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IMPACT OF SALTWATER INTRUSION ON AGRICULTURAL PRODUCTIVITY AND WATER USE AMONG COASTAL COMMUNITIES

by
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AN ABSTRACT OF THE THESIS OF

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Coastal aquifers are vulnerable to potential saltwater intrusion due to overexploitation of groundwater and potential climate change impacts such as sea level rise, altered precipitation patterns, and decreased groundwater recharge. In its turn, saltwater intrusion poses a threat to agricultural productivity due to increased salinity that is invariably damaging to soils and plantations. This study assesses the quality of groundwater resources at a pilot area along the Eastern Mediterranean (South Lebanon) with a special reference to saltwater intrusion using specific salinity indicators. It then examines the economic impact of saltwater intrusion on agricultural productivity of an important coastal crop, banana, in the pilot area.

While the overall groundwater quality was reasonably acceptable, evidence of secondary saltwater intrusion was recorded. Banana farmers are apparently using both groundwater and surface water resources for crop irrigation, an unplanned effort reducing the impact of groundwater salinity on banana production. With the expected increase in impacts of climate change on water resources, the conditions can deteriorate justifying the development of mitigation measures and adaptation strategies, to control or adapt to potential impacts of saltwater intrusion.

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ABBREVIATIONS

CDR Council for Development and Reconstruction

CS Council for the South

DC Dwarf Cavendish

EC Electrical conductivity

EERC Environmental and Engineering Research Center

GC Giant Cavendish

GIS Geographic Information System

GQI Groundwater Quality Index

GQI_{SWI} Groundwater Quality Index Saltwater Intrusion

LARI Lebanese Agriculture Research Institute

LRA Litani River Authority

MoA Ministry of Agriculture

MoE Ministry of Environment

MoEW Ministry of Energy and Water

MoIM Ministry of Interior and Municipalities

MoPH Ministry of Public Health

NPK Nitrate-Phosphorus-Potassium fertilizer

PS-SW Primary Salinity - Saltwater

RWE Regional Water Establishments

SA-FW Secondary Alkalinity - Freshwater

SAR Sodium Adsorption Ratio

SLWE South Lebanon Water Establishment

SS Secondary Salinity

TDS Total Dissolved Solids

TH Total Hardness

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CHAPTER 1

INTRODUCTION

The vulnerability of water resources to climate change impacts has been at the forefront of global climate change research. These impacts are reflected in many regions by a decrease in precipitation and an increase in temperature leading to an increase in the net demand for water (IPCC 2014; EPA 2014). Groundwater resources in coastal zones are particularly sensitive in this context because of decreased aquifer recharge (lower precipitation) and increased net water demand (higher temperature) resulting in higher groundwater abstraction rates and saltwater intrusion (Rasmussen *et al*. 2013), potentially exacerbated by sea level rise also associated with climate change. As such, the susceptibility of coastal groundwater resources to saltwater intrusion has evolved to become a challenge of global proportion with the Mediterranean and South-Atlantic coastal aquifers being highly affected (Stigter *et al*. 2014). The situation is particularly critical in arid and semi-arid climatic regions of the Eastern Mediterranean, where freshwater resources are limited in comparison with continuously increasing water demands (De Montety *et al*. 2008; Masciopinto 2013). Overexploitation and mismanagement coupled with climate change impacts increased the potential of saltwater intrusion, which can negatively affect agricultural production and yield of coastal crops through the accumulation of salts causing adverse effects on both soils and crops. Soil salinity reduces water infiltration rates reflected by the breakdown of soil aggregates and the dispersion and swelling of clay minerals, which result in poor crop establishment. Moreover, groundwater salinization increases the presence of salts in the root zone, which exercises an osmotic effect on plants forcing them to exert more energy to extract water from the soil and hence consuming this energy instead of using it for growth, flowering or fruiting and thus, the plant's ability to grow is ultimately stunted (Blaylock 1994). Increased salinity also reduces plant growth and yield through ion toxicity, defined mainly by an accumulation of Na^+ and Cl^- ions (Grattan 2002; Rahman *et al*. 2011) which employ competitive interactions with other nutrient ions (e.g. K^+, NO_3^-, $H_2PO_4^-$) for binding sites and transport proteins in root cells causing nutrient imbalance in plants (Ondrasek *et al*. 2010). Ion toxicity affects crop production directly as diminished nutritional relations (Ca^{2+}/Na^+ and K^+/Na^+) decrease the crop's economic and nutritional value due to reduced fruit size and shelf life, non-uniform fruit shape, and decreased vitamin content (Ondrasek *et al*. 2010). Such effects of salinity on soils and crops can be defined by the interrelation of the electrical conductivity either in the irrigation water (EC_w) or in the root zone (EC_s), and the sodium adsorption ratio (SAR) (Grattan 2002). Other indicators such as molar ratios and Groundwater Quality Indices (GQIs) have been commonly used to classify the groundwater quality of coastal aquifers with special reference to saltwater intrusion (De Montety *et al*. 2008; Delbani *et al*. 2013; Babu *et al*. 2013; El-Moujabber *et al*. 2006; Ekhmaj *et al*. 2014; Odemis *et al*. 2006 and Soni and Pujari 2010). The Piper Diagram is also used to infer hydro-geochemical facies and define chemical relationships among groundwater samples (Piper 1944; Sadashivaiah *et al*. 2008).

The physiological impacts of salinity on soils and crops, the loss in crop yield and the decreased quality of crops reduce the economic attractiveness of salt-sensitive coastal crops (Mokhtari 1999; Palacios *et al*. 2000; Naifer *et al*. 2011) that have low tolerance for salts. In this context, this study assesses the impacts of saltwater intrusion on agricultural productivity and water use for irrigation. For this purpose, groundwater characterization was conducted along a pilot coastal agricultural area in south Lebanon (Figure 1) with special reference to saltwater intrusion and associated economic implications highlighting potential mitigation measures and adaptation strategies. The pilot area, which relies partially on groundwater resources for crop irrigation, was selected based on field screening surveys involving multiple site visits and interviews with key informants. The main crops that are grown in the area consist mainly of banana and citrus, both salt-sensitive and susceptible to the effects of irrigation with saline water (Arvanitoyannis and Mavromati 2009; Storey and Walker 1999; Tanji and Kielen 2002).

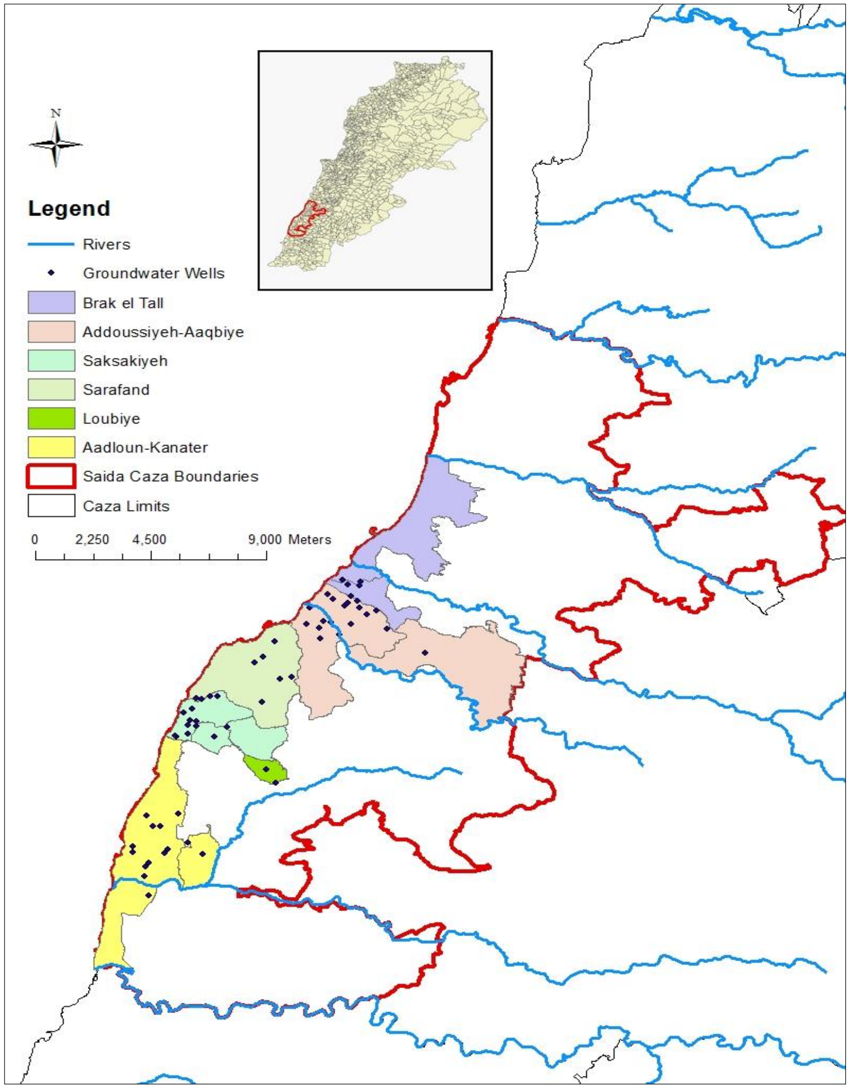

Figure 1 Pilot study area with irrigation wells

CHAPTER 2

MATERIALS AND METHODS

A. Groundwater Characterization

Groundwater samples were collected over three rounds in October 2013, May 2014, and October 2014 from wells along coast of the pilot area (Figure 1). A total of 60, 61, and 55 samples were collected in the three sampling rounds, respectively with the aim to capture the seasonal difference with respect to salinity (dry and wet) and to evaluate the spatial extent of saltwater intrusion in the pilot area. The samples were analyzed at the Environmental Engineering Research Center (EERC) at the American University of Beirut (AUB) for relevant physical and bio-chemical parameters such as pH, TDS, EC, total hardness, calcium, magnesium, alkalinity, chlorides, bromides, sodium, potassium, nitrates, and sulfates following standard analytical methods (APHA/AWWA/WEF 2005; WHO 2003; WHO 2011) as outlined in Table 1.

Table 1 Analytical methods for water quality analysis

Quality Indicators	Analysis	Reference
pH, Conductivity	Electrochemically	APHA/AWWA/WEF 2005
TDS	Gravimetry	WHO 2003
Cl^-	Silver Nitrate Titration	
NO_3^-, SO_4^{2-}	Spectrophotometry	
Alkalinity	HCl Titration	APHA/AWWA/WEF 2005
Total Hardness, Ca^{2+}, Mg^{2+}	EDTA Titration	
Na^+, K^+	Atomic Absorption Spectroscopy (Photoelectric Flame Photometry)	WHO 2011
Br^-	UV-VIS Spectrophotometry	

Saltwater is characterized by the presence of chloride (Cl^-) and sodium (Na^+) ions, which make up to 84% of the total ionic composition, while freshwater is mostly comprised of calcium (Ca^+) and bicarbonate (HCO_3^-) ions. The hydro-chemical parameters were used to examine the correlation strength between groundwater quality properties (Karahanoğlu 1997; Ebrahimzadeh and Boustani 2011; Prasanna *et al.* 2010; Narany *et al.* 2014). The existing relationships among various parameters are then used to identify the origin of salinity. Pearson's correlation analysis, assuming linear correlation, was conducted among parameters for the three seasons.

Molar ratios (Table 2) based on the hydro-chemical characteristics of the well water samples were also used to evaluate the occurrence of saltwater intrusion, by distinguishing saline water from freshwater. The concentrations of the water constituents were converted from milligram per liter (mg/l) to milli-equivalent per liter (meq/l). Consequently, the molar ratios were calculated based on meq/l values for each constituent. The main molar ratios indicative of saltwater intrusion are the Na/Cl, Br/Cl and $Cl/(HCO_3+CO_3)$ ratios. Additional molar ratios, such as HCO_3/Cl, SO_4/Cl, and Ca/Cl are also used to detect the origin of groundwater salinity (Vengosh and Rosenthal 1994; Saou *et al*. 2012). Saline water, associated with saltwater intrusion is characterized relative to seawater by low Na/Cl ratios. Combined with other geochemical parameters, low Na/Cl ratios could be an indicator of the origin of salts, even at relatively low Cl^- concentrations, during the early stages of salinization. The low Na/Cl ratio is distinguishable from the high Na/Cl ratio (> 1), which are typical of anthropogenic sources like domestic waste (El

Moujabber *et al*. 2006). The HCO_3/C1, SO_4/Cl, and Ca/Cl ratios that are negatively related to the increase in the $C1^-$ concentrations are indicative of salinization processes. This is a result of the dissolution of soluble salts occurring in the surrounding aquifer rocks which leads to an increase in the concentration of $C1^-$ ions and a gradual decrease in HCO_3/C1, SO_4/Cl, and Ca/Cl ratio values (Vengosh and Rosenthal 1994). In the event of saltwater intruding into an aquifer, Ca^{2+} is released and consequently the Ca-Cl water type, representing secondary salinity, is developed (Saou *et al*. 2012).

Table 2 Main hydro-chemical indicators of saltwater intrusion

Molar Ratio (meq/l)	Justification for Use	Reference
Na/Cl	Low ratios are indicative of saltwater intrusion, as Na/Cl ratios of coastal aquifers, subject to saltwater intrusion, are usually lower than the marine values	Babu *et al*. 2013; El Moujabber *et al*. 2006
Br/Cl	Low Br/Cl ratios indicate high Cl^- concentrations and hence the effect of saltwater intrusion	Lee and Song 2007
Cl/(HCO_3+CO_3)	Used to contrast the relative abundance of the dominant seawater and freshwater anions, high ratios indicate the effect of salinization	Ekhmaj *et al*. 2014

A Piper pattern diagram was used to distinguish between saline and freshwater sources, thus giving an indication of saltwater intrusion. Multiple indices such as the Groundwater Quality Index (GQI) were developed by transforming the concentrations of water quality parameters into qualitative scores to provide a better understanding of groundwater resource dynamics and ultimately serve as a comprehensive tool for policy and decision makers (Adhikari *et al*. 2012; Babiker *et al*. 2007). In this context, while generalized GQIs serve to categorize the state of groundwater quality, a more specific GQI, tailored specifically to the assessment of saltwater intrusion, is helpful in understanding the extent of saltwater intrusion. The salinity-specific GQI for Saltwater Intrusion (GQI_{SWI}, %) translates information from the Piper diagram and assesses the fraction of seawater (fsea)[1] (Equation 1) generating a two-stage numerical indicator for seawater intrusion (Tomaszkiewicz *et al*. 2014). The development and interpretation of the GQI_{SWI} is represented in Equation 1 to 5 and illustrated in Figure 2, whereby the middle diamond-shaped field of the Piper diagram is divided into six domains (or subsections) I, II, III, IV, V, VI, representing Ca-HCO_3, Na-Cl, mixed Ca-Na-HCO_3, mixed Ca-Mg-Cl, Ca-Cl, and Na-HCO_3 type waters, respectively. Domain I represents freshwater whereas domain II represents saline water. The horizontal line across the center of the diagram denotes the mixing of freshwater and saltwater which is represented numerically by the GQI $Piper_{(mix)}$ (Equation 2) that defines the mixing of saline and fresh water and ranges from 0 (representing Na-Cl type waters with high salinity i.e. Domain II) to 100 (representing Ca-HCO_3 water types that are highly fresh i.e. Domain I). The GQI $Piper_{(mix)}$ is also used in conjunction with the GQI $Piper_{(dom)}$ (Equation 3) that defines the mixing of secondary saline and primary alkaline water, and is equally scaled from from 0 (representing Ca-Cl type waters i.e. Domain V) to 100 (representing Na-HCO_3 type waters i.e. Domain VI).

The seawater fraction, *fsea*, is also used as a groundwater quality index, GQI_{fsea} (Equation 4), which serves as a more representative saltwater index. The GQI_{fsea}, in

[1] Fraction of seawater (fsea), a common tool to identify saltwater intrusion, in a water sample can be approximated from the concentrations of Cl^- (mCl) (in meq/l). A range from 0-566 meq/l is assumed for freshwater and seawater, respectively (Tomaszkiewicz *et al.* 2014)

addition to the GQI $Piper_{(mix)}$ are used to calculate the final GQI_{SWI} (%) (Equation 5), which represents the ultimate index used for saltwater intrusion assessment. Therefore, the GQI_{SWI} ranges between 0 and 100, where 0 is indicative of seawater and 100 represents freshwater. According to Tomaszkiewicz *et al*. (2014), index values above 75 are typical of freshwater sources, while those below 50 are for saline groundwater and seawater. Values between 50 and 75 represent mixed-salinity groundwater.

$$fsea = \frac{mCl(sample) - mCl(freshwater)}{mCl(seawater) - mCl(freshwater)} \tag{1}$$

$$GQI\ Piper(mix) = \left[\frac{(Ca+Mg)}{Total\ Cations} + \frac{(HCO3)}{Total\ Anions}\right] \times 50\ (\frac{meq}{l}) \tag{2}$$

$$GQI\ Piper(dom) = \left[\frac{(Na+K)}{Total\ Cations} + \frac{(HCO3)}{Total\ Anions}\right] \times 50\ (\frac{meq}{l}) \tag{3}$$

$$GQI\ fsea = (1 - fsea) \times 100 \tag{4}$$

$$GQI\ SWI = \frac{GQI\ Piper(mix) + GQI\ fsea}{2} \tag{5}$$

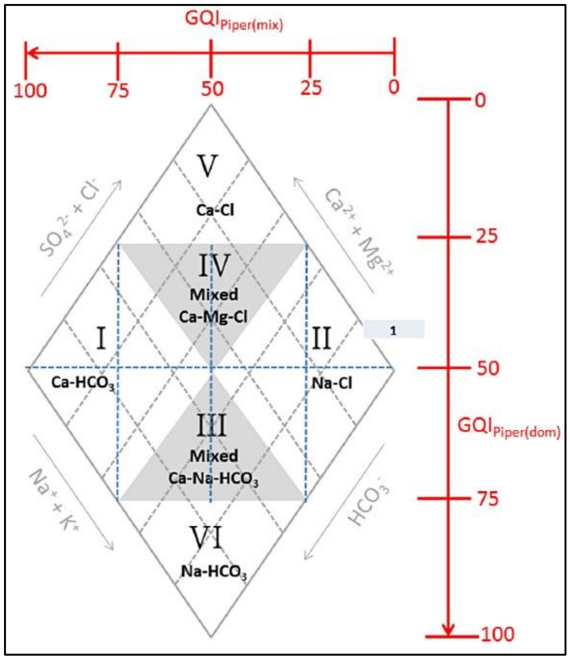

Figure 2 Development of the $GQI_{Piper(mix)}$ and $GQI_{Piper(dom)}$

Major ions including cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) and anions (Cl^-, CO_3^-, HCO_3^-, SO_4^{2-}, Br^-), EC_w, the Sodium Adsorption Ratio of the irrigation water (SAR_w), the molar ratios, and the GQI_{SWI} were analyzed statistically to determine whether there are significant differences between the mean concentrations over the three sampling seasons. The relevant parameters associated with salinity include EC_w, Na^+, and Cl^-. Seasonal variations were analyzed to determine statistically significant differences between two or more groups of an independent variable (i.e. time) on a continuously dependent variable (EC_w, Na^+ and Cl^- concentrations). A repeated measures ANOVA test was conducted following log transformation of the concentration values to determine if the levels of EC_w, Na^+ and Cl^- were varying for each well over seasons. Repeated measures ANOVA tests are conducted when samples are measured multiple times to see changes in concentration while accounting for any temporal differences. When a statistically significant difference was recorded in the concentrations of the constituents over the sampling seasons, the repeated measures ANOVA tests were followed by a Bonferroni post-hoc test.

B. Farmers' Questionnaire

The impacts of saltwater intrusion on agricultural production and crop yield were also assessed using field survey questionnaires (refer to Appendix) administered to farmers through a one on one interview process to collect information related to (1) well data (number of wells per plot, well elevation and depth, frequency of use, perceptions on water quality), (2) banana production data on yield and selling prices, (3) irrigation data (methods used, frequency, sources, expenditure), and (4) fertilizer data (types, quantities, expenditure).

C. Economic Analysis

The adverse effect of groundwater salinity on crop yield is translated into an economic burden on farmers, which can be assessed using a crop-water production function that relates water salinity and crop yield coupled with the production cost/selling prices of banana as collected through the farmers' questionnaires (Equation 6). A linear regression and various statistical analyses (Kruskal Wallis H test, Mann-Whitney U test) were first conducted to establish a representative relationship between the reported yield and the groundwater quality parameter indicative of salinity (EC_w). Two salinity groups were then established based on farmers irrigating with water at $EC_w < 1$ dS/m (Low Salinity Group, n = 21) and farmers irrigating with water at $EC_w > 1$ dS/m (High Salinity Group, n = 18). Average net revenue for all farmers in the Low and High Salinity Groups is then estimated and the difference between the average net revenue of both groups was attributed to change in the yield associated with salinity of water ($EC_w < 1$ dS/m vs $EC_w > 1$ dS/m).

$$N_r = T_r - P_c \quad (6)$$

$$T_r = Y_b x S_p \quad (6a)$$

$$P_c = L_c + GW_c + SW_c + F_c + I_c \quad (6b)$$

Where N_r = Net revenue (\$/m^2/yr)
T_r = Total revenue (\$/m^2/yr)
P_c = Production cost (\$/m^2/yr)
Y_b = Banana yield (kg/m^2/yr)
S_p = Selling price of banana (\$/kg)
L_c = Labor cost (\$/m^2/yr)
GW_c = Groundwater extraction cost (\$/m^2/yr)[2]
SW_c = Surface water cost (\$/m^2/yr)[3]
F_c = Fertilizer cost (\$/m^2/yr))[4]
I_c = Irrigation cost (\$/m^2/yr)[5]

The Ayers and Westcot (1985) empirical model (Equation 7) was also applied in an effort to quantify future impacts of salinity. The model links banana crop yields to soil salinity (EC_s), which in turn is related to the water salinity (EC_w) as expressed in Equation (7a).

$$Y = 100 - b\,(EC_s - a) \quad (7)$$

$$EC_s = 1.5 \times EC_w \quad (7a)$$

---

[2] Cost of operation (diesel, electricity bills) and maintenance
[3] Cost related to subscription tariff
[4] Cost of both mineral and organic fertilizers
[5] Cost of installing drip and sprinkler systems

Where Y = Banana yield (%)
a = Salinity threshold value (ds/m)
b = Yield loss per unit increase in soil salinity (%)[6]

D. Mitigation and Adaptation Framework

A framework for mitigation measures and adaptation strategies was developed in an effort to minimize saltwater intrusion and/or cope with increased salinity. The framework discusses the country-specific legal institutions responsible within the water sector, as pertaining to groundwater management and protection. Large-scale and specific pilot scale mitigation measures are described in the framework, along with corresponding technical, financial and administrative/institutional constraints. Adaptation strategies and common irrigation management practices pertaining to agricultural productivity are presented under future scenarios where salinities are expected to increase.

[6] Values of a and b for bananas are 0.73 dS/m and 27.8%, respectively (Western Fertilizer Handbook 1995)

CHAPTER 3

RESULTS AND DISCUSSION

A. Groundwater Characterization

Table 3 presents averages of the laboratory analysis results of various indicators for the three sampling rounds.

Table 3 Descriptive summary of hydro-chemical parameters

Parameter	Irrigation Threshold Standard[(a)]	Unit	October 2013 (n=60)		May 2014 (n=61)		October 2014 (n=55)	
			Mean	STD	Mean	STD	Mean	STD
EC_w	700	uS/cm	1,100.8	845.0	1,236.5	856.0	1,054.6	469.0
Cl^-	107	mg/l	332.7	339.8	186.3	279.1	168.2	142.9
Ca^{2+}	NA[(b)]	mg/l	160.0	95.6	129.7	83.0	138.1	83.8
Mg^{2+}	NA	mg/l	74.4	58.5	55.6	50.4	37.8	15.9
TH[(c)]	NA	mg/l as $CaCO_3$	705.8	352.7	552.4	318.3	500.3	223.3
HCO_3^-	91.5	mg/l as $CaCO_3$	282.3	41.6	318.2	42.9	277.2	36.0
pH	6.5-8.4	-	6.93	0.2	6.95	0.1	7.11	0.1
NO_3^-	5	mg/l	37.9	26.7	38.1	24.8	45.3	26.3
SO_4^{2-}	NA	mg/l	104.3	238.8	91.3	214.8	81.5	158.2
Na^+	69	mg/l	169.3	211.5	73.2	59.8	34.3	29.6
K^+	NA	mg/l	4.1	6.2	5.0	6.3	3.7	3.5
Br^-	NA	mg/l	1.2	1.1	0.9	0.7	2.9	3.8

[(a)] Misstear *et al.* 2006; [(b)] NA = Not available; [(c)]Total Hardness

Mean Na^+ concentrations exhibited significant temporal variations across all seasons[7] (p value < 0.05), with the highest mean Na^+ concentration observed for October 2013. For Cl^-, mean concentrations differed statistically from October 2013 to May 2014 but not from May 2014 to October 2014, with the highest mean concentration also recorded for October 2013. The EC_w levels over the sampling seasons were considered significant at the 90% CI[8] ($p = 0.087 < 0.10$). However, the presence of potential outliers and the change in temperature resulting from transporting the samples to the lab (Radtke *et al*. 2005; Hayley *et al*. 2009) may have induced potential errors in measurement and contributed to the large variation observed in EC_w measurements in the pilot area. A significant temporal difference across all seasons was also observed for the SAR_w[9]. Given that SAR_w values were low throughout the seasons, with the lowest in October 2014 (a dry season), this is indicative of little to no danger of sodium hazard (Venkateswaran and Vediappan 2013), corroborated by the low average Na^+ concentrations detected in October 2014.

Pearson's correlation analysis[10] is presented in Table 4, with coefficients highlighted in bold indicating strong correlations, defined as correlation > 0.6. The strong positive correlations observed between EC_w and Cl^- ions (0.840) and between Br^- and Na^+ ions (0.638) are indicative of saltwater intrusion, suggesting that such ions are derived from

[7] Repeated measure ANOVA with Greenhouse-Geisser correction, used when the sphericity test (test for equal variances) has been violated
[8] Statistical significance is usually taken at 95% CI, however given the large variability in the groundwater data, a larger confidence interval was also used to report results
[9] One-way ANOVA (after log transformation) with Bonferroni post-hoc test
[10] The correlation analysis between groundwater quality properties showed no differences in the correlations across seasons, thus October 2014 (n=55) was taken as a reference for the analysis

the same source of saline water, as observed in a study conducted in the Rhone delta in the South of France (De Montety *et al*. 2008). Similar results were also observed in the Erzin coastal plain in Turkey (Karahanoğlu 1997); the plains of Zarghan Shiraz (Ebrahimzadeh and Boustani 2011) and Amol-Babol (Narany *et al.* 2014) in Iran, and the Neyveli Basin in South India (Prasanna *et al.* 2010). However, a better indicator of the exact source of salinity as originating from seawater is seen in the correlation between Na^+ and Cl^- ions, which was not established given the low correlation strength between the two ions[11].

[11] The correlation between Na^+ and Cl^- ions was expected to be higher for October 2014 as it was preceded by a dry summer season, when in fact it was not ($r = 0.496 < 0.6$). Coupled with the fact that the correlations did not exhibit significant seasonal variations, conclusive evidence on the increase of saltwater intrusion in the study area could not be fully ascertained

Table 4 Correlation coefficient between hydro-chemical parameters (October 2014)

Parameter	EC (dS/m)	Cl^- (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	TH (mg/l as $CaCO_3$)	HCO^{3-} (mg/l as $CaCO_3$)	pH	TDS (ppm)	Na^+ (mg/l)	K^+ (mg/l)	Br^- (mg/l)
EC	1										
Cl^-	**0.840**	1									
Ca^{2+}	**0.754**	0.369	1								
Mg^{2+}	0.461	0.440	0.065	1							
TH	**0.842**	0.475	**0.956**	0.355	1						
HCO^{3-}	0.133	-0.028	0.050	0.135	0.086	1					
pH	0.029	-0.141	0.018	0.255	0.092	-0.032	1				
TDS	**0.898**	**0.673**	**0.792**	0.384	**0.855**	0.084	0.004	1			
Na^+	0.527	0.496	0.118	0.274	0.191	0.147	0.155	0.461	1		
K^+	0.158	0.077	-0.118	0.398	0.006	0.543	0.231	0.127	0.482	1	
Br^-	0.490	0.317	0.347	0.379	0.437	0.070	-0.029	**0.624**	**0.638**	0.403	1

A summary of the descriptive statistics of the molar ratios Na/Cl, Br/Cl and $Cl/(HCO_3+CO_3)$ over the sampling seasons is presented in Table 5. According to Lee and Song (2007), groundwater samples with Na/Cl ratios lower than 0.86 indicate that fresh groundwater is contaminated with saline water. The results observed in October 2014 (0.40 ± 0.32) point to possible contamination. However, in October 2013 (dry season) and May 2014 (wet season), the mean Na/Cl ratios were observed to be high (ratio close to 1), suggesting rainfall may not exert important influences on the evolution of Na/Cl ratios and are furthermore indicative of possible anthropogenic sources of contamination as opposed to salinity sources. Similar findings were reported by El-Moujabber *et al*. (2006) along the same coastline to the north of the study area (Choueifat-Rmeyle region). Mean Br/Cl ratios were also lowest during the dry season with a mean of 0.00212 ± 0.00172 in October 2013. As for $Cl/(HCO_3+CO_3)$ ratio, the groundwater samples collected in October 2013, May 2014 and October 2014, were slightly to moderately affected by salinization with mean ratios of 3.37 ± 3.38, 1.70 ± 2.59, and 1.78 ± 1.56, respectively[12]. Therefore, the low Na/Cl and Br/Cl ratios and the high $Cl/(HCO_3+CO_3)$ ratio are suggestive of groundwater salinization, as was observed in the coastal areas of Korea (Lee and Song 2007).

[12] Salinization extent as a function of $Cl/(HCO_3+CO_3)$ ratio (Lee and Song 2007):
< 0.5: none
> 0.5 but < 6.6: slight to moderate
> 6.6: severe

Table 5 Descriptive statistics for molar ratios used to assess saltwater intrusion

	Ratio								
	Na/Cl			Br/Cl			Cl/(HCO_3+CO_3)		
Parameter	October 2013	May 2014	October 2014	October 2013	May 2014	October 2014	October 2013	May 2014	October 2014
Min	0.06	0.03	0.10	0.00000	0.00000	0.00123	0.73	0.28	0.27
Max	6.21	4.70	1.58	0.00786	0.01986	0.08249	25.99	18.60	7.74
Mean	0.98	0.91	0.40	0.00212	0.00374	0.00948	3.37	1.70	1.78
Std Dev	1.29	0.69	0.32	0.00172	0.00324	0.01217	3.38	2.59	1.56

Linear relationships between molar ratios and Cl^- concentrations highlight the influence of saltwater intrusion as depicted in Figures 3, 4, and 5, which represent bivariate plots between Cl^- (based on log transformations in meq/l) on one end and the molar ratios on the other. Table 6 represents the linear correlations between the molar ratios and the Cl^- concentrations for the three sampling rounds.

Table 6 Summary of correlations between molar ratios and chloride concentrations

	Na/Cl vs. Cl^-			Br/Cl vs. Cl^-			Cl/(HCO_3+CO_3) vs. Cl^-		
	October 2013	May 2014	October 2014	October 2013	May 2014	October 2014	October 2013	May 2014	October 2014
Pearson's Correlation	-0.225	-0.528	-0.464	-0.580	-0.691	-0.261	0.969	0.987	0.987
p-value	0.084	0.000	0.000	0.000	0.000	0.055	0.000	0.000	0.000
	Ca/Cl vs. Cl^-			HCO_3/Cl vs. Cl^-			SO_4/Cl vs. Cl^-		
	October 2013	May 2014	October 2014	October 2013	May 2014	October 2014	October 2013	May 2014	October 2014
Pearson's Correlation	-0.679	-0.861	-0.829	-0.968	-0.987	-0.987	-0.357	-0.362	-0.663
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000

A significantly negative relationship between the Na/Cl ratio and the Cl^- concentrations was observed for the three rounds. However, the relationships were not considerably strong (< 0.6) in May 2014 or October 2014. Secondary salinization was further confirmed in the pilot area given the statistically significant negative relationships that existed between Br/Cl, SO_4/Cl and HCO_3/Cl ratios and Cl^- ions, as well as the significantly positive relationship that existed between the Cl/(HCO_3+CO_3) ratio and the Cl^- concentrations over the sampling seasons.

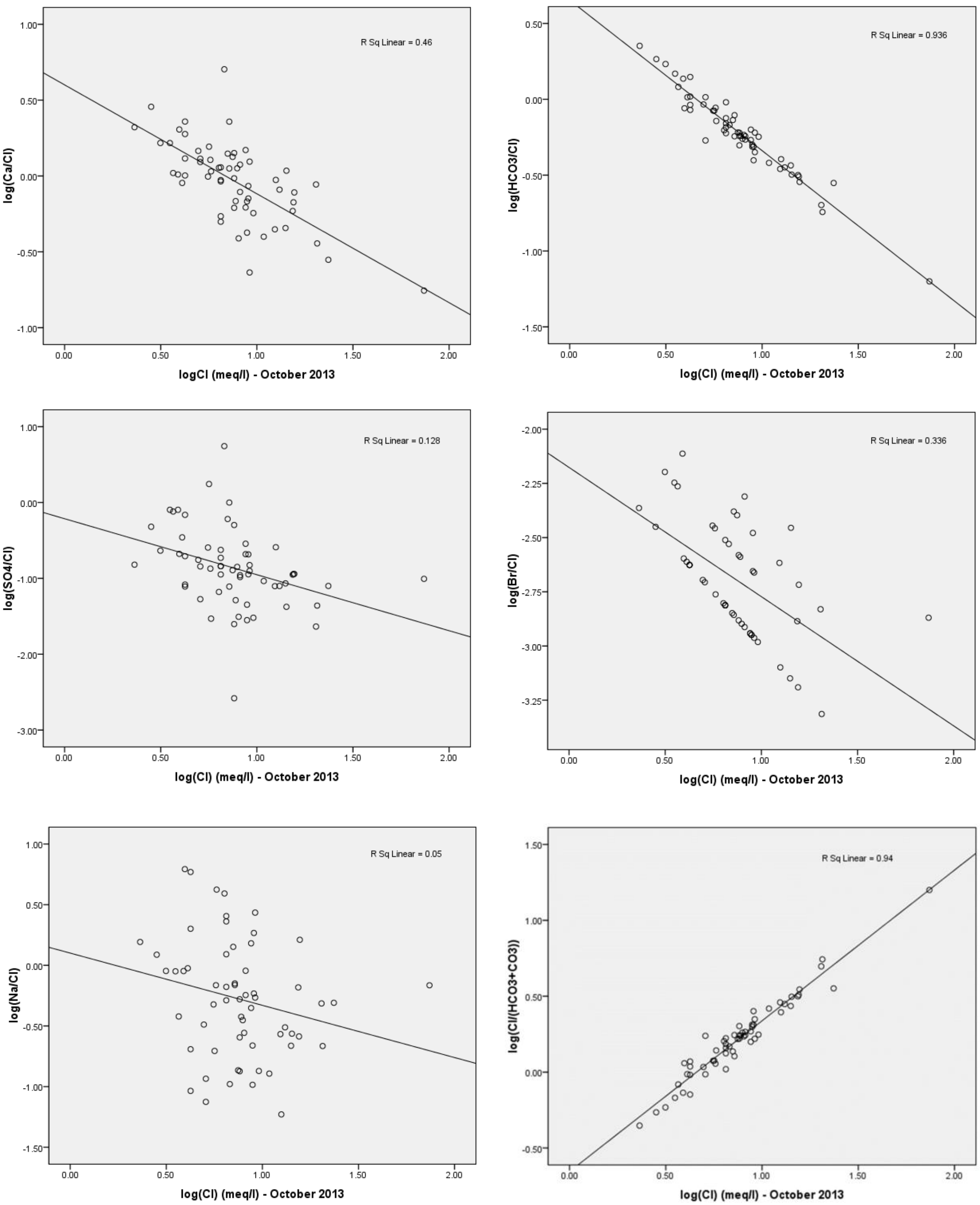

Figure 3 Relationships between molar ratios and Cl^- concentrations for October 2013

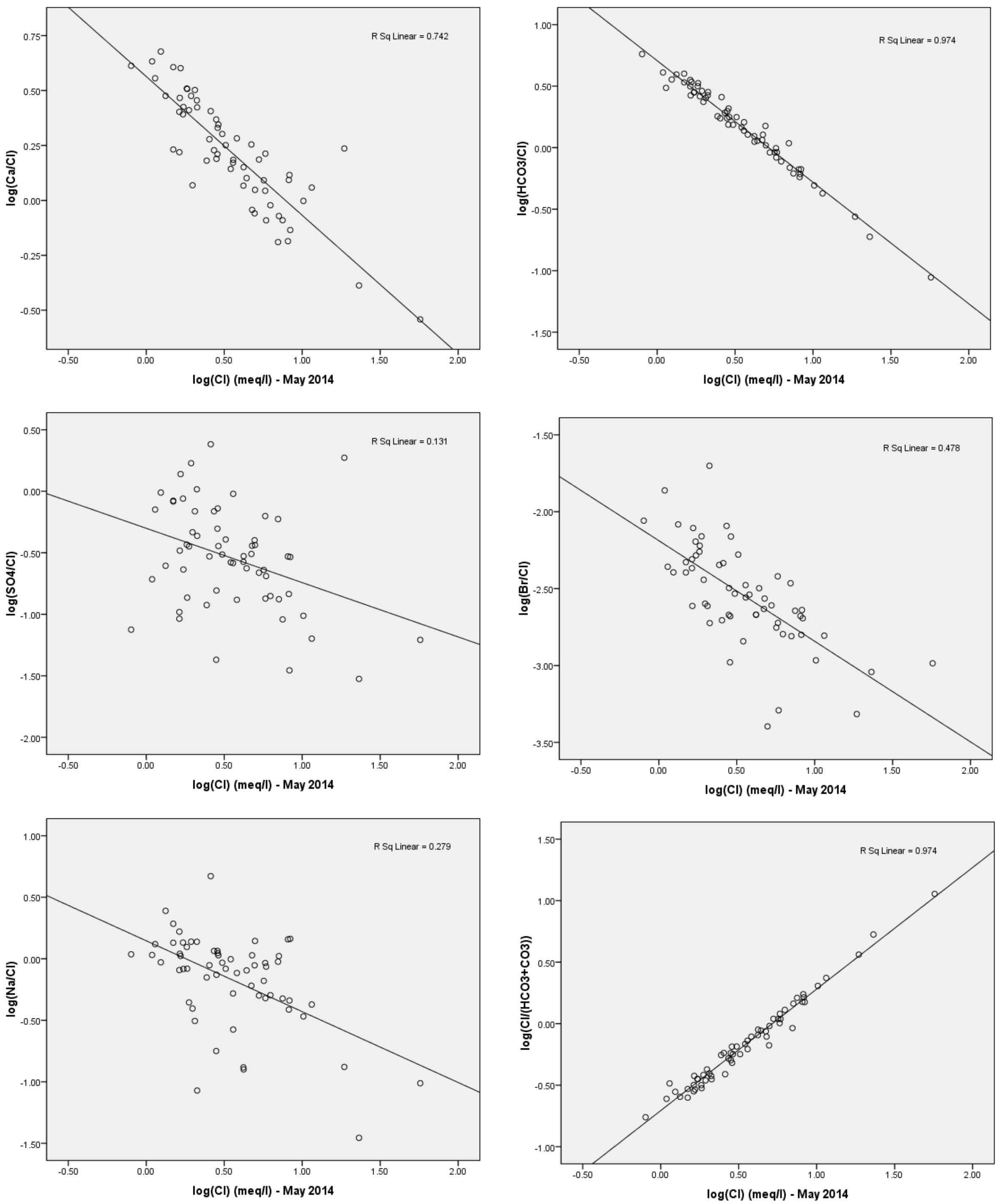

Figure 4 Relationships between molar ratios and Cl^- concentrations for May 2014

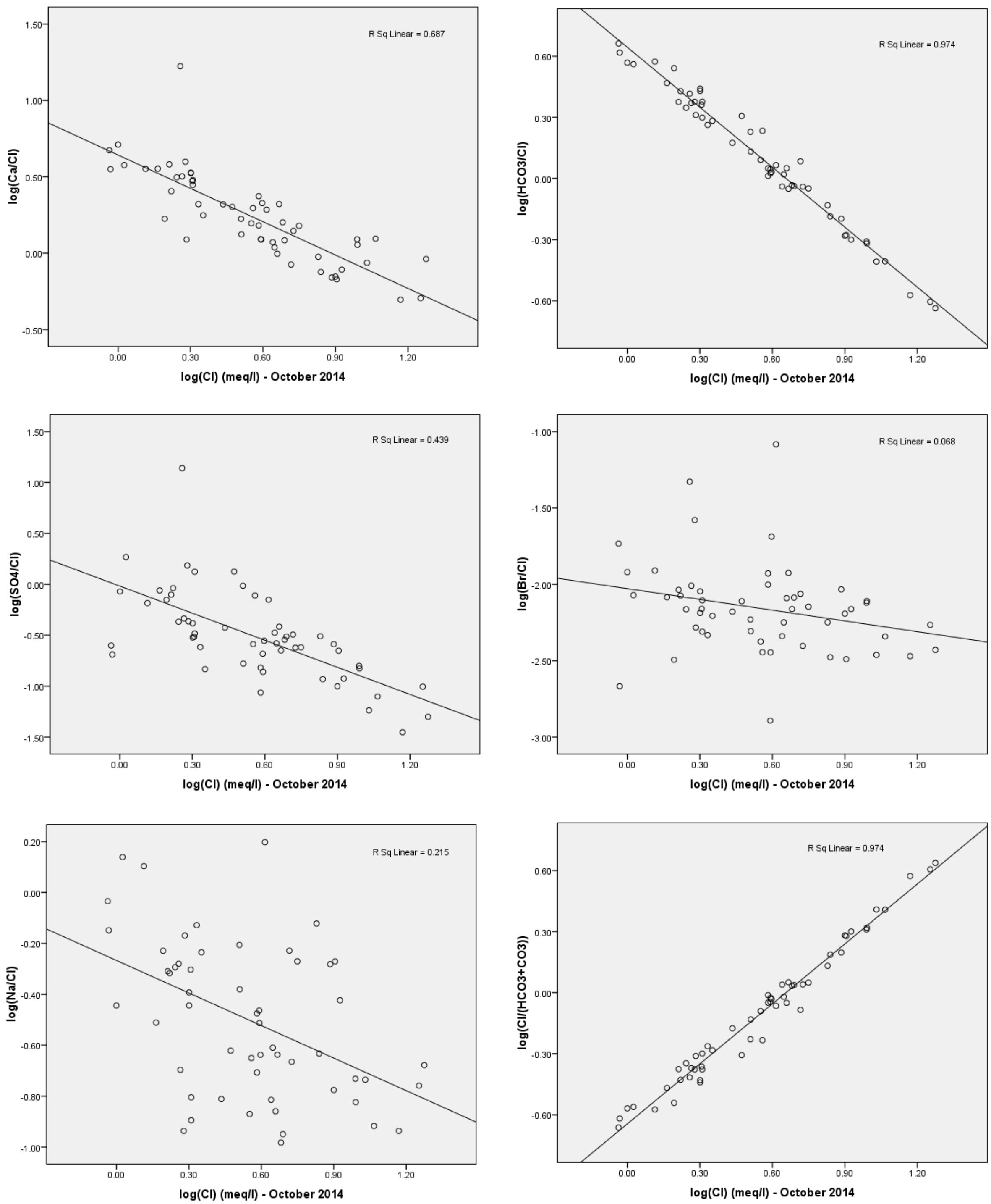

Figure 5 Relationships between molar ratios and Cl^- concentrations for October 2014

The Piper diagrams (Figure 6) over the sampling seasons identified four main hydro-chemical facies. Based on the classification for water types (Table 7), the major domains identified were Domain I (Ca-HCO_3; Secondary Alkalinity –Freshwater (SA-FW)), Domain II (Na-Cl; Primary Salinity – Saltwater (PS-SW)), and Domain IV and V (Ca-Mg-Cl and Ca-Cl, respectively; Secondary Salinity (SS)). Several wells were observed to be transitioning from the Ca-HCO_3 type to the Ca-Mg-Cl type, representing a shift from secondary alkalinity to secondary salinity, as confirmed by the linear regression analysis (refer to Table 6). Few wells also transitioned from the Ca-Mg-Cl type to Na-Cl, representing a shift from secondary salinity to primary salinity. Such changes in the groundwater chemistry generally indicate seawater influence (Lee and Song 2007) and mark the anticipated salinization of freshwater resources and the potential for future primary salinity.

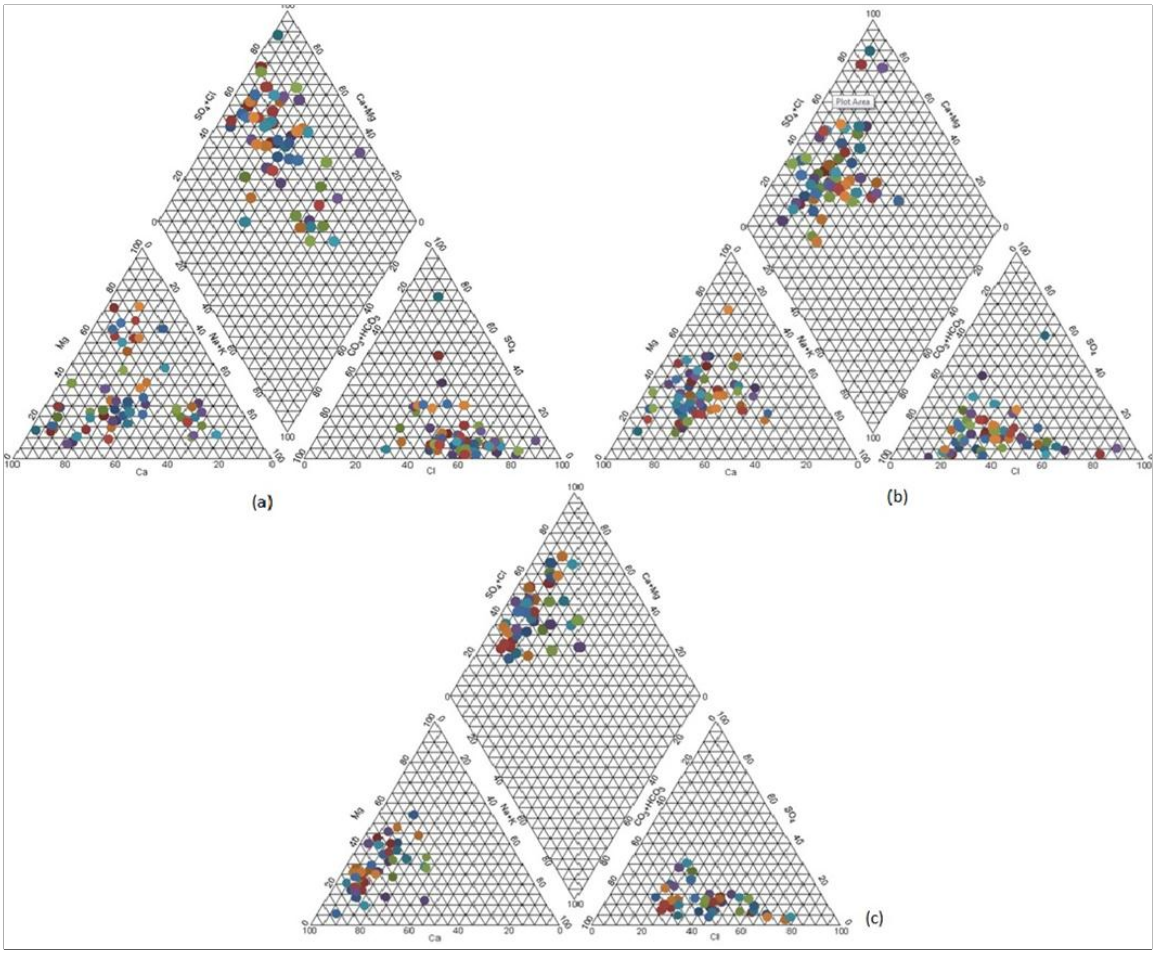

Figure 6 Piper diagrams for pilot study area for (a) October 2013, (b) May 2014, and (c) October 2014
Each dot represents a different well, thus a different color

Table 7 Classification of water types in the pilot area

			% of Samples		
Domain	Water Type	Description	October 2013 (n=60)	May 2014 (n=61)	October 2014 (n=55)
I	Ca-HCO_3	SA-FW[1]	0	0	18
II	Na-Cl	PS-SW[2]	5	0	4
I-IV	Ca-HCO_3 & Ca-Mg-Cl	SA-FW moving to SS[3]	35	85	56
IV-II	Ca-Mg-Cl & Na-Cl	SS moving to PS-SW	23	8	0
V	Ca-Cl	SS	30	7	22

[1] Secondary Alkalinity – Freshwater; [2] Primary Salinity – Saltwater; [3] Secondary Salinity

The GQI_{SWI} ranged between 54 and 93 (Table 8). Mean GQI_{SWI} levels exhibited statistically significant temporal differences from October 2013 to May 2014 but not from May 2014 to October 2014. The lowest GQI_{SWI} (i.e. poorest groundwater quality with respect to saltwater intrusion) was observed during the dry season of October 2013 with a mean GQI_{SWI} of 75.43 ± 5.79, further confirming the early mixing of fresh and saline water.

Table 8 Descriptive statistics for GQI_{SWI} (%) in pilot area

GQI_{SWI} (%)	October 2013	Location	May 2014	Location	October 2014	Location
Min	54.28	Saksakiyeh	63.28	Aaqbiye	73.49	Tefahta
Max	85.49	Brak el Tall	93.21	Addoussiyeh	91.76	Addoussiyeh
Mean	75.43		81.90		83.07	83.07
Std Dev	5.79		6.19		4.90	4.90

B. Farmers' Questionnaire

The plots of land varied in size with an average of ~100,000 m^2 (Table 9). They had at least one well (54.7%), with 45.3% having two or more wells. Wells were located at an elevation ranging between 1.3 and 171.6 m above sea level, averaging at ~37. Well depths ranged from 6 m to 450 m with an average of 123 m. While the main source of irrigation for banana is groundwater from wells located in the plots (53.8% of famers), more than 42% of farmers used the regional irrigation project (Qasimiya and Ras Al Ain) in conjunction with well water for irrigation purposes and only 1.9% relied exclusively on surface water. Around 83% of farmers used mostly drip irrigation, 10% of farmers used a combination of flooding and drip irrigation systems, and 4% of farmers using only sprinkler systems. Average irrigation time was around 4 hours a day. The surface water received through the Qasimiya and Ras Al Ain project is highly subsidized and the tariff is based on the size of the cultivated land (average of 0.03 USD/m^2/year) instead of actual volume used. While there is no tariff imposed on groundwater, farmers incur costs associated will well water extraction (pump maintenance and electricity or fuel for operating private generators). Combining the costs pertaining to pump maintenance, electricity and diesel fuel costs, the average cost of providing water from wells over the irrigation season (starting in May of each year and ending with the first rain of the fall-winter season) reaches ~ 0.38 USD/m^2/year.

Table 9 Descriptive statistics for plot properties

Property	Minimum	Maximum	Mean	Standard Deviation
Total plot size (m^2)	1,300	1,000,000	100,000	165,770
Total area of banana grown (m^2)	250	350,000	40,030	64,460
Number of wells per plot	1	6	1.69	1.02
Well elevation (m, above sea level)	1.3	171.6	37.12	41.81
Well depth (m)	6	450	123.3	123.7

Banana production in the region is a dominant trade with a strong year-round season, with a variety of bananas grown. According to the results of the interviews, 51% of bananas grown are of the Dwarf Cavendish group (DC) with 27.5% of farmers growing both DC and Giant Cavendish groups (GC) simultaneously. The average land size that is grown with banana in the pilot area was around 40,000 m^2, with an average of 7 kg/m^2. The weight per bunch of banana ranged from a minimum of 15 kg to a maximum of 50 kg, averaging around 29 kg per bunch. In the southern coast of Lebanon, bananas are traded by *ratel*, equivalent to 2.5 kg, as reported in the questionnaires. The trade season for banana begins around October of each year, with a high of 1.2 USD/kg. Prices decrease throughout March and April reaching a low of 0.3 USD/kg because of high production.

C. Economic Analysis

Crop yield did not prove to be affected by increases in EC_w[13]. In parallel, a negative relationship was found between the net revenue of farmers (in USD/m^2 /year) and salinity but was not reported as significant. Moreover, when compared to a function of the two salinity groups, differentiation between the Low Salinity Group and the High Salinity Group did not prove to be influential on crop yield and net revenue of farmers, although it did show that production in the Low Salinity Group was higher than in the High Salinity Group, by approximately 2.5 USD/m^2/year, representing the cost of salinity incurred on farmers.

Coupled with the results of the groundwater characterization which indicated that although early salinization had been detected in the pilot area, the current levels of salinity were not exerting a significant impact on the production of banana, thus leading to the

[13] EC_w values from October 2014 were used as a proxy for the economic assessment. A non-significant relationship was observed between EC_w and crop yield ($r = -0.120$, $p = 0.423 > 0.05$)

consideration that other factors may be playing a more dominant role in the production of banana. Hence, soil conditions (not explored in this study), cultivation and irrigation practices as well as the physiological nature of the banana crop are considered factors that potentially influence the effect of salinity on banana production. Moreover, the effects of salinity from groundwater resources (wells) are countered by the use of fresh surface water (Qasimiya and Ras Al Ain Irrigation project) in conjunction with well water.

It is well established that as salinity levels continue to rise, their impact on banana production will become more pronounced. The Ayers and Westcot (1985) model predicts that the maximum potential yield happens when $EC_s < 0.73$ dS/m. EC_s values > 0.73 dS/m will result in production losses with more than 50% decrease in crop yield when ECs > 2.53 dS/m (Table 10).

Table 10 EC_s impact of banana yield

Potential Yield (%)	ECs (dS/m)
100	0.73
90	1.09
75	1.63
50	2.53
0	4.33

The maximum yield in the study area, assumed to be the average crop yield of farmers under optimal conditions for banana growth (i.e. crop yield of farmers with EC_w < 1 dS/m) is around 7.45 kg/m^2. Overall, the crop yield in the pilot area is close to the national Lebanese yield that averages 8 kg/m^2 (Abou Masleh 2007). Similar yields (8.4 kg/m^2) have also been reported under optimal conditions in Israel[14]. On the other hand, the crop yield at farms with water samples > 1 dS/m EC_w was around 5.56 kg/m^2. This signifies a yield decrease of approximately 25%. Yet, in comparison to surrounding coastal areas in the MENA region, these yields are considered above average when compared to yields reported in Egypt (3.9 kg/m^2) (Saad *et al*. 2003), Oman (2.26 kg/m^2) (MAF/ICBA 2012), and Jordan (1 kg/m^2) (de Langhe 2002).

While high salinity levels are not currently being experienced in the pilot area, this does not diminish the projected impacts of climate change on accelerating coastal saltwater intrusion along the entire coastline. Current crop yields, which appear to be only minimally affected, will be significantly affected if salinity levels continue to rise. Current EC_w levels along the coast of Beirut exceeded 16 ds/m in April 2014 as a result of over-exploitation and mismanagement of groundwater resources. As such, salinity along the southern coast of Lebanon may in fact increase in the future to levels comparable to those currently experienced in Beirut if over-pumping continues and climate change impacts start to manifest. Note that if salinity levels in the pilot area even reach the lowest EC_w values observed in Beirut (9.5 dS/m in June 2014), the plantation of bananas in the south will be

[14] http://www.haifa-group.com/files/guides/banana.pdf

rendered economically non-viable. Under such a scenario, farmers will have to the switch towards more salt-tolerant crops. This was the case in the Al-Batinah region of Oman, whereby banana crops were replaced by salt-tolerant tomato varieties, when EC_s values ranged between 2.5 dS/m – 7.5 dS/m (Naifer *et al*. 2011).

D. Mitigation and Adaptation Framework

Within the context of saltwater intrusion, mitigation measures consist of actions implemented to reduce climate change-induced effects. While effective mitigation actions are essential, they are not the only aspect of climate protection that local governments can engage in. Adaptation strategies are equally important as they involve recognizing impacts of climate change that are already occurring and will continue into the future requiring pre-planning to maximize the positive aspects of these impacts while protecting ecosystems from potential negative impacts (ICLEI 2014). With increased effects of climate change, the salinity of groundwater resources in close proximity to coastlines is expected to increase, thus protection of groundwater resources from saltwater intrusion is imperative. At a country level, the water sector is governed by several governmental entities and ministries with associated water establishments and centers (Table 11). The Ministry of Energy and Water (MoEW) through its Regional Water Establishments (RWE) including the South Lebanon Water Establishment (SLWE) and the Litani River Authority (LRA)[15], is the main entity governing the water sector in coordination with other regulatory bodies

[15] Responsible for planning and operating irrigation and hydro-electrical schemes associated with the Litani River (i.e. the Qasimiya and Ras Al Ain Irrigation Project)

such as the Ministry of Environment (MoE) that is responsible for environmental protection and setting standards for water quality monitoring. The Ministry of Interior and Municipalities (MoIM) and the Council for the South (CS) are also involved in executing and monitoring of small-scale municipal works that relate to water infrastructure. While the Ministry of Agriculture (MoA) assisted with its research centers such as the Lebanese Agriculture Research Institute (LARI)[16], is an equally important institutional player involved in the study, supervision, and monitoring of irrigation and drainage projects, as well as the distribution of irrigation water, in practice, the role of the MoA has been marginalized mainly due to funding for large-scale irrigation projects from international organizations, shifting the responsibility of designing and implementing irrigation projects to the Council for Development and Reconstruction (CDR) (MoE/UNDP/ECODIT 2011) that has emerged as the main implementing agency for major water development projects coordinating amongst various ministries (Darwish 2004).

[16] Responsible for conducting applied and basic scientific research for the development and advancement of the agricultural sector with stations in the South, and involvement in maintaining close ties with farmers (LARI 2009)

Table 11 Key players and responsibilities in the water sector in Lebanon
(Adapted from MoE/UNDP/ECODIT 2011; and El-Fadel *et al.* 2000)

	Legal Institutions Responsible							
Function	MoEW[1]	MoE[2]	MoIM[3]	MoA[4]	LRA[5]	SLWE[6]	CDR[7]	CS[8]
Planning	X			X		X	X	
Licensing and Permitting	X	X	X					X
Capital Investments	X		X			X	X	X
Infrastructure Construction	X		X	X		X	X	X
Operation and Maintenance	X					X		
Financing (National)	X					X	X	
Financing (International/External Organizations)	X						X	
Regulations and Guidelines	X	X						
Water Quality/Quantity Monitoring	X	X			X			

[1]Ministry of Energy and Water, [2]Ministry of the Environment, [3]Ministry of Interior and Municipalities, [4]Ministry of Agriculture, [5]Litani River Authority, [6]South Lebanon Water Establishment, [7]Council for Development and Reconstruction, [8]Council for the South

Controlling saltwater intrusion under the governance of existing institutions is therefore an important step in protecting groundwater resources. Common physical control methods can play a role, although they may not be feasible at times within the context of developing communities with limited financial, technical and operational resources (Table 12). The main feasible measure that can be implemented at this stage is the reduction of extraction rates from the irrigation wells. This can be achieved through economic tools and regulatory enforcement (Table 13).

Table 12 Common methods of controlling saltwater intrusion

Method	Description	Justifications for use	Limitations of control methods	References
Subsurface barriers	Defined as underground semi-impervious or impervious structures constructed in coastal aquifers	Simultaneously impedes inland infiltration of saltwater and increases groundwater storage capacity of an aquifer	– High construction costs – Procedural difficulties of political, social, and economic nature	Khomine *et al*. 2011 Basri 2001
Artificial recharge through injections wells	Surface water is artificially made to infiltrate into the ground, commonly at rates and quantities greater than natural recharge	Provides artificial recharge of confined aquifers and is effective in the case of highly fractured hard rocks and karstic limestone	– Problematic for arid and semi-arid regions with unavailability of adequate surface water in quantity and quality – High capital, and operation and maintenance costs	Sherif and Hamza 2001; Luyun Jr. *et al*. 2011; FAO 1995

Table 13 Specific groundwater management activities related to saltwater intrusion control

		Legal Institutions Responsible					
Activity	Implementation Strategy	MoEW[1]	MoE[2]	MoIM[3]	MoA[4]	LRA[5]	CS[6]
Regulating groundwater exploitation	Reduction of pumping rates through tariff restructuring, metering water wells, and enforcing penalties for over-exploitation	X	X	X		X	
Monitoring groundwater quality	Establishing monitoring stations with regular testing for water quality parameters relevant to salinity	X	X			X	
Regulating well permits and licensing	Introduction of controls over the import of pumps and drilling equipment	X		X			X
Rehabilitating/modernizing irrigation systems	Shifting from gravity-fed irrigation to pressurized systems using on-farm irrigation systems (e.g. drip irrigation)	X			X	X	X

[1]Ministry of Energy and Water, [2]Ministry of the Environment, [3]Ministry of Interior and Municipalities, [4]Ministry of Agriculture, [5]Litani River Authority, [6]Council for the South

However, the implementation strategies are met with technical, financial, as well administrative and institutional constraints, summarized in Table 14.

Table 14 Constraints facing groundwater management

Category	Constraints	References
Technical	– Insufficient number of skilled staff due to lack of up-to-date training and limited equipment for routine maintenance, measurement or monitoring of water supply and quality – Lack of implementation of modern irrigation and water-saving technologies	El Fadel *et al.* 2000 Stephan 2007 Karaa *et al.* 2009 INECO 2009 World Bank 2010
Financial	– Deficient allocation of funds for proper maintenance and rehabilitation of the water supply and distribution system – Inadequate collection of fees from consumers leading to poor financial management in water authorities	
Administrative and Institutional	– Lack of coordination between ministries and water authorities – Lack of law enforcement of water regulations regarding use and distribution – Lack of political will in regulating and implementing well permits and licensing and payment of fines	

While mitigation measures have been at the forefront of various policy and management decisions, it has become increasingly evident that mitigation alone cannot be an effective strategy to limit the vulnerability to the causes and consequences of saltwater intrusion. Adaptation strategies, in synergy with mitigation measures, must also form a part of the planning, policies and discussion procedures concerned with salinity management (Bhamidipati *et al*. 2012). Such strategies encompass initiatives to reduce the susceptibility of natural and human systems against actual or expected climate change effects (ICLEI, 2014). In the context of adapting to saltwater intrusion, those may include relocating wells inland, changing land use patterns by switching to more salt-tolerant crops, and managing irrigation patterns to improve water use and enhance drainage and leaching of salts (Sherif and Hamza 2001; Ayers and Westcot 1985; Kashef and Csallany 1977). Within the study framework, the common agricultural practices that are conducted in the pilot area include various on-farm irrigation management practices that improve crop-water relations, especially with respect to salinity management such as the use of fertigation via drip irrigation, leaching of salts, and conjunctive use of groundwater and surface water.

Fertigation via drip irrigation systems has proven to be an effective irrigation method to control salinity in soils through applying water precisely and uniformly at high frequencies, potentially increasing yield and reducing root-zone soil salinity and drainage (Hanson *et al*. 2009), thus providing improved disease management since only the soil is wetted whereas the leaf surface stays dry (Ahmed *et al*. 2010). By supplying dissolved fertilizer to crops through an irrigation system, the nutrient-water relationship is more balanced to improve yield, save labor, and reduce compaction in the field resulting in the rapid and uniform uptake of nutrients by plants (NSW DPI 2000). However, the initial installation cost for drip irrigation systems is high with capital investment in the pilot area reaching a maximum of 1.20 USD/m^2/year. Moreover, if poorly managed, salt accumulation may still occur between drip emitters, therefore it is advisable to design drip irrigation systems with closely spaced emitters and provide adequate leaching of salts. The latter is an effective method of adapting to increases in soil salinity through excessive application of water to keep salts, which have accumulated in the soil, in soluble form and flush them below the crop root zone to maintain productivity (Fipps 2003). Mostly, rainfall provides adequate leaching, as is the case in the pilot area. However, farmers tend to practice leaching via their scheduled irrigation patterns. For instance, in the pilot area, farmers have claimed to practice leaching every other time fertigation is performed, meaning that every time fertilizers are passed in the drip irrigation system, the next irrigation is without fertilizers, thus accumulated salts in the soil either from the irrigation water itself or from the fertilizer residues are flushed. Equally important is the conjunctive use of groundwater and surface water resources, which is considered a strategic approach to reduce the susceptibility of crops to salinity (Evans and Evans 2011) (Figure 7). Conjunctive use of groundwater and surface water (via canals) is critical at stages of crop growth, such as the shooting period for bananas. By increasing the precision of water delivery and reducing soil-water logging and salinization, water productivities are significantly increased and salinity problems in shallow aquifers are reduced, leading to an increase in agricultural productivity (Foster *et al*. 2010).

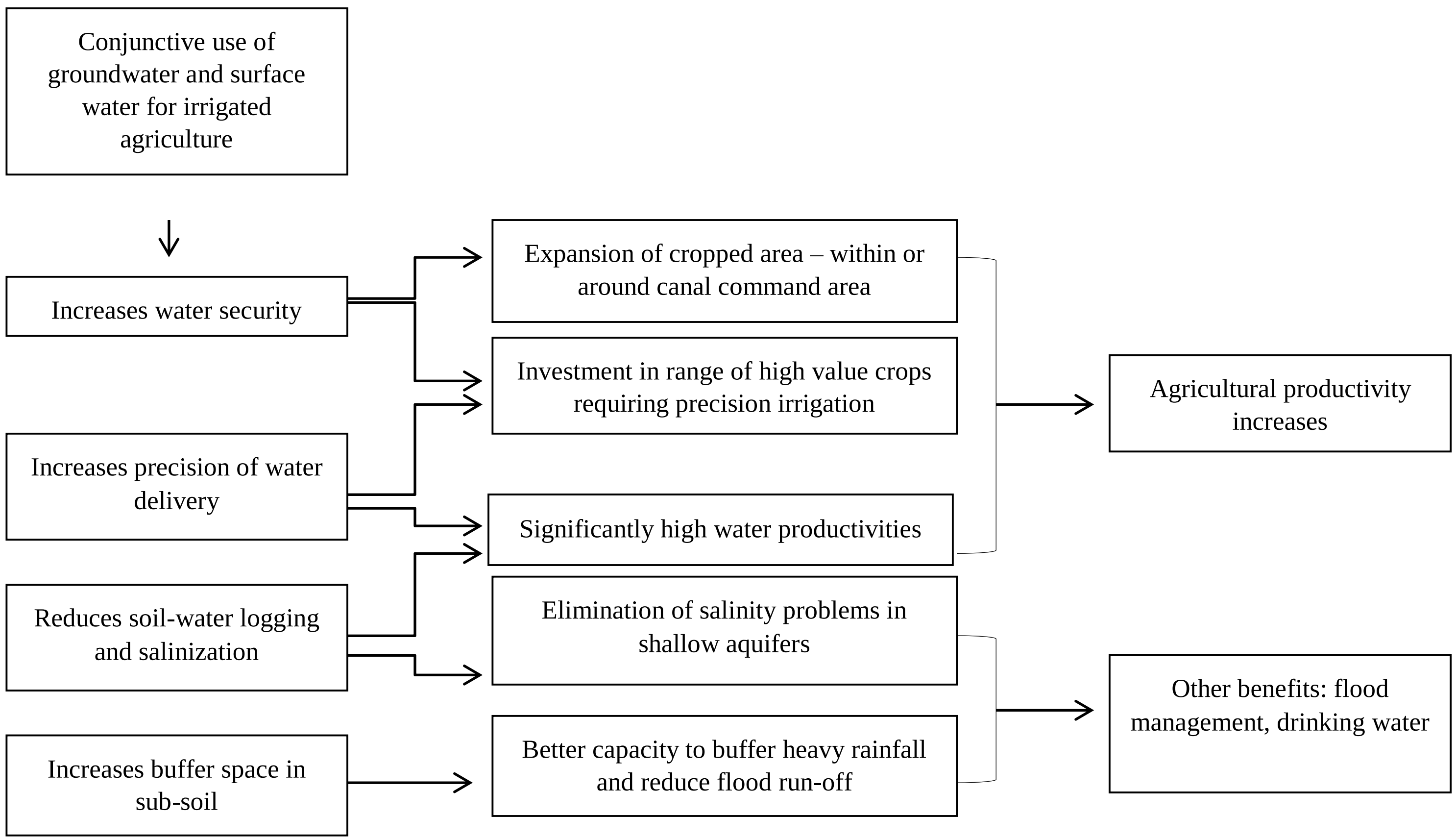

Figure 7 Benefits of conjunctive use (adapted after Foster *et al*. 2010)

CHAPTER 4

CONCLUSION

Early evidence of saltwater intrusion has been demonstrated mostly during the dry seasons, as discerned in the low Na/Cl, Br/Cl, HCO_3/Cl, SO_4/Cl, and Ca/Cl ratios as well as high Cl/(HCO_3+CO_3) ratios, ascertaining slight to moderate salinization. Dominant water types of Ca-HCO_3 to Ca-Mg-Cl to Ca-Cl confirm that the groundwater is shifting from freshwater to secondary saline waters, with few wells transitioning to Na-Cl type (primary salinity). Saltwater intrusion is expected to increase with climate change due to a projected decrease in precipitation and groundwater recharge, and an increase in water demand leading to overexploitation of groundwater during the summer months in particular. Various parametric and non-parametric statistical tests indicated that banana production has not been affected yet at the encountered level of salinity mainly because of indirect adaptation measures practiced by the farmers through fertigation via drip irrigation, leaching of salts, and the conjunctive use of groundwater and surface water. The combination of adaptation strategies and methods of banana cultivation (multiple banana varieties, single and high-density planting techniques) suggest that, within the context of this study, production is not governed as much by the quality of the groundwater used for irrigation as by the agricultural and irrigation practices implemented by farmers. However, adaptation strategies are faced with technical and operational limitations. For example, conjunctive use of groundwater and surface water may exacerbate secondary salinization, if not managed with knowledge on the appropriate use of irrigation water of different qualities which can cause sub-optimal use of land and water resources (Qureshi *et al*. 2004).

Moreover, even if salinity impacts are not evident at present, future salinity will pose a threat to agricultural productivity. The cumulative effects of climate change, particularly decreased precipitation patterns, increase sea level rise and increase in demand for water (high abstraction rates), saltwater intrusion with related impacts are predicted to aggravate justifying the adoption of early measures to protect groundwater exploitation. Regulatory tools emphasizing tariff restructuring and well permitting processes are vital in this context to ensure sustainability.

Uncertainties in the results of the groundwater characterization and economic assessment include (1) potential errors associated with sample collection and water quality analysis; (2) small sample size and short study period to establish clear temporal and spatial relationships between water quality parameters and saltwater intrusion; and (3) data on crop yield and selling prices for banana were based on estimations obtained from farmers without field/market ascertainment. The yield and economic profit from bananas, in specific, is highly dependent on banana varieties, soil characteristics, and irrigation and cultivation practices, making it difficult to control for external factors, as related to the effect of groundwater salinity on banana production.

Appendix I. Questionnaire

Questionnaire Identification					
	Area	|___|		**Coordinates**	N:______________________
	QID				E:________________________
Schedule					
	First Visit	DD.MM.YY |___|___|.|___|___|.|___|___|	AT1	Start of interview (time)	hh:mm |___|___|:|___|___|
			AT2	End of Interview (time)	hh:mm |___|___|:|___|___|
	Second Visit	DD.MM.YY |___|___|.|___|___|.|___|___|	AT3	Start of interview	hh:mm |___|___|:|___|___|
			AT4	End of Interview	hh:mm |___|___|:|___|___|
	Total visits carried out |___|				
	Editing Date			DD.MM.YY	|___|___|.|___|___|.|___|___|
	Coding Date			DD.MM.YY	|___|___|.|___|___|.|___|___|
	Data entry Date			DD.MM.YY	|___|___|.|___|___|.|___|___|
Staff					
	Interviewer	|___|___|		**Coder**	|___|___|
	Supervisor	|___|___|		**Data entry operator**	|___|___|
	Editor	|___|___|			
Respondent					
	Name of farmer (respondent) (optional) ____				
	Name of plot owner, if different (optional) ____				
	Interview status				
	1	Interview completed		**COMMENTS:**	
	2	Refusal converted			
	3	Partly completed			
	4	No usable information			
	5	Household unit is vacant			
	6	No contact			
	7	Refusal			

سوف ابدأ بالسؤال عن حجم نشاطك الزراعي؟

حجم النشاط الزراعي			
AS1	هل أنت:	١ ٢ ٣ ٤ ٥ ٩٨	تملك الأرض الزراعيّة تستأجر الأرض الزراعيّة تضمن الأرض الزراعية تملك الارض وستثمرها وكيل الارض لا جواب
AS2a b٢AS	كم عدد العاملين لديك في الموسم الزراعي (بدوام كامل وجزئي)؟	ذكر انثى	|___||___| |___||___|
AS3	ما كان مجموع انفاقك على تعيين العاملبن؟ ذكر انثى ليرة لبنانية		________________ ________________
AS4	هل يعمل معك احد من افراد العائلة؟	1 2 98	نعم كلا لا جواب
AS5	اذا نعم، من يعمل معك في الزراعة؟	١ ٢ ٣ ٤ ٥ ٦ ٧ ٩٧	الاب|___||___| الام |___||___| الزوج/ الزوجة |___||___| الاخ |___||___| الاخت |___||___| الابن |___||___| الابنة|___||___| N/A غير ذلك، حدد __________
AS5A			
AS6	ما هو اجمالي الحيازة الزراعية/ المستثمرة لديك في هذه المنطقة؟ ____________________ دنم N/A ٩٧ ٩٨ لا جواب ٩٩ لا اعلم		

الآن سوف اسألك معلومات عن الاراضي التي تملكها/ تستثمرها

معلومات حول الاراضي (Land Data - LD)					
LD١	هل تملك/تستثمر اي اراضي اخرة؟		١ نعم ٢ كلا ٩٧ N/A ٩٨ لا جواب 99لا اعلم		
LD2	ما عدد الاراضي التي تملكها/ تستثمرها؟			|___||___|	
			٩٨	لا جواب	
			٩٩	لا اعلم	
		A	B	C	D
		المنطقة	ملك/ استثمار	مساحتها	هل تزرعها؟
LD3	الأرض ١	________ ٩٨ لا جواب ٩٩ لا اعلم	________ ٩٨ لا جواب ٩٩ لا اعلم	________ ٩٨ لا جواب ٩٩ لا اعلم	١ نعم، حدد ________ ٢ كلا ٣ كنت في الماضي ٩٨ لا جواب
4	الأرض 2	________ ٩٨ لا جواب ٩٩ لا اعلم	________ ٩٨ لا جواب ٩٩ لا اعلم	________ ٩٨ لا جواب ٩٩ لا اعلم	١ نعم، حدد ________ ٢ كلا ٣ كنت في الماضي ٩٨ لا جواب
5	الأرض 3	________ ٩٨ لا جواب ٩٩ لا اعلم	________ ٩٨ لا جواب ٩٩ لا اعلم	________ ٩٨ لا جواب ٩٩ لا اعلم	١ نعم، ________ ٢ كلا ٣ كنت في الماضي ٩٨ لا جواب
6	الأرض4	________ ٩٨ لا جواب ٩٩ لا اعلم	________ ٩٨ لا جواب ٩٩ لا اعلم	________ ٩٨ لا جواب ٩٩ لا اعلم	١ نعم ٢ كلا ٣ كنت في الماضي ٩٨ لا جواب

الآن سوف اسألك معلومات عن الاطار الزراعي في الاراضي التي تزرعهاموز و/او حمضيات

مصادر الري			
WS1	هل يوجد اي آبار ارتوازية في هذه الأرض؟	١	نعم
		٢	كلاGo to WS3
		98	لا جواب
		99	لا اعلم
WS2	ما عدد هذه الآبار		|___|___|
		97	N/A
		٩٨	لا جواب
		٩٩	لا اعلم
WS3	هللديك آبار غير مستعملة في هذه الأرض؟	١	نعم
		٢	كلا
		97	N/A
		98	لا جواب
		99	لا اعلم
a٣WS	؟ ما عددها؟		|___|___|
		٩٧	N/A
		٩٨	لا جواب
		٩٩	لا اعلم
WS4	لماذا لا تستعمل هذه الآبار؟	١	لأنها اصبحت جافة
		٢	لأن زادت نسبة ملوحتها
		٣	غيره، حدد ___________________
		٩٧	N/A
		98	لا جواب
		99	لا اعلم

سوف اسألك عن خصائص كل بئر

مياه الآبار (Well water)				
WW		A	B	C
	الخصائص	**البئر ١**	**البئر ٢**	**البئر ٣**
1	نوع البئر	١ خاص ٢ مشترك ٩٩ لا أعلم	١ خاص ٢ مشترك ٩٩ لا أعلم	١ خاص ٢ مشترك ٩٩ لا أعلم
2	حالة البئر	١ مغطّى ٢ مفتوح ٩٩ لا أعلم	١ مغطّى ٢ مفتوح ٩٩ لا أعلم	١ مغطّى ٢ مفتوح ٩٩ لا أعلم
3 ٣a	طريقة السحب	١ مضخّة ٢ نقل باليد ٣ غير ذلك، حدد: __________ ٩٩ لا أعلم	١ مضخّة ٢ نقل باليد ٣ غير ذلك،حدد: ________ ٩٩ لا أعلم	١ مضخّة ٢ نقل باليد ٣ غير ذلك، حدد: __________ ٩٩ لا أعلم
٤	عمق البئر	|___|___|___| م	|___|___|___| م	|___|___|___| م
٥	سنة الحفر	|___|___|___|___|	|___|___|___|___|	|___|___|___|___|
٦	استعمالات البئر	١ ري فقط ٢ ري واستعمالمنزلي ٣ وللشرب ٩٨ لا جواب 97 N/A ٩٩ لا اعلم	١ ري فقط ٢ ري واستعمال منزلي ٣ وللشرب ٩٨ لا جواب 97 N/A ٩٩ لا اعلم	١ ري فقط ٢ ري واستعمال منزلي ٣ وللشرب ٩٨ لا جواب 97 N/A ٩٩ لا اعلم
7	وتيرة الاستعمال	|___|ساعة/ الأسبوع 97 N/A ٩٨ لا جواب ٩٩ لا أعلم	|___|ساعة/ الأسبوع 97 N/A ٩٨ لا جواب ٩٩ لا أعلم	|___|ساعة /الأسبوع 97 N/A ٩٨ لا جواب ٩٩ لا أعلم
8	نوعية المياه في الشتاء	١ المياه جيدة ٢ المياه مالحة 3 للمياه لون، حدد________ ٤ المياه كلسية ٥ للمياه رائحة معدنيّة ٦ للمياه رائحة غريبة ٧ المياه ملوّثة جرثوميّاً 97 N/A ٩٨ لا جواب ٩٩ لا أعلم	١ المياه جيدة ٢ المياه مالحة 3 للمياه لون، حدد________ ٤ المياه كلسية ٥ للمياه رائحة معدنيّة ٦ للمياه رائحة غريبة ٧ المياه ملوّثة جرثوميّاً 97 N/A ٩٨ لا جواب ٩٩ لا أعلم	١ المياه جيدة ٢ المياه مالحة 3 للمياه لون، حدد________ ٤ المياه كلسية ٥ للمياه رائحة معدنيّة ٦ للمياه رائحة غريبة ٧ المياه ملوّثة جرثوميّاً 97 N/A ٩٨ لا جواب ٩٩ لا أعلم

9	نوعية المياه في الصيف	١	المياه جيدة	١	المياه جيدة	١	المياه جيدة
		٢	المياه مالحة	٢	المياه مالحة	٢	المياه مالحة
		3	للمياه لون، حدد________	3	للمياه لون، حدد________	3	للمياه لون، حدد________
		٤	المياه كلسية	٤	المياه كلسية	٤	المياه كلسية
		٥	للمياه رائحة معدنيّة	٥	للمياه رائحة معدنيّة	٥	للمياه رائحة معدنيّة
		٦	للمياه رائحة غريبة	٦	للمياه رائحة غريبة	٦	للمياه رائحة غريبة
		٧	المياه ملوّثة جرثوميّاً	٧	المياه ملوّثة جرثوميّاً	٧	المياه ملوّثة جرثوميّاً
		97	N/A	97	N/A	97	N/A
		٩٨	لا جواب	٩٨	لا جواب	٩٨	لا جواب
		٩٩	لا أعلم	٩٩	لا أعلم	٩٩	لا أعلم

10	هل لاحظت ارتفاع في نسبة ملوحة المياه	١ نعم ٢ كلا 97 N/A ٩٨ لا جواب ٩٩ لا اعلم	١ نعم ٢ كلا 97 N/A ٩٨ لا جواب ٩٩ لا اعلم	١ نعم ٢ كلا 97 N/A ٩٨ لا جواب ٩٩ لا اعلم
11	هل ارتفاع نسبة الملوحة هو امر جديد؟	١ نعم كلا ٢ N/A ٩٧ لا جواب ٩٨ لا اعلم ٩٩	١ نعم كلا ٢ N/A ٩٧ لا جواب ٩٨ لا اعلم ٩٩	١ نعم كلا ٢ N/A ٩٧ لا جواب ٩٨ لا اعلم ٩٩
11a	منذ متى كان ذلك؟	1 منذ اقل من ٦ اشهر 2 منذ ١,٥ سنة 3 منذ اكثر من عامين 4 منذ اكثر من ٥ اعوام 97 N/A 98 لا جواب 99 لا اعلم	1 منذ اقل من ٦ اشهر 2 منذ ١,٥ سنة 3 منذ اكثر من عامين 4 منذ اكثر من ٥ اعوام 97 N/A 98 لا جواب 99 لا اعلم	1 منذ اقل من ٦ اشهر 2 منذ ١,٥ سنة 3 منذ اكثر من عامين 4 منذ اكثر من ٥ اعوام 97 N/A 98 لا جواب 99 لا اعلم
12	هل لاحظت آثار سلبية من ملوحة المياه على نمو النباتات؟	١ نعم ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	١ نعم ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	١ نعم ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
13	ما هي هذه الآثار؟	١ انخفاض/توقف في النمو ٢ حريق/اصفرار في اطراف الاوراق ٣ غيره, حدد .... ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم		

Adaptation Measures (AM)	
في حال ارتفاع نسبة الملوحة في مياه البير هل تستخدم طرق للتكيف مع الملوحةعلى هذه الأرض؟	١ نعم ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
في حال ارتفاع نسبة الملوحةفي مياه البير اي من الطرق التالية تستخدم، على هذه الأرض للتكيف مع الملوحة؟	

AM1	تغيير موقع البير	١ نعم ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
AM2	اغلاق البير	١ نعم ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
AM3	تخفيض/الحد من استعمال مياه البير	١ نعم ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
AM4	معالجة المياه	١ نعم , كيف؟................ ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
AM5	هل تستخدم اي طرق اخرى؟	١ نعم AM5a حدد، ________________ ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
AM6	ما كان مجموع انفاقك على تطبيق تلك الاجراءات؟	|___||___||___||___||___||___||___||___| ليرة لبنانية ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم

هل تستعمل، على هذه الارض، في زراعة هذه الاصناف ادوية زراعية مثل:

	المنتوجات الزراعية (Agricultural Produce)			
		موز (A)	حمضيات (B)	غيره (C)
٥	نوع نظام الرّي	١ تعويم / تطويف ٣ رذاذ فوقي ٤ بالنقطة ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	١ تعويم / تطويف ٣ رذاذ فوقي ٤ بالنقطة ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	١ تعويم / تطويف ٣ رذاذ فوقي ٤ بالنقطة ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
٦	موسم الرّي	من / الى ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	من / الى ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	من / الى ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
٧	كمية مياه الرّي باليوم	م٣ |___|___|___| ٩٧ N/A	م٣ |___|___|___| ٩٧ N/A	م٣ |___|___| ٩٧ N/A
٣	وتيرة الري	|___|ساعة/ الاسبوع ٩٨ لا جواب ٩٩ لا اعلم	|___|ساعة/ الاسبوع ٩٨ لا جواب ٩٩ لا اعلم	|___|ساعة/ الاسبوع ٩٨ لا جواب ٩٩ لا اعلم
٨	كلفة تمديد نظام	ليرة |___|___|___| لبنانية/ دونم ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	ليرة |___|___|___| لبنانية/ دونم ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	ليرة لبنانية/ دونم |___| ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
٤	مصدر المياه الرّي	٢ بئر العق ٣ تجم ٤ مياه صهاريج	٤ مياه صهاريج	٤ مياه صهاريج
9	حجم الانتاج	كغ|___|___|___|	كغ|___|___|___|	كغ|___|

	في٢٠١٣؟ ٩٨ ٩٩	٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
10	سعر المنتوج	 97 N/A 98 لا جواب 99 لا اعلم	 ٩٧ N/A 98 لا جواب 99 لا اعلم	 ٩٧ N/A 98 لا جواب 99 لا اعلم
11	بالمقارنة مع المواسم الماضية؟	1 ارتفع ٢ انخفض ٣ لم يتغير ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	1 ارتفع ٢ انخفض ٣ لم يتغير ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	1 ارتفع ٢ انخفض ٣ لم يتغير ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم

AG		(A) موز	(B) حمضيات	(C) غيره	السعر
1	يوريا	الكمية |___|كغ/موسم ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	الكمية |___|كغ/موسم ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	الكمية |___|كغ/موسم ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	|___|$/كغ ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
2	فوسفيت الأمونيوم الثنائي	الكمية |___|كغ/موسم ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	الكمية |___|كغ/موسم ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	الكمية |___|كغ/موسم ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	|___|$/كغ ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
3	كبريتات	الكمية |___|كغ/موسم ٩٧ N/A	الكمية |___|كغ/موسم ٩٧ N/A	الكمية |___|كغ/موسم ٩٧ N/A	|___|$/كغ ٩٧ N/A

	الأمون يوم	٩٨ ٩٩	لا جواب لا اعلم	٩٨ ٩٩	لا جواب لا اعلم	٩٨ ٩٩	لا جواب لا اعلم	٩٨ 99	لا جواب لا اعلم
4	اسمدة النيترو جين الأخر ى	الك مية ٩٧ ٩٨ ٩٩	|___|كغ/موسم N/A لا جواب لا اعلم	الك مية ٩٧ ٩٨ ٩٩	|___|كغ/مو سم N/A لا جواب لا اعلم	الك مية ٩٧ ٩٨ ٩٩	|___|كغ/موسم N/A لا جواب لا اعلم	 ٩٧ ٩٨ ٩٩	|___|$/كغ N/A لا جواب لا اعلم
5	الكلس	الك مية ٩٧ ٩٨ ٩٩	|___|كغ/موسم N/A لا جواب لا اعلم	الك مية ٩٧ ٩٨ ٩٩	|___|كغ/مو سم N/A لا جواب لا اعلم	الك مية ٩٧ ٩٨ ٩٩	|___|كغ/موسم N/A لا جواب لا اعلم	 97 98 99	|___|$/كغ N/A لا جواب لا اعلم
6	الأسمدة الفوسفا تية	الك مية ٩٧ ٩٨ ٩٩	|___|كغ/موسم N/A لا جواب لا اعلم	الك مية ٩٧ ٩٨ ٩٩	|___|كغ/مو سم N/A لا جواب لا اعلم	الك مية ٩٧ ٩٨ ٩٩	|___|كغ/موسم N/A لا جواب لا اعلم	 ٩٧ ٩٨ ٩٩	|___|$/كغ N/A لا جواب لا اعلم
7	اسمدة البوت اسيوم	الك مية ٩٧ ٩٨ ٩٩	|___|كغ/موسم N/A لا جواب لا اعلم	الك مية ٩٧ ٩٨ ٩٩	|___|كغ/مو سم N/A لا جواب لا اعلم	الك مية ٩٧ ٩٨ ٩٩	|___|كغ/موسم N/A لا جواب لا اعلم	 ٩٧ ٩٨ ٩٩	|___|$/كغ N/A لا جواب لا اعلم
٨	خليط NPK	الك مية	|___|كغ/موسم	الك مية	|___|كغ/مو سم	الك مية	|___|كغ/موسم	$/|___| كغ	|
		٩٧	N/A	٩٧	N/A	٩٧	N/A	٩٧	N/A
		٩٨	لا جواب	٩٨	لا جواب	٩٨	لا جواب	٩٨	لا جواب
		٩٩	لا اعلم	٩٩	لا اعلم	٩٩	لا اعلم	٩٩	لا اعلم
٩		الك مية	|___|كغ/موسم	الك مية	|___|كغ/مو سم	الك مية	|___|كغ/موسم	/$|___| كغ	

	سماد عضوي	٩٧ N/A	٩٧ N/A	٩٧ N/A	٩٧ N/A
		٩٨ لا جواب	٩٨ لا جواب	٩٨ لا جواب	٩٨ لا جواب
		٩٩ لا اعلم	٩٩ لا اعلم	٩٩ لا اعلم	٩٩ لا اعلم

سوف اسألك بعض التفاصيل عن كلفة ومشاكل الري

كلفة الري والمشاكل التي تمت مواجهتها		
WE1	هل تستخدم، على هذه الأرض،طرق للمحافظة على المياه؟	١ نعم ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
WE1A	حد أدنى من الحرث	١ نعم ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
WE1B	الري في الليل او في الصباح	١ نعم ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
WE1C	تخفيض الضغط في نظام الري	١ نعم ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
WE1D	فوهات توفير المياه او الطاقة	١ نعم ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
WE1E	استخدام السماد او معالجة التربة عضويا	١ نعم ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم

WE1F	طرق اخرى لتوفير المياه		١	نعم
			WE1Fa	حدد ____________ ________
			٢	كلا
			٩٧	N/A
			٩٨	لا جواب
			٩٩	لا اعلم
WE2	هل حصل ولم تتمكن من الري؟		١	نعمWE2a في اي سنة؟ ………………………
			٢	كلا Go to WE5
			٩٧	N/A
			٩٨	لا جواب
			٩٩	لا اعلم
WE3	اذا نعم، هل حصل ذلك بسبب:			
WE3A	نقص في المياه السطحية	١	نعم	
		٢	كلا	
		٩٧	N/A	
		٩٨	لا جواب	
		٩٩	لا اعلم	
WE3B	نقص في المياه الجوفية	١	نعم	
		٢	كلا	
		٩٧	N/A	
		٩٨	لا جواب	
		٩٩	لا اعلم	

WE3C	مياه مالحة	١ ٢ ٩٧ ٩٨ ٩٩	نعم كلا N/A لا جواب لا اعلم
WE3D	مياه ملوّثة	١ ٢ ٩٧ ٩٨ ٩٩	نعم كلا N/A لا جواب لا اعلم
WE3E	كلفة تأمين مياه مرتفعة	١ ٢ ٩٧ ٩٨ ٩٩	نعم كلا N/A لا جواب لا اعلم
WE3F	طرق اخرى	١ WE3Fa ٢ ٩٧ ٩٨ ٩٩	نعم حدد، ________________________ _ كلا N/A لا جواب لا اعلم
WE4	في تلك الحالة, هل اتخذت اي اجراءات؟	١ ٢ ٩٧ 98 ٩٩	نعم كلا N/A لا جواب لا اعلم
WE4a	ما هي الاجراءات التي اتخذتها؟		____________________________________ ______

WE5	ما كان مجموع انفاقك على تأمين مياه الري من مصادر سطحية في آخر موسم؟		___|___||___||___||___||___||___||___| |__ ليرة لبنانية
		٩٧	N/A
		٩٨	لا جواب
		٩٩	لا اعلم
WE6	ما كان مجموع انفاقك على تأمين مياه الري من مصادر جوفية في آخر موسم ؟		___|___||___||___||___||___||___||___| |__ ليرة لبنانية
		٩٧	N/A
		٩٨	لا جواب
		٩٩	لا اعلم

الآن سوف اسألك عن تربة هذه الأرض:

تربة الأرض Soil			
S1	هل لاحظت ارتفاع في نسبة ملوحة التربةخلال الاعوام الماضية؟	1	نعم ____________________
		٢	كلا Go to MS1
		٩٨	لا جواب
		٩٩	لا اعلم
S2	اذاكان الجواب نعم، هل لاحظت آثار سلبية من ملوحة التربة على نمو النباتات؟	١	نعم
		٢	كلا Go to MS1
		٩٧	N/A
		٩٨	لا جواب
		٩٩	لا اعلم
S3	اذا كان الجواب نعم، ماهي المحاصيل الأكثر تأثرا؟		____________________ ____________________ ________
		٩٧	N/A
		٩٨	لا جواب
		٩٩	لا اعلم

S4	ما هي هذه الآثارالسلبية؟	١ ظهور قشرة بيضاء ٢ منع في انبات البذور 3 عدم انتظام ظهور شتلات المحاصيل ٤ غيره, حدد …………………………………… ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
S5	هل ترتب عليك اي تكلفة مالية اضافية من جراء هذه الآثار السلبيةللتربة المالحة؟	١ نعم ٢ كلا Go to MS1 ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
S6	اذا كان الجواب نعم، كم تُقدّر هذه التكلفة المالية الاضافية لسنة ٢٠١٣؟	|___||___||___||___||___||___||___||___| ليرة لبنانية ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم

الآن سوف اسألك عن طريقة العناية بالتربة لمنع او معالجة ارتفاع الملوحة فيها:

MS1	هل تستخدمطرق لمنع او تخفيض نسبة الملوحة في التربة؟	١ نعم ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
MS1A	استخدام انظمة خاصة لتصريف المياه من التربة	١ نعم ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
MS1B	الري الفيضاني الدوري بالمياه العذبة	١ نعم ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
MS1C	تعديل الجدول الزمني للري	١ نعم ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
MS1D	تحويل المحصول الى محاصيل اكثر تحملا للملوحة	١ نعم ______________ ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
MS1E	معالجة التربة	١ نعم, ٢ كلا ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
MS1E1	اذا كنت تعالج التربة، كيف؟	

الأن سوف اسألك عن استعدادك للدفع لمواجهة مشكلة الملوحة:

الاستعداد للدفع(WTP)			
WTP1A	هل انت مستعد للمساهمة مع البلدية في معالجة مشكلة ارتفاع ملوحة الآبار المستخدمة للري؟	1 2 97 98 99	نعم , كلا N/A لا جواب لا اعلم
WTP1B	ما هو المبلغ الشهري الذي انت مستعد لدفعه للمساهمة مع البلدية في معالجة مشكلة ارتفاع ملوحة الآبار المستخدمة للري (ليرة لبنانية)؟	|___|___|___|___|___|___|	
A٢WTP	اذا كنت تعاني من مشكلة ملوحة, على الصعيد الشخصي,هل انت مستعد للمساهمة في معالجة مشكلة ارتفاع ملوحة الآبار المستخدمة للري؟	1 2 97 98 99	نعم , كلا N/A لا جواب لا اعلم
WTP2B	اذا كنت تعاني من مشكلة ملوحة، ما هو المبلغ الشهري الذي انت مستعد لدفعه لتطبيق اجراءات تخفيفية على مستوى مجمل اراضيك الزراعية لمواجهة او معالجة زيادة الملوحة في مياه الآبار المستخدمة للري (ليرة لبنانية)؟	|___|___|___|___|___|___|	

Water Quality/Soil Quality			
WQ	هل انت على استعداد ان تدع الباحثين ان يأخذوا عينات من المياه\التربةمن ارضك لدراسة الآثار السلبية لملوحة المياه على القطاع الزراعي؟	١ ٢ ٩٧ ٩٨ ٩٩	نعم كلا N/A لا جواب لا اعلم

سوف أطرح عليك بعض الأسئلة حول الوضع المالي العام لمنزلك

الوضع المالي (Financial Status)			
FS1	عدد الغرف في المنزل: **فقط النوم والصالونات** (دون المطبخ، الحمام، الشرفة والمخزن/موقف السيارة)		|___|___|
FS2	هل تملك المنزل الذي تسكن فيه؟	١	نعم، ملك
		٢	كلا، إيجار
		٣	كلا، حدد____________________
		٩٨	لا جواب
		٩٩	لا أعلم
FS3	ما هو المصروف الشهري الإجمالي للعائلة؟		|___|___|___|,|___|___|___|,|___|___|___| ليرة
		٩٨	لا جواب
		٩٩	لا اعلم
FS4	ما هو الدخل الشهري الإجمالي للمنزل؟	1	٥٠٠ دولار وما دون
		٢	٥٠٠-١٥٠٠ دولار
		٣	١٥٠٠-٤٠٠٠ دولار
		٤	٤٠٠٠ – ٦٠٠٠ دولار
		٥	أكثر من ٦٠٠٠ دولار
		٩٨	لا جواب
		٩٩	لا أعلم
FS5	ما عدد السيّارات التي يملكها سكّان المنزل؟		|___|___|
		98	لا جواب
		99	لا اعلم

سوف أطرح الآن بعض الاسئلة عن العائلةوالعمل:

<table>
<tr><th colspan="11">معلومات اجتماعية وديموغرافية (Socio-Demographic and Work Information)</th></tr>
<tr><td></td><td>SD1</td><td colspan="9">ما هو عدد الأفراد الذين يسكنون في المنزل؟ |___|___|</td></tr>
<tr><td></td><td></td><td>SD2</td><td>SD3</td><td>SD4</td><td>SD5</td><td>SD6</td><td>SD7</td><td>WI1</td><td>WI2</td></tr>
<tr><td></td><td>إسم الفرد الذي يسكن في المنزل:</td><td>علاقته برب المنزل:</td><td>الجنس:</td><td>سنة الولادة:</td><td>هل هذا الفرد:</td><td>أين يتعلّم حاليا؟</td><td>أعلى مستوى علمي حصّله:</td><td>هل يعمل حاليا، ما العمل الحالي:</td><td>في أيّ قطاع يعمل؟</td></tr>
<tr><td></td><td></td><td>١ رب المنزل
٢ زوجة
٣ إبن \ إبنة
٤ أب \ أم
٥ أخ \ أخت
٦ حفيد \ حفيدة
٧ الصهر\ الكنة
٨ غيره
٩٧ N/A
٩٨ لا جواب
٩٩ لا أعلم</td><td>١ ذكر
٢ أنثى</td><td>سنة
|__|__|__|__|</td><td>١ لم يتعلّم
Go to SD7
٢ تعلم/ تخرج
Go to SD7
٣ يتعلم حالياً
Go to SD6
٩٧ N/A
٩٨ لا جواب
٩٩ لا أعلم</td><td>١ مدرسة خاصّة
٢ مدرسة رسميّة
٣ الجامعة اللبنانية
٤ جامعة خاصّة
٥ معهد
٩٧ N/A
٩٨ لا جواب
٩٩ لا أعلم</td><td>١ لا يقرأ ويكتب
٢ يقرأ ويكتب
٣ إبتدائي
٤ متوسّط
٥ ثانوي
٦ تقني
٧ جامعي
٨ دراسات عليا
٩٧ N/A
٩٨ لا جواب
٩٩ لا أعلم</td><td>١ لا يعمل
2 صاحب مؤسسة
3 موظّف
4 ربّ عمل \ مدير
5 ربة منزل
٦ متقاعد
٧ مزارع
٩٧ N/A
٩٨ لا جواب
٩٩ لا أعلم</td><td>١ مؤسّسة خاصة
٢ مؤسّسةعامة
٣ جمعيّة
٩٧ N/A
٩٨ لا جواب
٩٩ لا أعلم</td></tr>
<tr><td>A</td><td></td><td>|___|___|</td><td>|___|</td><td>|__|__|__|__|</td><td>|___|___|</td><td>__________|___|___|</td><td>|___|___|</td><td>__________|___|___|</td><td>__________ |___|___|</td></tr>
<tr><td>B</td><td></td><td>|___|___|</td><td>|___|</td><td>|__|__|__|__|</td><td>|___|___|</td><td>__________|___|___|</td><td>|___|___|</td><td>__________|___|___|</td><td>__________ |___|___|</td></tr>
<tr><td>C</td><td></td><td>|___|___|</td><td>|___|</td><td>|__|__|__|__|</td><td>|___|___|</td><td>__________|___|___|</td><td>|___|___|</td><td>__________|___|___|</td><td>__________ |___|___|</td></tr>
<tr><td>D</td><td></td><td>|___|___|</td><td>|___|</td><td>|__|__|__|__|</td><td>|___|___|</td><td>__________|___|___|</td><td>|___|___|</td><td>__________|___|___|</td><td>__________ |___|___|</td></tr>
<tr><td>E</td><td></td><td>|___|___|</td><td>|___|</td><td>|__|__|__|__|</td><td>|___|___|</td><td>__________|___|___|</td><td>|___|___|</td><td>__________|___|___|</td><td>__________ |___|___|</td></tr>
<tr><td>F</td><td></td><td>|___|___|</td><td>|___|</td><td>|__|__|__|__|</td><td>|___|___|</td><td>__________|___|___|</td><td>|___|___|</td><td>__________|___|___|</td><td>__________ |___|___|</td></tr>
</table>

___________ |___|___|	___________|___|___|	|___|___|	__________|___|___|	|___|___|	|__|__|__|__|	|___|	|___|___|		G

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