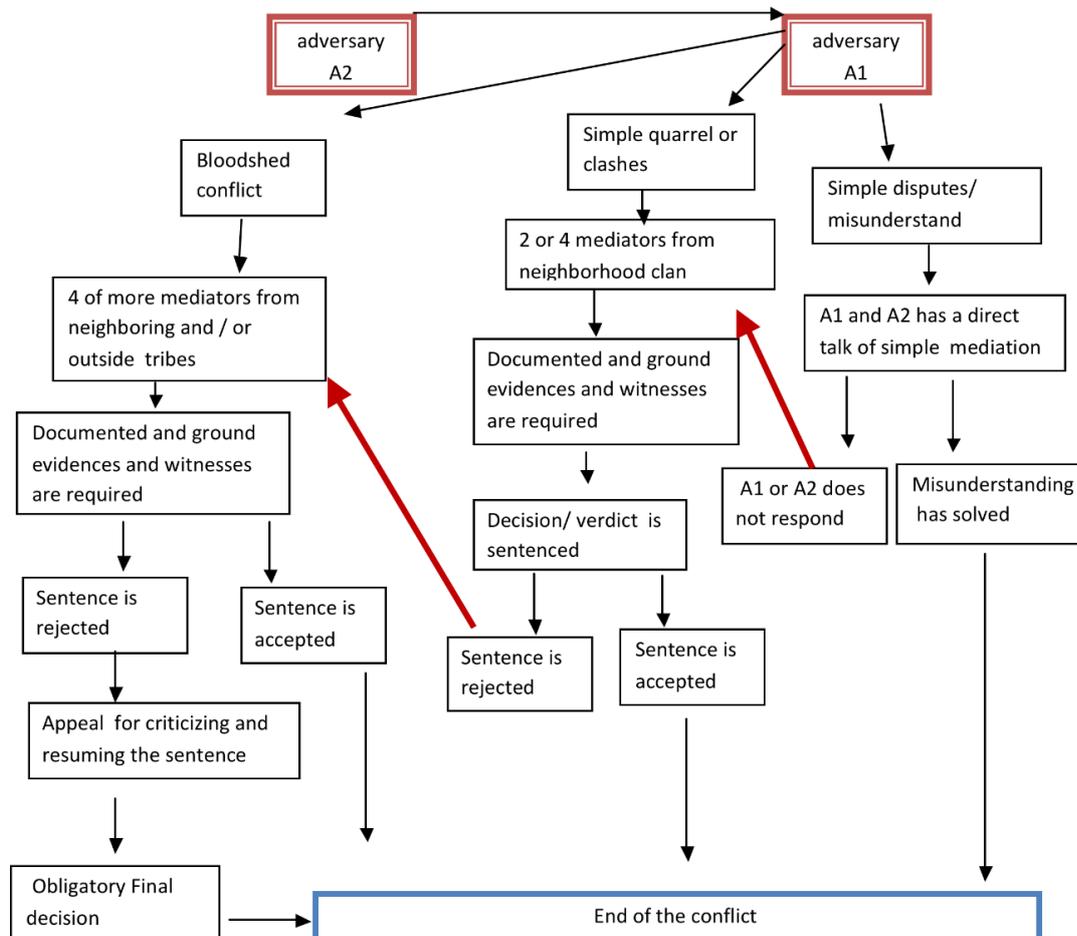
In the absence of law enforcement and state prestige, it is not rare that water access or allocation conflicts develop into bloodshed clashes not only between individuals but also between clans and tribes. Widely reported instances include those between Khuradah and Almarzoh clans in Taiz governorate and Ahl Bin Flis and Ahl Bin Hasan in Tulop –Ya'fa land in the

Abyan governorate (Al-Yazidi 2015). “According to an unpublished estimate, based on the criminal court cases, each year 2,500 people die as a result of a water-related conflict. Approximately one-third of the cases brought before the criminal court (and thus involve killings) are water-related cases” (The Hague Institute for Global Justice 2014: 5). Before these instances arise however, conflicts are mediated following traditional rules.

As described by Al-Yazidi (2015) focusing on the Ya’fa tribes of the Abyan governorate, the resolution of conflicts between water users follows a complicated system (Figure 50). Individual users who have not responded to direct talks or the intervention of mediators within a conflict situation can be requested to appear in front of their clan through the mediation of 2 to 4 arbitrators who will come up with resolutions that will meet the interests of both sides. Arbitrators are asked for evidence and witnesses that will prove the claims of each of the parties. If the dispute has resulted in some kind of bloodshed or serious damage, conflicting parties will select 4 or more mediators (or those will be appointed), usually from neighbouring tribes.

Such mediation is usually started by volunteers who initiate communications between the conflicting parties in order to stop further escalation and attempt to resolve the conflict. Volunteers can continue the mediation and arbitration task themselves, they can add somebody else or they can establish a new arbitration team (committee). The conflicting parties have nothing to do with selection of the arbitrator team, but each of them can select one representative who can defend his interests, as one might use a lawyer, in front of the arbitrator team. Solutions ruled by the arbitrators in such instances when the conflict has escalated are obligatory for both conflicting parties. If these are not accepted however, both conflicting parties can resume the procedure in front of a new group of arbitrators who will review the sentence. If this new group of arbitrators proves that the previous sentences are wrong, the previous group of arbitrators will pay the cost of their arbitration and prove that their original ruling was appropriate. After the review, either sentence will be implemented as the final decision.

Figure 50. Conflict resolution in the Ya'fa tribes



Source: Al-Yazidi 2015.

7.4.3 Dismembering local traditions

As mentioned above, corruption and patronage networks not only had an impact on central politics and state rule but also on local communities, impacting traditional structures of community rule and leadership. As the former President Saleh “deliberately co-opted sheikhs to secure tribal loyalty, which increased the dependency of sheikhs on the government”, he also “divided tribes and stimulated tribal conflicts by, for example, appointing local individuals as sheikhs, who are often without status or experience in customary law or tribal traditions. This undermined the authority of authentic sheikhs and created competition and divisions along tribal lines. [...] the authority of sheikhs further declined as a result of the 2011 revolution” (The Hague Institute for Global Justice 2014: 2-3). The use of groundwater in rural areas for agriculture has contributed over the years to a shift in the local structure of power (through economic means via land co-optation) in Yemen, “offering even greater power to sheikhs and influential elites, which led to the marginalization of smallholders in rural areas and the urban poor” (The Hague Institute for Global Justice 2014: 29). With the death of the elder generations, local traditional authority is disappearing and the new leadership is less powerful at the local level, involved in political struggles and affected by the legitimacy crisis that impregnates all levels of formal government (The Hague Institute for Global Justice 2014).

The example of the Tihama Plain in the Hudaydah governorate is symptomatic of this trend, exemplifying Yemen's agrarian and socio-economic and cultural changes. Agrarian change originated in the 1980s, leading towards a gradual process of agriculture commoditization. Additionally, "[e]xternal forces (subsidized inputs, cheap fuel, ban on imports, cheap land, etc.) all contributed to the attractiveness of investments in the Tihama [Hudaydah governorate] by newcomers, in many instances urban businessmen. At the same time, several local farmers migrated to Saudi Arabia in search for better remunerated labour. This process was paralleled by social differentiation and weakening of power and authority of traditional local leadership i.e. sheikhs. Altogether, this meant a decrease in the levels of trust and cooperation, and an increase in individualism and opportunism. Customary laws and traditional rules concerning water access, distribution and use, once so fundamental for local social organization around water management and farming and for socio-economic development, have been gradually losing importance and strength in the wadi in the last decades. The new investors who lack knowledge and respect for traditional irrigation practices, have aggravated this situation." (The Hague Institute for Global Justice 2014: 134).

With the revolution in 2011, the lack of "rule of law creates opportunities for individual sheikhs and other powerful individuals to garner wealth through claiming new land and water resources without being confronted by local resistance" (The Hague Institute for Global Justice 2014: 3). The capacities of local rulers to impart justice and find legitimacy have also eroded. Practices of community rule are bound by protocols with different degrees of sophistication (Figure 50). Newly appointed sheikhs and their capacity to deal with conflicts has decreased, as they "either lack knowledge, or their involvement in patronage systems prevents them from operating in the service of their community" (The Hague Institute for Global Justice 2014: 5).

8 Annex 2

8.1 The state and political systems in the Arab world

As the state is an important actor and almost an entity per se in this study, a digression is relevant in order to clarify concepts and processes originating within the political, institutional and bureaucratic apparatus of the state, which in turn affect the development and structure of groundwater governance and politics in the Arab World. This study is also interested in understanding the limits of state action and regulation regarding the management and regulation of groundwater. More broadly though, and as will be described later, these limits can be internal, related to the state's own political and administrative structures, and can also be external, affected by other actors such as local communities and users.

Following Ayubi (1995), three opposing features seem to be recurrent within Arab states: 1) formal and centralizing structures of state power, regulation and control; 2) the role of informal linkages and institutions within society; and 3) the increasing role of the market and its impact on Arab national and local economies.

The first feature embodies the need to develop and materialize centralizing structures of formal state power, regulation and control arising from the process of decolonization and the breaking of the Ottoman Empire, reflecting on larger political processes, national-level institutions and the characterization of wider political economy, legal and bureaucratic systems (ibid.). Until the Arab Spring, the study of politics and state systems in the Middle East was characterized mainly by the emphasis on authoritarian regimes and a focus on the 'democracy lag' in the Middle East (c.f. Posusney 2004). As a trend, these approaches were in many cases part of a prevailing cultural theory about the persistence of authoritarianism in the Middle East, sometimes permeated with orientalist attitudes positing an intrinsic incompatibility between democratic values and the Islamic religion (ibid.). The Arab world was portrayed to be in constant tension between religion and state and yet in some contexts such as Egypt, political systems allowed for both to exist, moderating long-term objectives for Islamic groups in a direction that can embrace certain democratic values (e.g. political parties and representation) although not necessarily in a secular framework of separation between religion and state (ibid.). Institutional political configurations in authoritarian regimes were also able to create openings for different types of political and social participation based on diffused and local community interventions from groups such as the Muslim Brotherhood and the 'Wasat' movement in Egypt (Wickham 2004 in Posusney 2004).

The second feature, on the contrary, focuses on the role of informal institutions, social and cultural networks of kinship and patronage within the context of local communities and networks of nepotism all the way to the top of the formal structures of state power (Ayubi 1995). These networks, and local and personal political processes, make the substrata of wider regional and national politics across political and social scales from local communities to higher instances of government authority and rule (e.g. networks or patronage, social capital and wealth linked to land ownership, favouritism and rent-seeking activities). At this level, characterizations of Arab communities and societies purport the role of local community processes, power, and traditions, arising from a more anthropological and sociological understanding of these phenomena and reflect underlying mechanisms of social organization, structure and rule. This second avenue, which would also include conceptions of tribalism in the Middle East and the extent and effects of values and norms in specific social groups and communities, emphasizes indigenous community processes driven by trust, cooperation and local rule occurring within civil society. These norms in tribal cultures such as in Jordan

manifests itself in the establishment and continuation of consensual processes and ad hoc conflict resolution within the context of wide-ranging social networks, which in turn come from a seamless and more extensive web merged with wider state processes, - rather than a dichotomy between both (Antoun 2000).

Coupled with the third strand of studies focusing on market forces and their impact on Arab societies, these processes seem to operate at the same time in the underbellies of state politics (Ayubi 1995) and as it happens they will be mentioned in this research, reflecting different elements which are again relevant for our study on groundwater governance and groundwater politics in the Arab World in as much as they can both illustrate and complement the study of systems of groundwater abstraction, regulation, management and ultimately governance. As Antoun (2000) elaborates, an intricate and complex reality of historical norms, traditions, communities, politics and social rules seems to be at play across states and societies in the Arab world. As this author reflected however, the more common views of civil society and social institutions in the Middle East focus on formal associational life, political parties, elections, rights of citizenship, or limitations on the arbitrary exercise of state authority but have often left aside indigenous institutions, interpersonal relations or informal institutionalized relations (ibid.). Although these views allude to traditional structures such as religious networks, tribes, and patron-client relations, they do not give them proper attention.

The evolution of the Arab state and its power and bureaucratic structures portrays a complex system where law, interests, customs, and informal arrangements exist and can thrive. As Bensman (1987: 70) also put forward, “older practices of bribery, baksheesh, the purchase of favors, and the particularism of class and status became vehicles for facilitating bureaucratic administration” and, by extension, of government function and rule. In Yemen for instance, extensive networks of patronage reaching outside the inner circles of the ruling family and its entourage and including all elites in the country in order to ensure their adherence and compliance to government rule (Van Steenbergen et al. 2015

Traditional forms of social capital and network in the Arab World (called ‘*wasta*’), served as mechanisms to provide social status and community recognition as well as alternatives to the provision of services and resources by the state (El-Said and Harrigan 2009). In Jordan however, the advent of a more capital and market-based society helped pervert this system, evolving towards patron-client relations and creating corruption and bribery as a malformation of this traditional system (ibid.). This rent-seeking culture in the Arab World and its relation with factionalism and corruption (Hafez 2009) has transpired over the years to different instances of government and water management and irrigation are not an exception (Elshorst and O’Leary 2005; Huppert 2013; Huppert and Wolff 2002; Transparency International 2008). The following sections will explore in more detail the different instruments used by the state, and communities to control and regulate groundwater abstraction and the differing problems across the region for its implementation and enforcement.

8.2 Characterizing the Arab State

The concept of ‘the state’ is traditionally associated with a specifically bounded territory over which a supra-individual apparatus exercises a monopoly of coercive authority, legitimacy via symbols and shared history providing an ideological rationalization and justification for this monopoly of coercion (Khoury and Costiner 1990). In the Middle East and North Africa however, the process of state formation has been evolving, leading to a constant re-arrangement of political and social forces (as seen during and after the so-called ‘Arab spring’). Monarchs, the military, and other elites have faced various degrees of difficulty in trying to build exclusive monopolies of authority and control bringing different instances of change or otherwise

concessions to social, religious or political groups (ibid.). Additionally, the very process of state formation during the twentieth century led to the voluntary or forced breakup of traditional norms and forms of tribal authority and the erosion of old tribal loyalties. This created new groups and movements within the state retaining certain traditional characteristics but immersed in modern processes of economic development and industrialization, class, ethnicity and nationalism (ibid.). These events and complexity of civil society movements do not allow for the representation of the notion of 'a state' as a unique and monolithic entity exercising authority and power. The state is represented instead as one of a number of social formations whose structures and functions do not necessarily correspond to the model of the European state in contemporary terms (ibid.).

The fact that the externally imposed nation state in the Middle East and North Africa during colonization was defined as a national and not as a communal polity has also generated over time a variety of forms of government and rule in the region. The supposition that this form of government was to be based on sovereignty required an established citizenship and a corresponding national loyalty and identity, something that clashed with a lack of social and institutional infrastructure (Tibi 1990). Moreover, the conflict originated with the dual legacy of the Ottoman Empire and Colonialism brought the division of society along confronted lines. The Ottoman legacy emphasized pre-national identities and loyalties based on religion (Muslims and non-Muslim divided along religious and ethnic lines) whilst the legacy of European colonialism brought the instrumentalization of existing tribal-ethnic and religious divisions in society. These two opposing forces have simultaneously mobilized a unifying nationalism as a reaction to colonial rule and a divisive tribalism following reinvigorated identity values (ibid.). Bureaucracies in turn served to provide prestige, esteem, jobs, and favours to the members of the relatively small middle and upper strata existing in these societies (Bensman 1987). For this author, "the creation of bureaucratic offices was an attempt to provide social and economic status and opportunities for surplus members of the middle and upper classes [...] to prevent the disaffection of members of these classes who could, in their dissatisfaction, become a source of revolutionary opposition" (Bensman 1987: 67).

This heritage brought the representation of some of these societies as strong although existing within weak states (Migdal 1985 in Tibi 1990). This way of characterizing Arab societies was used as a way to explain the fragmentation found in Middle Eastern societies when it comes to putting together communities and formal political apparatuses. The tensions between community and traditional norms and the rule of law are considered the main cause for these fragmentations. A similar hypothesis is encapsulated in the idea 'tribes with flags' as one of Tahseen Bashir's memorable political phrases referring to all countries in the Arab world except Egypt.⁸⁰ The lack of proper and functioning formal institutions in these newly established nation-states to cope with the social and economic problems created by the rapid economic

⁸⁰ The sentence was mentioned in Neil MacFarquhar's Times obituary for the Egyptian diplomat Tahseen Bashir in 2002. The original sentence by Tahseen Bashir was: "Egypt as the only nation-state in the Arab world, the rest are just tribes with flags", <http://www.nytimes.com/2002/06/14/world/tahseen-bashir-urbane-egyptian-diplomat-dies-at-77.html> (Accessed 3rd November 2013). This was later used by Thomas Friedman in his article for the New York Times in March the 22nd 2011 (without referring to these previous references) mentioning that there are two kinds of countries in the Middle East: those that are 'real countries' with long histories and strong national identities (Egypt, Tunisia, Morocco, Iran) and those that could be called 'tribes with flags' or more "artificial states with boundaries drawn in sharp straight lines by pens of colonial powers that have trapped inside their borders myriad of tribes and sects who not only never volunteered to live together but have never fully melded into a unified family of citizens" (Libya, Iraq, Jordan, Saudi Arabia, Syria, Bahrain, Yemen, Kuwait, Qatar, and the United Arab Emirates). As the article continues, "[t]he tribes and sects that make up these more artificial states have long been held together by the iron fist of colonial powers, kings or military dictators." <http://www.nytimes.com/2011/03/23/opinion/23friedman.html> (Accessed 9th January 2014).

development and population increased has meant that society had to resort to its pre-national ties as a solution thereby preserving and encroaching patron-client relationships (Tibi 1990).

This leads us to what Ayubi (1995: 2) has called the 'Arab specificity' needed to be appraised and understood when studying the state, politics and society in the Arab world.⁸¹ The object of Ayubi's research is however an 'over-stated Arab state', one in which its real power, efficacy and significance might have been overestimated. Although this 'Arab state' is a 'fierce state' frequently coercive so that it can preserve itself, it is however not a 'strong state' as it lacks in varying degrees the infrastructural power to access and regulate its subjects effectively (e.g. through taxation), and it also lacks ideological hegemony enabling it to "forge a historic social bloc that accepts the legitimacy of the ruling stratum" (Ayubi 1995). Thus, according to Ayubi, we are presented with a more 'corporate state' ranging between a more 'organic', solidaristic and communitarian strand on one end (e.g. Gulf states) and a more organizational and interest-based, populist and socially and mass-mobilisational strand on the other end (e.g. Egypt during Mubarak) (ibid.). For this author, the concept of 'corporatism' allows to link the concepts of community (understood in the terms of ethnic or religious community) and that of the state (understood as this imported European concept arising from colonial rule and imitation) and reflect the way in which various 'corps' act or are utilized are intermediaries between the community and the state (ibid.).

⁸¹ This 'Arab specificity' exists for Ayubi (1995: 2) as much as there is a European or American specificity in politics, far though from orientalist claims on its "utter peculiarity and uniqueness".