Food and Agriculture Organization of the United Nations

REMOTE SENSING FOR WATER PRODUCTIVITY

TECHNICAL REPORT: CAPACITY DEVELOPMENT SERIES

Stakeholder mapping and needs assessment - Lebanon

International Water Management Institute

Remote Sensing for Water Productivity

Technical report: capacity development series

Stakeholder mapping and needs assessment - Lebanon

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FAO, in partnership with and with funding from the Government of the Netherlands, is developing a programme to monitor and improve the use of water in agricultural production. This document is part of the fourth output of the programme: capacity development to increase land and water productivity.

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More information on the project can be found at http://www.fao.org/in-action/remote-sensingforwater-productivity

Abbreviations and acronyms

CNRS	National Council for Scientific Research
CNTPL	Cooperative of Native Tree Producers of Lebanon
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
ICT	Information and Communication Technologies
IoT	Internet of Things
IT	Information Technology
IWMI	International Water Management Institute
LARI	Lebanese Agricultural Research Institute
LRA	Litani River Authority
LRB	Litani River Basin
LRBMS	Litani River Basin Management Support Program
LRI	Lebanon Reforestation Initiative
MEW	Ministry of Energy and Water of Lebanon
MoA	Ministry of Agriculture of Lebanon
NGO	Non-Governmental Organization
RCED	Research Center for Environment and Development
RDC	Rural Development Center
RSC	Remote Sensing Center
SEC	social and environmental corridor
SMS	Short Message Service
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
WaPOR	FAO portal to monitor WAter Productivity through Open access of Remotely sensed derived data
WUA	Water Use Association

1. Project Background

1.1 Introduction

In 2009, the World Water Council highlighted the fact that without major technological innovations to improve irrigation management services for millions of farmers and reduce the stress on water systems around thve world, there is little hope of bringing the water equation into balance (World Water Council, 2009). Information and Communication Technologies (ICT) can be used to improve water management at the level of both managers, and farmers, and enable better planning, water monitoring, rule enforcement, communication, and coordination.

Several success stories have been reported around the world on the use of technological tools and approaches that improved farming systems and farmers' livelihoods (FAO, 2015, 2017). In irrigation management, ICT tools constitute the enabling environment for proper decision-making and help providing efficient use of water (Sne, 2005). This is done through proper water monitoring by means of sensors used for water metering, which highly facilitates inter-sectorial water allocation. In many places, this approach has a remarkably significant impact on agricultural water management and in particular on irrigation practices. Irrigation can therefore become controlled and optimized by several applications based on a variety of control systems or a combination of these. Soil moisture levels, canopy temperatures and crop water requirements based on climate data and plant evapotranspiration are measured to allow optimal water application; thus saving on volumes of water applied at every irrigation event and throughout the season (ATSE, 2012).

ICT tools not only support the physical improvement of irrigation management at the farm level, but can strengthen the exchange of information at basin or regional level, between irrigation schemes. Through structured information systems and the use of real-time data, it eases information exchange and ensures access to reliable information. If adequately used, water users, managers and authorities can be linked through an effective communication system where knowledge can be transferred, enabling the development of irrigation management technical skills at the different scales within a basin.

Given the scarcity of land and water resources, global strategies to increase food production should focus efforts on increasing production per unit resources, i.e. the combined increase of production per unit land surface (yield expressed in kg/ha[1]) and the increase of production per unit water used (water productivity expressed in kg/m^3). Closing land and water productivity gaps is a complex task which requires: (i) monitoring of current levels of productivity in various crop production systems; (ii) assessment of observed productivity relative to potential; (iii) identification and analysis of the underlying causes of the productivity gaps; and (iv) evaluation of options and identification of viable solutions to close the productivity gaps in the local context.

To support these processes, this project is applying analysis of high resolution satellite images in conjunction with specific algorithms to determine spatial and temporal variability of agricultural water and land productivity. Through the project activities, the FAO portal to monitor WAter Productivity through Open access of Remotely sensed derived data (WaPOR. https://wapor.apps.fao.org) was developed. WaPOR uses satellite information to compute and map key variables related to water and agriculture, such as evapotranspiration, biomass production and water productivity. The provision of near real time information through such open access data portal will enable a range of service-providers to assist farmers attain more reliable yields and to improve their livelihoods; irrigation operators will have access to new information to assess the performance of systems and to identify where to focus investments to modernize the irrigation schemes; and government agencies will be able to use the information to monitor and promote the efficient use of natural resources.

This report presents the work undertaken to identify key stakeholders in the agriculture and ICT sector and the capacity needs of farmers to improve water productivity in a sustainable manner, through two components; the first surveys the role and capacities of various stakeholders in the ICT and agriculture sector in Lebanon, and the second presents and analyzes the results of a survey into the capacity needs of farmers in relation to the use of ICT in agriculture in the Bekaa valley.

1.2 Capacity Building

The International Water Management Institute (IWMI) is implementing Component 4 of the project to meet the objective of improving the capacity of the direct beneficiaries to improve water productivity in both rain-fed and irrigated systems in a sustainable manner. The direct beneficiaries include: (i) national institutions involved with ICT services for water and agriculture as well as Non-Governmental Organizations (NGOs) and the private sector; (ii) Water User Associations (WUAs) and extension services, irrigation authorities; and (iii) the farmers themselves. Capacity development is a strategic enabler of project impact, ensuring that the communities will ultimately benefit from the tools developed across all project components. The capacity development program will be targeted at individual sites, and these pilot activities will generate lessons, good practices and learning materials that will enable replication and outscaling in other areas and countries. Recommendations will address both rain-fed and irrigated systems.

The implementation of Component 4 is guided by three key objectives:

Objective 1: *Identify relevant stakeholders and undertake stakeholder needs assessment*

Objective 2: *Identify current activities for ICT and other solutions in agricultural water management and undertake capacity building with identified partners*

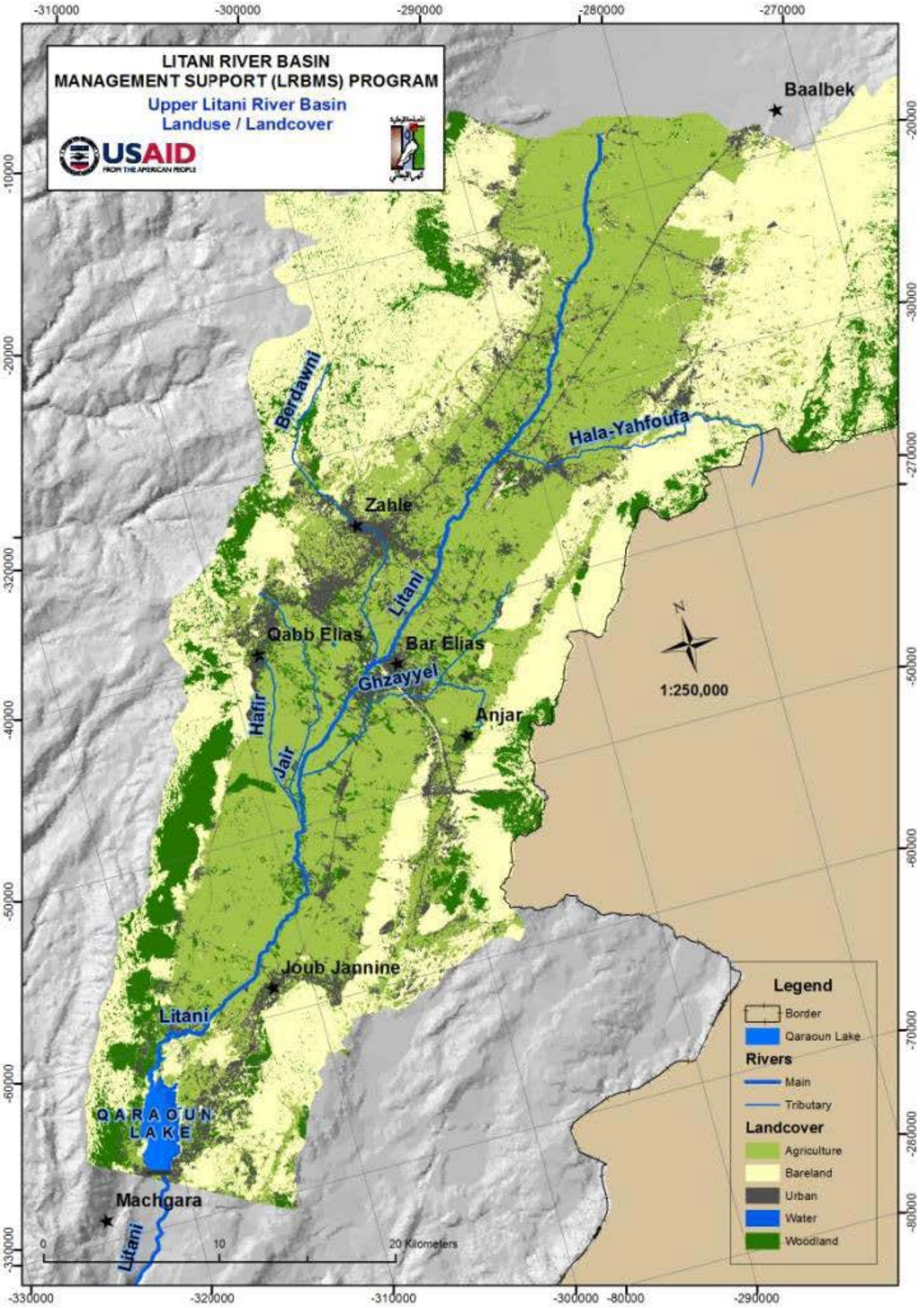
Objective 3: *Develop, design, pilot, and evaluate potential solutions to increase water productivity sustainably*

This report provides a summary of the country based outputs generated through the activities undertaken to meet Objective 1, and provides recommendations for the activities needed to meet Objectives 2 and 3.

1.3 Site Information

The Bekaa valley is Lebanon's largest agricultural area, and provides the biggest share of the country's agricultural production (MoA and FAO, 2010). It is a large plain of fertile agricultural land (around 110,000 ha), drained by the Litani River and its tributaries (Figure 1). Naturally wellendowed in water, it has been cultivated since ancient times by several civilisations. Several large springs discharge from the Karstic mountains outcropping on each side of the valley, forming rivers in the plain. The Bekaa is also very rich in groundwater. There are several aquifers in the Bekaa; the Quaternary (alluvial) aquifer underlying most of the agricultural lands, several Karstic aquifers

Figure 1. The Litani watershed draining most of the Bekaa plain

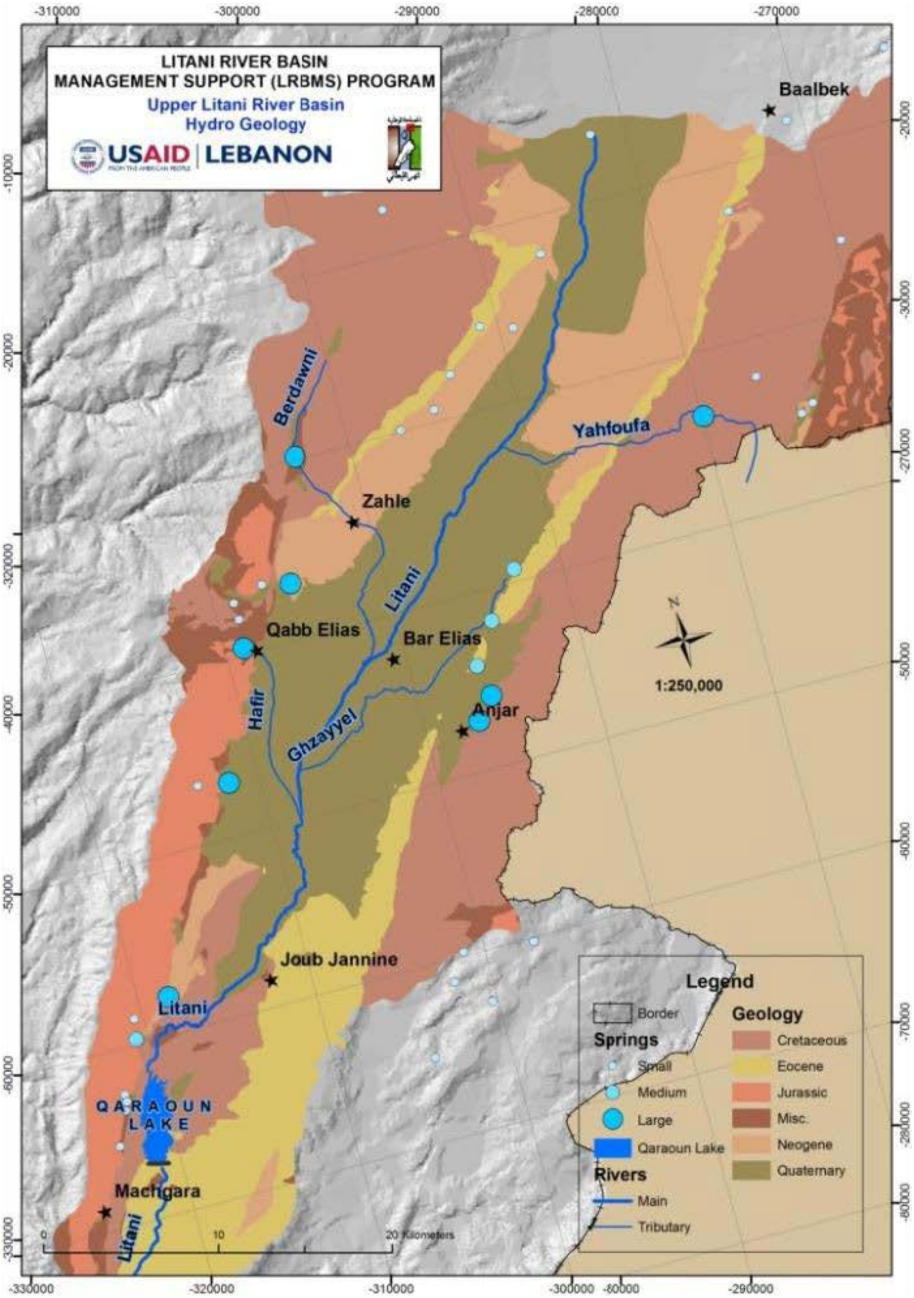


Source: USAID-LRBMS, 2012a.

(Eocene, Cretaceous and Jurassic), forming the mountain chains surrounding the plain and the Neogene aquifer (semi-alluvial) outcropping in some parts at the fringe of the valley (Figure 2).

Irrigation has historically developed around mountain springs and along rivers, from which water was first derived by gravity, supplying collective community-based irrigation systems. In the plain, farmers used hand-dug shallow wells to irrigate small farms (Baldy, 1960). Irrigation remained relatively limited until the 1950s. In the 1960s, following the introduction of pumping and drilling technologies, irrigation expanded rapidly: pumps started to be used on rivers, and tubewells were drilled in all aquifers. In less than two decades, a major part of the Bekaa was irrigated, chiefly by private initiatives (Nassif, 2016). In the late 2000s, around 65% of the Bekaa lands were irrigated from groundwater, while the rest was irrigated from rivers and springs (Verdeil et al. 2007). Nowadays, due to a reduction in surface water resource availability (USAID- LRBMS, 2012; Nassif, 2016), areas irrigated from groundwater are expected to be even higher.

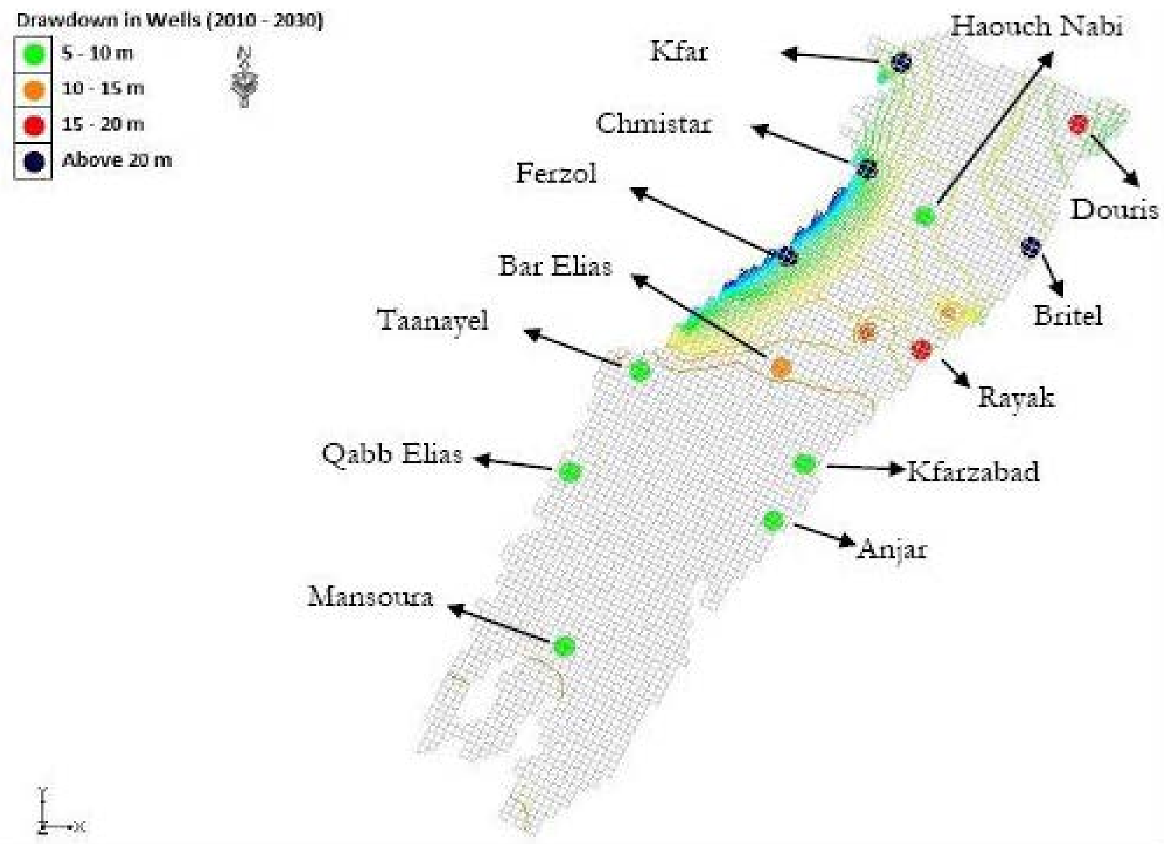
Figure 2. The Bekaa aquifers



Source: USAID-LRBMS, 2012a.

Since the 1950s, pressure on water has heavily increased. In parallel to the irrigation boom, the Bekaa population has substantially increased, which has translated to more water withdrawals for drinking, industrial, and domestic use. Over a period of five decades, these sustained water withdrawals from springs, rivers and aquifers have led to groundwater overexploitation with the situation expected to deteriorate in the coming years (USAID-LRBMS, 2013; Nassif, 2016; Molle et al. 2017). Many springs have dried up, river flows have substantially decreased and water levels have dropped in all aquifers (Figure 3) and will expected to continue to drop at a significant rate (USAID-LRBMS, 2012c; 2013). Pollution is also a major problem. Many rivers (Litani, Berdaouni) as well as the Qaraoun dam, that collects the ULRB water, are highly polluted (USAID-LRBMS, 2011a, b; ELARD, 2011; IBRD, 2013). Today, water management is a crucial issue to be addressed in the Bekaa.

Figure 3. Projected drawdown of the Litani River Basin water tables (2030)



Source: USAID-LRBMS (2013).

1.3.1 Water management problems and needs

Previous studies have shown that improving water management in the Bekaa is needed at different levels. First, and most importantly, this was found to be required from public institutions. At the level of decision-makers, there is a serious need for improving the knowledge and monitoring of the different water resources and their current use, and substantial efforts are to be done to improve the planning of water allocation across areas and between different sectoral uses in the Bekaa (USAID-LRBMS, 2012a; Nassif, 2016; Molle et al. 2017). There is also a pressing need for improving and enforcing water management policies, such as clarifying and/or redefining water rights (surface and groundwater) and enforcing them (Nassif, 2016; Molle et al. 2017). Significant efforts should also be provided at the central level for treating wastewater and controlling pollutants since most of the domestic, industrial and agricultural waste water is currently discharged into the rivers (USAID-LRBMS, 2012a).

On the other hand, being the direct consumers of water resources, users have also an important role to play in quantitative and qualitative water management. The need to improve irrigation management at farm level is often highlighted, since agriculture is responsible for the largest share of water withdrawals in the Bekaa (USAID-LRBMS, 2012a). Over the last two decades several studies have recommended that farmers should reduce water input at farm level by switching to more efficient irrigation techniques (Karam and Karaa, 2000; Karaa et al. 2004; Jawhary, 2012) or use unconventional water sources such as treated wastewater (Karaa et al. 2004; Karaa et al. 2005). Moreover, several scientific trials have assessed the possibility of practicing deficit irrigation in the Bekaa to reduce water consumption and optimize yields (Karaa et al. 2007; Al Arab, 2011 and others).

2. Stakeholder mapping: **ICT and the agriculture sector**

2.1 The ICT Sector, Lebanon

The Lebanese ICT sector is characterized by relatively small scale but highly adaptive firms. It also enjoys many advantages, including a skilled workforce, outstanding advertising firms, media content providers and web portals, competitive Internet service providers, and well developed GSM cellular networks. Software programmers and designers in the Lebanese ICT sector are considered among the best in the Middle East. The Lebanese government has recently joined the private sector to develop e-government services in the country, though it has not yet developed adequate legal infrastructure for the sector. (ESCWA, 2007).

Lebanon's mobile connections have been rising since the 2010s, showing one of the largest growth in ICT development in the world (according to the ICT Development Index: Blominvest Bank, 2014). Internet penetration rate is expected to reach 77% by 2017, due in part to its small yet well-educated and literate population (BankMed, 2015). Lebanon's ICT sector shows a fairly diverse sub-sector growth, with computer hardware, software and Information Technology (IT) services all present. Computer hardware represents the largest share in the sector (62% according to 2015 data). This is followed by IT services (support, implementation, integration, training and maintenance) with 29% of the sector. The increase in this sub-sector (growing at an average rate of 14% since 2009) is due to the rising spending on e-services by businesses, telecom companies and government agencies (BankMed, 2015).

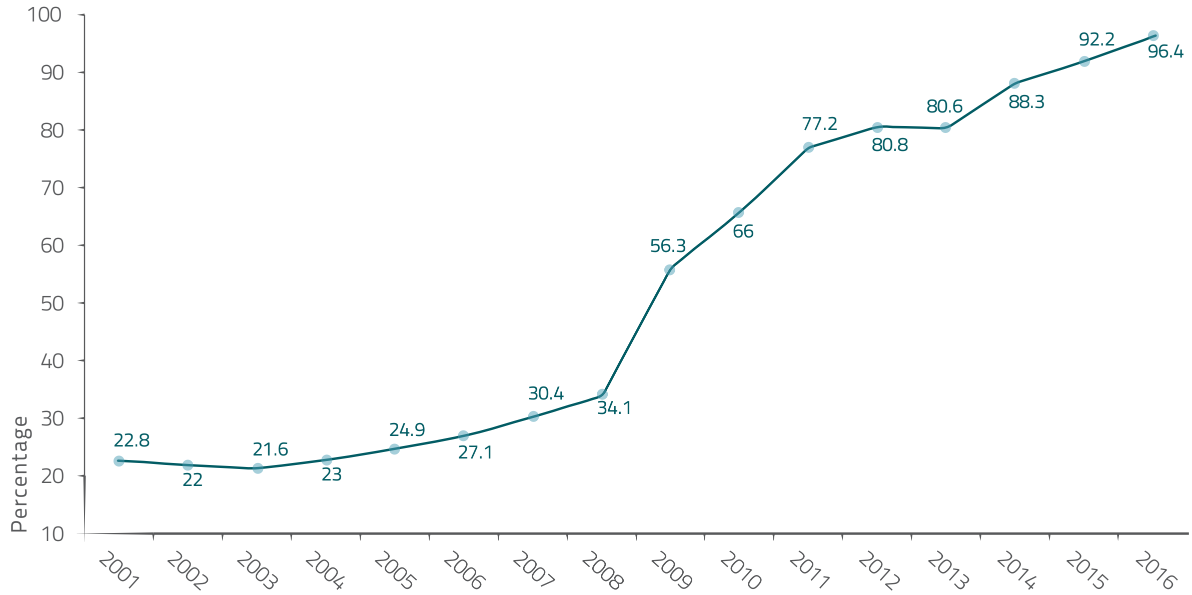
Technology revolution and consumer demands for smartphones have furthered the demand for mobile broadband to the expense of traditional short message services (SMS). The introduction of 3G in 2011 prompted the subscription to mobile broadband packages by consumers (158% higher in the first year and 173% in 2012). This trend followed and by the end of 2013 more than 50% of mobile subscribers (2.2 million) were subscribed to a mobile data plan, facilitated with the introduction of bundles and other types of new packages (Blominvest Bank, 2014). Communication expenses were at 4.6% of the Consumer Price Index in Lebanon in June 2014.

The availability of 4G services has been present in Lebanon since 2013. Initially the coverage was only small but during 2016, both phone operators Touch and Alfa implemented substantial 4G upgrades and expansions, supported by Huawei, Nokia and Ericsson. By the end of March 2017, according to the Telecoms Minister, Lebanon reached an 85% coverage of 4G mobile broadband across most parts of Lebanon. (Budde, 2017). According to Byblos Bank data, in 2016, 52 percent of adults in Lebanon had a smartphone. Also, 74% of Lebanese aged between 18 and 34 years have a smartphone while only 37 percent of those older than 35 years have such a phone (The Daily Star, 2016).

Information on the key partners involved in the agricultural and ICT sector for the Bekaa, and assessment of the information and communication flow channels was collected through discussions with a range of stakeholders (Table 1) to meet the following objectives:

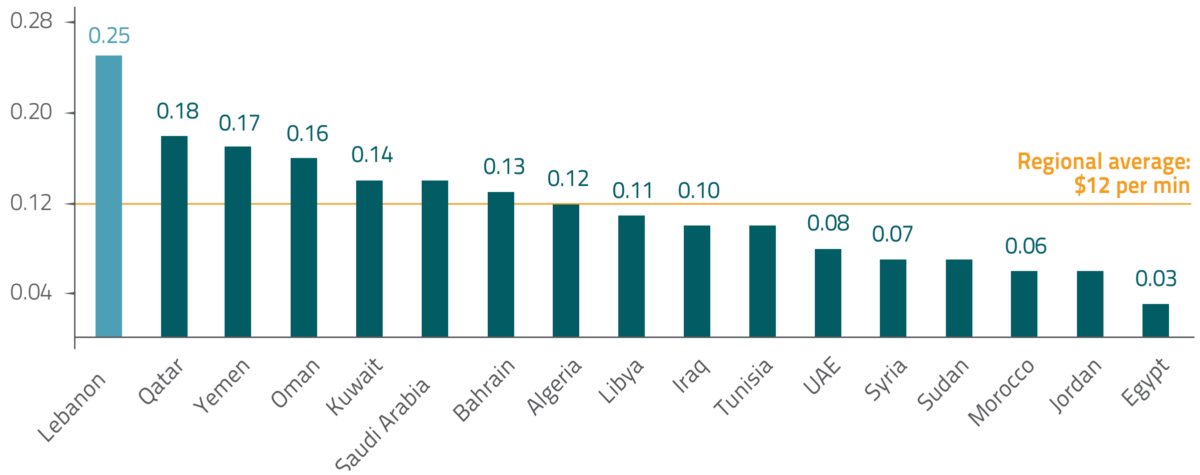
- review and identify the key partners in both the agriculture and ICT sector involved in agricultural water management and map existing information and communication flows and channels;
- review existing efforts in ICT and other solutions in water management for agriculture and irrigation production and productivity which are being piloted and out-scaled in Lebanon.

Figure 4. Mobile penetration rates in Lebanon



Source: Byblos Bank 2017.

Figure 5. Average basic prepaid price per minute in the Arab region



Source: Blominvest Bank, 2014.

The results presented here are based on a series of interviews conducted during a mission to Lebanon between January 28th and February 2nd 2018. For each institution, the results are summarized around three main aspects: 1) the general role of the institution; 2) Its recent activivties in irrigation, water management and/or agriculture; 3)

Its recent or projected experiences with ICT in irrigation and agriculture; throughout the description, problems and obstacles that could hinder the use or promotion of ICT tools are highlighted.

Table 1. Interviewed stakeholders

Institution	Department	Date of Interview
Litani River Authority	Rural Development Center of Kherbet Kanafar (South Bekaa)	30/01/2018
Lebanese Agricultural Research Institute	Department of Irrigation and AgroMeterology	31/01/2018
Tal Amara Station (CentralBekaa)	Department of Irrigation and AgroMeterology	31/01/2018
Beirut Arab University	Research Center for Environment and Development-Taanayel (Central Bekaa)	31/01/2018
Lebanese Agricultural Research Institute Fanar Station (Beirut)	Department of irrigation and agrometeorology	01/02/2018
Ministry of Agriculture Department of Rural Development	Department of Rural Development and of the Service of Rural Projects and Irrigation	01/02/2018
Alfa Company (Beirut)	Department of Internet of Things (IoT) Strategy Design	01/02/2018
	Corporate Strategy	
Centre National de la Recherche Scientifique National Center For Remote Sensing (Fanar)	Remote sensing center	02/02/2018
Arc en ciel	Department of agriculture	02/02/2108

2.1.1 The Lebanese Reforestation Initiative

Lebanon Reforestation Initiative (LRI) is a Lebanese NGO established in 2014. It aims at promoting sustainable reforestation throughout the Lebanese territory by improving the connectivity of forests and empowering communities to work together for the protection of forests and the environment. The LRI team holds multidisciplinary skills with academic background and experience in forestry, agricultural economics, native tree nursery production, Geographic Information Systems (GIS) mapping of natural resources, and environmental education. LRI is built upon partnerships with several Lebanese and international organizations, academic and research institutions, technical and development agencies, private enterprises and local communities.

The Lebanon Reforestation Initiative works closely with native tree nurseries across Lebanon with the objective of growing best suited seedlings, through the introduction of advanced growing equipment and techniques such as greenhouses and irrigation systems, and provision of required technical procedure and protocol manuals. LRI is currently assisting nursery managers in forming a professional cooperative of nurseries: the Cooperative of Native Tree Producers of Lebanon (CNTPL), which mission is to allow members to share best practices and promote sustainable reforestation practices and management. Other activities include native tree planting across the territory by supporting tree-planting practices of local reforestation actors. Until present, LRI have planted more than 25 different native tree species with the local organization and NGOs, including cedar, fir, juniper, pine, oak, wild pear and wild almond to promote future forest growth that supports enhanced biodiversity and wildfire protection. This amounts to more than 600 thousand native tree seedling in more than 30 sites. Since July 2015, LRI started focusing its planting efforts on specific Social and Environmental Corridors (SECs), including the North SEC extending from Ehden to Ehmej; the Rachaya SEC extending from Rachaya North towards Masnaa; and the Chouf Biosphere Reserve SEC. In all three regions, LRI is implementing its participatory approach to engage the local communities in planning and implementing reforestation activities.

LRI is promoting the use of specialized mapping tools in native tree reforestation projects in the country. One of the newest technologies adopted by the LRI is the use of GIS, remote sensing software, and the ArcGIS Online platform. The goal of web mapping is to allow reforestation specialists to use and share maps and data of suitable planting sites, site planning and monitoring, vegetation mapping, wildfire prevention, climate change impact on species distribution as well as on environmental threats, by projecting spatial data about environmental and social characteristics onto maps of specific areas of interest. Additionally, the mapping platform enables reforestation stakeholders to reach out to the private sector and the diaspora with reforestation proposals presented as story maps.

2.1.2 The Litani River Authority-Rural Development Centre of Kherbet Kanafar

The Litani River Authority (LRA) is a semi-autonomous authority acting under the supervision of the Ministry of Energy and Water of Lebanon (MEW). It was established in 1954 as an implementation agency for irrigation project that were planned to be put in place on the Litani River Basin (LRB). Today, it has large responsibilities in the water and irrigation sectors in Lebanon. It is responsible for: 1) implementing and managing irrigation and hydro-electric infrastructures on LRB; 2) measuring and monitoring surface water sources at national level, and groundwater sources at the level of the LRB; 3) providing extension services to farmers in different regions of Lebanon, especially with regards to on-farm irrigation. The Rural Development Center (RDC) of Kherbet Kanafar is one the local offices which provide extension services to farmers. It is located in the village of Kherbet Kanafat, in West-Bekaa, in the same region of Canal 900, the irrigation system managed by the LRA[1].

The RDC of Kherbet Kanafar is a large and very well equipped centre. It was built around 15 years ago through an European Union (EU) project. It is equipped with modern laboratories for water and soil testing. Since their implementation, many types of equipment have been added to these labs by international projects. The RDC is also equipped with a weather station, and surrounded with large agricultural lands meant to be used for agricultural experiments. It also includes an artificial wet-land built five years ago next to the Litani River. The purpose of the wetland is to contribute to the treatment of the Litani River's waters at this level.

Water and soil tests are provided to farmers at small fees (as compared to other laboratories). On average, the RDC receives 5 soil samples per week. Soil tests include a chemical analysis (N, P, K, Ca, and P); organic matter and soil texture). The cost is USD 25 for the full analysis. According to the RDC Director, this is much cheaper than the private labs or the university labs (e.g. AUB). Water tests include the usual full chemical analysis. It costs USD 14, not including the metals tests. However, it is not in the Mandate of LRA to provide official tests' results. The results they provide are only informative and cannot be used as official results (asked for administrative procedures). It is the Lebanese Agricultural Research Institute (LARI) that has that mandate, including water and soil testing. However, it was found that it is mainly the large agricultural farms that ask LRA for these tests[2]. The RDC labs are also used for the water quality monitoring program of the LRA (which is the responsibility of another department located in Beirut). Each month, 10 samples on the Upper Litani Basin, mainly from the Litani River, Qaraoun Lake, Ghozayel and Berdaouni are tested. The test results are sent to the Water Monitoring Department of the LRA.

The RDC is well connected to universities, and hosts students annually who come to use the soil and/or water labs for their thesis projects. The RDC is equipped with a weather station which is used by LRA to monitor the climatic conditions in West-Bekaa. The data is used as needed by the different LRA departments. In addition it is part of the mandate of RDC to provide information and training in agriculture and irrigation, both through field visits to farmers and providing them with trainings in the Center. However, despite being well equipped, the RDC was described by our two interviewees to have limited activity in the field due to an insufficient number of staff and limited financial resources. For example, visits to farmers are almost non-existent, and trainings are mainly provided in the frame of international projects.

1 It is to note however that the RDC is not directly involved in the management of Canal 900 (which is the role of a different department of the LRA)

2 The RDC Director mentioned Eddeh farms and Skaff farms located in West-Bekaa, as well as a commercial company, Debbaneh, renting LRA lands.

2.1.3 The Lebanese Agricultural Research Institute (LARI)

LARI is a state public institution specializing in agricultural research. Similarly to the case of the Litani River Authority, it is a semi-autonomous organization, which works under the Ministry of Agriculture with a mandate to develop research activities aimed at supporting the development of the agricultural sector in Lebanon. LARI is responsible for assessing the needs of the sector and developing services or practices to help farmers improve their agricultural production. Eight centers are distributed in the different regions across the country. The Tel Amara station (in Central-Bekaa) dates back to the 1940s and constitutes the largest of LARI's centres, including several departments and covering different agricultural subsectors (plant breeding, irrigation and agro-meteorology, plant biotechnology, pomology and viticulture, poultry science, plant protection, crop production and machinery). LARI's mission is to be well connected to the field and to provide farmers with the expertise needed. An interview with the Department of Irrigation and Agro-meteorology was conducted for the purpose of this report.

The Department of Irrigation and Agro-meteorology of Tel Amara is responsible for managing a network of weather stations distributed across the Lebanese territory. These stations monitor and archive climatic conditions and use measured data to forecast weather conditions to the public. There are different classes of weather stations (A, B, C) according to the number of parameters recorded. Class A groups the most developed weather stations equipped to measure 13 parameters. Class B measures 8 parameters, and Class 3 with only 4. Only Class A and B weather stations record sufficient parameters that allow for a calculation of the evapotranspiration, which is the main indicator used in irrigation management (see Table 2 and Table 3). There is only 1 Class A weather station in the Bekaa. However, LARI has recently acquired a number of new equipment (new sensors) in order to upgrade the stations to Class B and/or A in the Bekaa and the rest of the territory.

Table 2. Weather Stations Managed by LARI in the Bekaa

Region	Village	Class
Central Bekaa	Tal Amara	A
	Haouch EL Oumara	C
	Barr Elias	C
South Bekaa	Ammik	B
	Rachaya El Fokhar	C
	Machghara	C
North Bekaa	Kaa	B
	Kaa	B
	Jabbouleh	C
	Doures	C
	Ras Baalbeck	B
	Talia	C

Source: LARI, Department of Irrigation and Agro-Meteorology.

Table 3. Parameters measured at LARI's weather stations

Class A	Class B	Class C
Solar Radiation (w/m²)	Solar Radiation (w/m²)	Precipitation (mm)
Wind Direction (deg.)	Wind Direction (deg.)	Leaf Wetness (min)
Precipitation (mm)	Precipitation (mm)	HC air temperature
Wind Speed (m/sec)	Wind Speed (m/sec)	HS relative humidity
Leaf Wetness (min)	Leaf Wetness (min)	Dew point
HC air temperature	HC air temperature	
HS relative humidity	HS relative humidity	
Soil temperature. 20 cm	Soil temperature. 20 cm	
Soil temperature. 40 cm	Soil temperature. 40 cm	
Air pressure (mBar)	Air pressure (mBar)	
Water mark (cbar)	Dew point	
Dew point		

Source: LARI, Department of Irrigation and Agro-Meteorology

Weather forecasts were commonly sent to citizens via SMS. Three years ago, LARI's communication with the public evolved from communication via SMS to the use of a free access smartphone application. This application is mainly designed to transmit useful information to farmers. The information is written in Arabic and is thus accessible to all the Lebanese population. Its operation costs USD 5,000/ year (data coverage and technical management). It is managed by Tal Amara station, where one employee is responsible for uploading information on the app after the approval of the directorate which might be hindering the rapid flow of information. The menu of the LARI app mainly includes: 1) Weather forecasts; 2) Updated information on the total rainfall; 3) Early warnings on the main pests and advices on their treatment; 4) recent news on LARI's activities and the publishing of new research. However, it was highlighted during discussions that LARI suffers from a lack of staff and financial resources, which prevents the Irrigation Department from providing sustained extension services to farmers. Thus, training to farmers and research activities are mainly undertaken in the frame of international projects.

The Fanar Station is one of the largest of the eight centers of the LARI, and is located close to Beirut. It includes several agricultural departments (plant pathology, agro-meteorology, soil etc.) and several laboratories (food testing, plant pathology, medicinal plants, water testing) used for academic research as well as providing services to the public. Results provided by LARI laboratories are considered to be official and are used for administrative procedures (selling, import, export of food products, selling water, certifying the health of seeds and seedlings, etc.). For the purpose of this report, the survey was conducted with the Climate and Irrigation Unit of LARI. Despite a limited number of staff and financial resources, this department was found to be very active in academic research and to be well connected to the farmers on the field (especially in the Bekaa).

LARI's Climate and Irrigation unit is, and has been, involved in many research projects related to water quality, irrigation and agriculture. For example, two projects concerning water-reuse were discussed. Both of the projects consisted at testing the use of treated wastewater on agricultural plants and both concerned water treatment plants located in the Bekaa (Iaat in North-Bekaa and Fourzol in Central-Bekaa). While the first experiment consisted in irrigating experimental plots (planted and managed by the researchers), the second experiment involved farmers who used the treated wastewater on their own plots. Another project related to waste water consisted in testing the quality of the treated water generated from the Kherbet Kanafar wetland.

Another recent research activity (ACLIMAS[3]) was conducted in the frame of SWIM, an EU funded project[4]. It consisted in assessing the impact of climate change on cereal crops and identifying the best irrigation practices for different varieties of cereals commonly planted in Lebanon. The project targeted the Bekaa region as a pilot area. It consisted of field experiments and demonstrations both at the level of LARI's experimental fields and on farmers' plots. Experiments with farmers were conducted in many different regions of the Bekaa in order to cover a maximum number of the Bekaa's micro-climates (the mentioned villages were Baalbeck, Doures, Saraine, Iaat, Ryak and Aana).

A recent project using an innovative technological instrument was described. It aims at assessing and developing the operation of a smartphone application used for on-farm irrigation management. It is conducted in partnership with the IAM[5] of Bari (Italy), the CNR[6] of Italy, and a consortium of Italian enterprises. These enterprises are funding the project. This application, (called Blue Leaf) is currently sold in Italy by the consortium whose goal is to adapt it to the Lebanese agricultural sector and market.

The Blue Leaf Application is a user friendly smartphone app that helps farmers in irrigation management. It supports decision-making on irrigation scheduling and application. It also provides the information needed to make decisions with regards to other farming practices, such as fertilization and pest management. The application must be connected to the nearest weather station so that it integrates the local climatic conditions. Farmers have to add a range of additional information in the application: crop types, soil characteristics (thus, a soil test must be conducted), planting characteristics (plot dimension, number of rows and distance between rows), irrigation techniques (gravity, sprinkler or drip) and their characteristics (dimensions of the irrigation system). A soil moisture probe, remotely connected to the app, has to be installed on the plot in order to record and integrate soil moisture data.

The Climate and Irrigation Unit has been approached with the objective to test and calibrate this application with regards to the Bekaa conditions (climatic conditions, farming and irrigation practices). For that, LARI started with conducting a number of field experiments. The app was tested during the irrigation season of 2017 on two major crops planted in the Bekaa: the wheat and the potato crops.

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3 Known as Adaptation to Climate Change of the Mediterranean agricultural systems.
4 Known as Sustainable Water Integrated Management.
5 Known as Institut Agronomique Méditerannéen. 6 Translate as the National Research Council.

Experiments were conducted as follows: for each type of crop, two plots were cultivated and irrigated under different conditions. One was irrigated according to a traditional irrigation method used by farmers while the other one according to the recommendations of the application. Several parameters were monitored and calculated, the main ones being the amount of irrigated water applied, the soil moisture content and the leaf water potential (indicating the level of water stress). The experiment yielded positive results. The amount of water recommended to be used by the Blue Leaf app was reduced by 20 to 25% in comparison to the amount of water normally applied by farmers with similar yields. This means that water productivity was improved in the plot irrigated under the conditions recommended by the Blue Leaf application.

In 2018, LARI will conduct the same experiments on other crops commonly practiced in the Bekaa: table grapes, chickpeas and vegetables. Other experiments must be conducted in the upcoming year but this is conditioned by obtaining funding. LARI has applied to a number of funding programs. Future experiments are planned to be conducted with farmers. Ideally, the experiment would be conducted with 40 farmers, and each of which would have to dedicate a 5 dun plot for the experiment. The required amount of funds needed was estimated to be 600,000 euros. The largest share of the cost is linked to the technological material used (namely the probes). The incentive for LARI would be to sell the application to farmers. It is worth noting that LARI stated an interest in working with farmers group to apply the same irrigation system.

2.1.4 Beirut Arab University - Research Center for Environment and Development

The Research Center for Environment and Development (RCED) of the Beirut Arab University is a research institution based in the Bekaa (Taanayel). It utilizes interdisciplinary approaches to develop, assess and monitor indicators and recommend management strategies for natural resources and means for sustainable development. It aims at working closely with the Bekaa communities and aims at fostering the participation and engagement of community members. The mission of the RCED is to go beyond the scientific laboratory research framework to involve the environmental and socioeconomic aspects of sustainable development[6].

The RCED is a large and well equipped centre and includes chemistry and microbiology laboratories (mainly used for water tests) as well as large agricultural fields partly used for agricultural experiments. The centre works on several projects related to water management, agriculture, plants preservation and other topics. It is well connected to municipal administrations in the Bekaa, public institutions (LRA, LARI, National Council for Scientific Research-CNRS, Bekaa Water Establishment-BWE and others) as well as international research centres and organizations.

There is an irrigation-management experiment taking place at the experimental fields of the RCED in Taanayel. It is conducted by the CNRS Remote Sensing Center and aims at testing the use of remote sensing technologies to improve irrigation of potato. The experiment is led by researchers from the CNRS and is logistically supported by the RCED team (See Box 5, Part 1).

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6 See: www.bau.edu.lb/Center/Research-Center-for-Environment-and-Development

According to RCED problems related to agriculture, water and irrigation management in the Bekaa occur at both the level of farmers and decision-makers. At the farmers' level, problems of overirrigation, over-use of fertilizers, and use of polluted water are seen to be the main challenges, exacerbated by the absence of sound water and agricultural policies. State marketing policies were also highlighted as a major issue; in Lebanon, little is done by the state to protect the local agricultural products, and there are no adequate policies that control the import of international agricultural products. The imported products, produced at cheaper production costs, represent a serious competition for the Lebanese agricultural products. Also, the limited presence of public institutions in the field was underlined. In fact, very limited extension services are given to farmers, both at the level of irrigation management and other farming practices. Public institutions do not show enough engagement in the agricultural and water sector, where a general lack of initiatives and projects that meet the real and immediate needs in these sectors is observed.

On the other hand, the inefficiency of public institutions translates in a weak sense of citizenship from the side of farmers. According to the interviewee, practices that contribute to pollution of waterways and unsound use of water is explained by a lack of trust in the public good, the latter resulting from a lack of trust in the state's engagement in bringing true development to the agricultural and water sectors. During the survey it was highlighted that ICT tools should be examined with a more contextual and critical perspective. It was noted that while it is true that ICT tools could be a good solution to improve irrigation management, it is more the national level problem of communication and information between public institutions and farmers that should be considered. Many communication channels are already available but not properly used, which highlights the fact that the problem is not in the technology itself but in developing and sustaining communication channels with farmers.

2.1.5 The Ministry of Agriculture

The Department of Rural Projects and Irrigation is part of the larger Department of Rural Development at the Ministry of Agriculture[7]. Its mandate is to implement or rehabilitate irrigation infrastructures in rural areas and to provide support to farmers with regards to irrigation practices. However, due to lack of budget, this department does not have the capacity to implement irrigation infrastructures, and its role instead seems to be limited to assisting farmers in improving their irrigation practices. It should be noted that this is normally done through the local offices of the Ministry of Agriculture, whose role is to provide extension services to farmers in the field.[8]

The department's activities are constrained by the lack of funds, given that the budget provided by the Ministry has been reduced and also due to the fact that the main source of funding comes from international projects and development aid. Currently, the department is working on a project promoting the use of drip irrigation in different regions of Lebanon, providing drip irrigation systems to farmers along with the technical trainings required.

One of the missions of the Ministry of Agriculture (MoA) in Lebanon is to provide farmers with information they need to improve their agricultural production. For this, information channels should be improved. Systematic

7 Because of a lack of staff, the director of the Rural Development Department is also the director of the Rural Projects and Irrigation Department.

8 Part of the Ministry of Agriculture, there are 30 local offices distributed in different regions of Lebanon. There is one office in the Bekaa region, located in Zahle.

process where information is collected, stored, processed and conveyed in a proper way to farmers should be developed. Unfortunately, this system is nonexistent at the Ministry. The first problem is the flow of information at the level of the Ministry itself and the fragmentation of between the different units. This implies that projects and research activities tend to be duplicated.

Over the past years, AIMS[9] (Agriculture Information Management System), an FAO project, was developed in cooperation with the MoA with the objective to improve communication and information flow at the level of the Ministry. It specifically aimed at collecting reports and data from the different departments of the Ministry and centralizing them in one informatics platform that would be accessible by everyone at the Ministry. Unfortunately, the project is not seen as a success within the ministry and the created platform was left unused. The main obstacle was the lack of coordination, both between the project consultants and the Ministry employees and among the different departments of the Ministry. Data sharing is unfortunately not a common practice and such initiatives should come with a stronger support and enforcement from the central administration of the Ministry.

In addition to the internal communication problems, it is difficult to obtaining data from other public institutions working on agriculture and water management. For example, there is no systematic coordination between the Ministry and the LARI, even though LARI falls administratively under the authority of the Ministry of Agriculture. Part of its mission is to produce research material to be used by the Ministry through practical projects. However, in practice LARI and the MoA rarely cooperate in common initiatives.

2.1.6 Alfa Company

Alfa Company is a Mobile Network Operator. It is one of the two internet providers in Lebanon subcontracted by the Ministry of Telecommunications. Alfa manages a wide internet network, described by our interviewees to cover all of the Lebanese territory. They provide mobile internet plans for individual users and businesses. They have tailored plans for businesses using machine to machine technologies and also provide mobile services for individuals and enterprises. At the present moment, they do not provide services related to the agricultural sector but they are interested in developing such services if they find a good responsiveness in this sector.

Alfa Corporate Strategy department underlined the company's interest in the market of ICT in agriculture and more specifically in irrigation. The reason is that they consider that there is a need for using technological tools for water monitoring in Lebanon because of the situation of current and future water scarcity of the country. The department has been reflecting on the topic and questioning the fact that ICT tools have not yet been developed in the Lebanese Market despite the fact that there is a need for them, that such equipment can easily be available on the Market, and that the internet networks in Lebanon are well developed. In their opinion, the main obstacle is the lack of incentives related to farmers where the latter seem to lack the financial means or the adequate awareness to use such tools.

9 AIMS is is a global FAO initiative which goal is to empower agricultural information management specialists in creating access to agricultural knowledge. It works at several level: 1) Information Management Resources, 2) Recommendations in Information & Data Management, 2) Community of Practice, 3) Capacity Development. (www.aims.fao.org/about).

Alfa has a strong interest in exploring options for supporting the development of ICT tools for Agriculture and Irrigation in Lebanon. They are aware that the direct financial benefits of such a venture to Alfa won't be high and they emphasized that they are not looking for big margins in this sector. However, they view this initiative as a corporate strategy through which they would be promoting Alfa's corporate social responsibility.

According to Alfa, their company is well equipped to provide high speed internet needed for the operation of remote sensing based tools and platforms. Concretely, they can provide reduced tariffs for farmers using remote sensing tools in agriculture and irrigation. They underlined that end-users could include be stock farmers (e.g. poultry and cattle farmers) or agro-industries using automated processes (e.g. T° control, control of machinery etc.). Alfa can also provide reduced tariffs for water authorities or other public institutions using remote sensing based tools for water monitoring or other agricultural practices.

It was also noted that, there is an emerging demand for billing and charging capabilities (gsma.com)[10]..In the smartphone sector and the mobile industry, there is now a well-established and complex network of service and content provider relations. Similarly, in the M2M sector (machine to machine), a proliferation of revenue and content stream is leading to more complex billing, settlement and fund clearance requirements (gsma.com). Alfa claimed that they currently provide billing services in Lebanon to various industries and that they are willing to develop such services in the agricultural sector.

Finally, alfa underlined their willingness to contribute to research initiatives aiming at developing the use of ICT tools in agriculture and/or irrigation management. Concretely, they would consider providing free of charge data connectivity (or reduced tariffs) to a project testing the use of ICT tools (such as LARI's current project with GreenLeaf; see Box 6). They are open to partner with public institutions (such as LARI or the CNRS), or development organizations working on such initiatives. In addition to internet access, they proposed to provide services related to data analytics.

2.1.7 The National Centre for Remote Sensing

The Remote Sensing Center (RSC) was established in 1995. Its mission is to produce research material using remote sensing and GIS tools, to be used by public institutions as support for decision making. The RSC produces information for different sectors such as urban planning, natural hazards, and coastal zone management. A large share of the RSC projects is focused on environmental resource management such as watershed management, natural resources and forestry. Since its establishment, the RSC has proven its role as a revolving platform among the different ministries. It provided various thematic maps and GIS data bases in different fields, and made them accessible to public institutions, the private sector and the public. Additionally, the RSC develops remote sensing tools to be used in direct management processes, such as early warning systems and long term observatories (cnrs.edu.lb).

RSC focuses on research activities and projects with practical use and impact. For example, a large proportion of their activities are dedicated to identifying natural hazards. Based on satellite imageries and remote sensing monitoring tools, they have the capacity to locate potential forest fires, floods, avalanches and earthquakes. The

10 Billing and charging refers to a wide range of mobile network operator (MNO) capabilities, including charging, management of multiple revenue streams, account management, payment and collection, customer care, and invoicing

RSC is also very active in the agricultural and irrigation sectors, and provides paid services to the private sector. For example, it has been recently approached by a large winery in West-Bekaa to conduct drone based mapping of their farm. The activity focused on soil characterization and plants water stress assessment with the purpose to determine the impact of climatic change on the health of the vineyards. In addition, the Ministry of Economy (which commits to purchase wheat harvests from all wheat farmers every year) has commissioned the RSC to monitor areas cultivated with wheat with the purpose of better allocating governmental subsidies to this crop (See Part 1, Box. 5).

Another project concerns the assessment of real time evapotranspiration from potato crops in the Bekaa. The experiment is conducted at the RCED (BAU) in Taanayel using remote sensing tools. It consists of using satellite imageries of the plot taken at different stages of growth to extract a number of parameters and calculate evapotranspiration (such as vegetation index and surface temperature)[11]. In parallel, evapotranspiration is calculated on the ground through the use of the traditional methods, and results are compared.

Finally, within the current FAO project on water productivity funded by SIDA, the RSC was assigned by the FAO to train Lebanese stakeholders on the concept and use of Water Productivity. The training was given by our interviewee and other researchers and took place at the RSC. The participants came from different public institutions working on agriculture and irrigation.

2.1.8 Arc en ciel

Arc en ciel is a local NGO active in different development fields (social work, environment, health, and agriculture). Since 2009, the Agricultural Program of arc en ciel manages Taanayel farm, a domain owned by the Jesuite institution, which includes 260 ha of agricultural lands and an animal farm in Taanayel (Central Bekaa). In order to promote sustainable agriculture, the agricultural program of arc en ciel manages Taanayel farm using sustainable farming practices.

This agricultural program includes a number of practices and techniques that aim to reduce agricultural pollution and energy use, and improve water efficiency[12]. For example, arc en ciel works on reducing the application of chemical fertilizers and bio-pesticides and produce organic fertilizers and bio-pesticides on farm). They also work on improving water management and optimizing water productivity. To that end, a water monitoring system was put in place to calculate the amounts of water that flows into and out of the farm[13]. In order to reduce the use of diesel energy, the farm was equipped with solar panels. The solar energy produced serves for irrigation (water pumping) and other activities.

All these practices are intended to be pilot practices. They serve to assess the feasibility to outscale them at the level of other farms of the Bekaa. Farmers are regularly invited to Taanayel farm to observe and participate to field demonstrations.

11 For a similar experiment see Tang et al., 2007. http://www.hydro.ucla.edu/SurfaceWaterGroup/Presentations/2007/qiuhong_AGU_2007.pdf

12 See: www.arcenciel.org/agriculture-environment/

13 Taanayel farm is irrigated from Jdita-Chtaura River, a tributary to the Litani.

From January 2014 to June 2015, the agricultural program of arc en ciel led a project that aimed at testing and promoting "smart irrigation". The project, called "Agriculture Response for Development" (ARD), was partly funded by the United Nations Development Programme (UNDP), and included a component focused on improving water management by implementing and promoting innovative and efficient pilot technologies and practices. A pilot study was conducted on a 3 ha apple orchard, and involved construction of an automated irrigation system using a set of sensors: humidity and temperature sensors placed in the soil, phytogram sensors measuring the water and ions flow in the trunk, and a weather station providing data on rainfall, temperature and humidity. These devices were connected to a computerized system which was in turn connected to an irrigation controller giving orders to irrigate.

The computer used a model integrating the different data. Based on the model calculations, an automated signal was sent to the system for irrigation. Irrigation water was provided through a pumping system designed to control the amount of fertilizers in the water, and solar energy was used to operate the pumps. At the end of the experiment, several stakeholders were invited to observe and understand the system's operation. A number of farmers from North and Central Bekaa were invited to Taanayel to observe the experiment and learn about the outcomes.

The results of the experiment were positive. The system was found to have significantly reduced water use and improved water productivity. However, as described by the director of the agricultural program, it was found that the system was not financially affordable for farmers. Furthermore, its installation and operation was found to be complex and not easy to be manipulated by farmers. Based on her experience in the Bekaa, our interviewee observed that smart devices are not a priority for agricultural development. Currently the agricultural program of Arc en ciel is focusing on developing marketing opportunities for farmers (mainly in the fruit trees sector). They are helping farmers with creating processed products such as dried fruit and fruit chips. They are also helping them with branding and labeling.

2.1.9 Agrytech

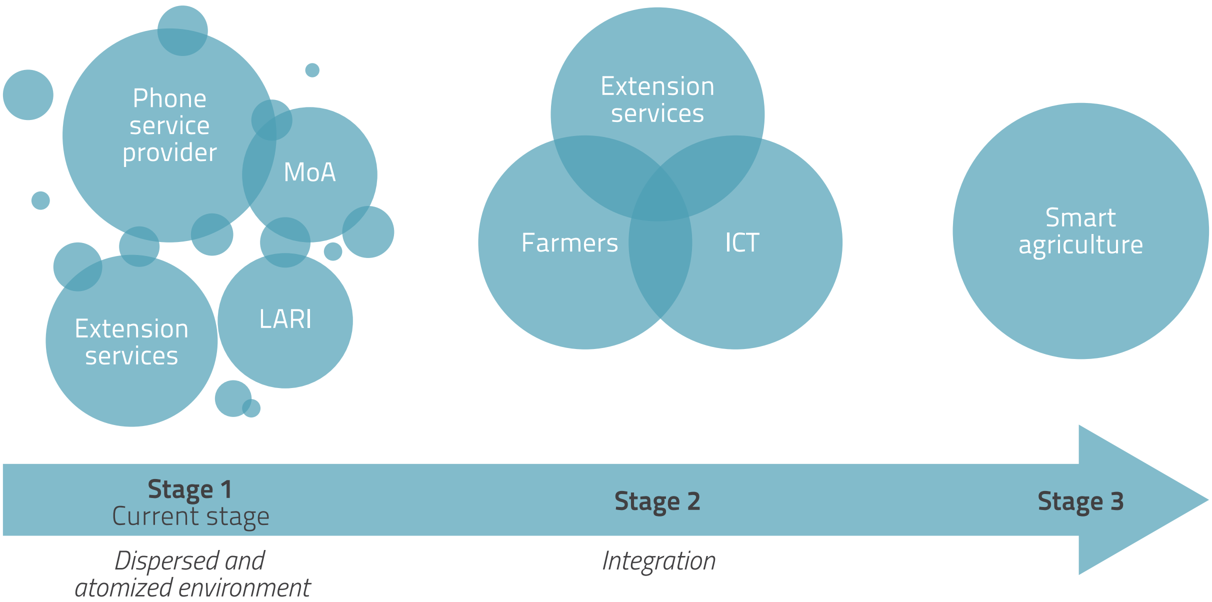
Agrytech is a program jointly funded by the Kingdom of Netherlands and Berytech and aims to source and accompany startups with innovative ideas in the Agri-Food sector. It provides them with technical and business resources as well as community support to allow them to scale their ideas into successful businesses with global impact. Agrytech is an equity-based program offering up to 40,000 USD of grant with a 12-month support for successful business ideas. The Agrytech program identifies the needs in the agri-food sector which require innovative solutions. These needs can be listed as follows: robotics, remote sensing, automation, e-commerce, traceability, big data, artificial intelligence, sensors, IoT, internet, logistics, drones, energy efficiency, payments, urban agriculture, and supply chain. One of the projects indirectly funded by AgrytechBerytech program in 2015 aimed at testing and promoting "smart irrigation" practices with Arc En Ciel entitled "Agriculture Response for Development" (ARD), the project described above. The goal of the project was to improve water management by implementing and promoting innovative and efficient pilot technologies and practices.

2.2 ICT and the agriculture sector: key findings

The potential for the evolution of ICT in agriculture in Lebanon can be portrayed in three different stages (Figure 6). Presently, the sector is dispersed and atomized, with a series of stakeholders and actors present but without much consistency of purpose or objective. It is imperative that the relevant sectors involved are integrated and share a common objective and purpose in order to enable at a later stage (Stage 3) the development of smart agriculture.

A substantial number of initiatives are being implemented in Lebanon, and supported by different stakeholders; however, these initiatives lack coordination and follow-up efforts and are often disconnected from the market and user needs. This is translated, at the field level, by a significant replication of activities and interventions, not

Figure 6: Evolution of the ICT sector in agriculture in Lebanon



always conceptualized by experts in the field or not practically addressing the real constraints and needs. This is affecting their success and the adoption of ICT in agricultural water management in the country. The assessment also identified a number of other factors which were found to hinder the use of ICT tools, which can be summarized as follow:

- An observed lack of effective dissemination of results which hinders the building of continuity within a clear intervention axis in the agricultural sector in general and the corresponding water management sub sector in particular;

- The limited duration of projects: funding agencies require quick measurable outcomes within a limited timeframe, which prevents the sustainability of the initiatives implemented;

- Limited data availability and data sharing, with data not easily accessible and not shared among actors in the sector due to a lack of coordination and absence of a sharing mechanism and the corresponding supporting infrastructure;

- The wide range of problems facing the agricultural sector which means that ICT and the use of technology does not represent a priority for the stakeholders involved;

- The lack of funds: the little availability of sufficient funds to support the implementation and replication of the activities, the involvement of farmers, and the infrastructure needed to support ICT;

- The absence of efficient and active extension services;

- The lack of sufficient funds to ensure the sustainability and follow up of executed initiatives accompanied by the lack of proper return-on-investment strategies.

Consequently, the main recommendations suggested are the following:

- Improving the extension services to support farmers in coordination with research institutions, agricultural extension services would allow to convey farmers needs to the institutional level;

- Improving the coordination between the different actors and national and international agencies;

- Improving coordination between the institutional level and the field level to allow the participation of farmers in the decision-making process;

- Encouraging start-up and incubation programs to tackle not only technological innovations but also institutional and data sharing issues;

- Promoting a constant dialogue between donors and the Ministry of Agriculture in order to better customize the calls for projects to the actual needs of the sector in order of priority;

- Improving the dissemination of results and useful information to farmers;

- Setting up an efficient data sharing mechanism and infrastructure;

- Developing and encouraging technological innovations having a reasonable and feasible return-on-investment.

- Build on existing communication platforms and ICT tools in order to improve them rather than replicating.

3. Capacity needs assessment: **Farmers**

3.1 Research methodology

The purpose of this section of the report is to assess water management at the level of the farmers, exploring the opportunity to use ICT tools as a solution for on-farm irrigation management in the Bekaa valley. The objective of the study reported here was to research the use of ICT tools by farmers in the Bekaa plain in Lebanon, in agriculture in general and irrigation in particular, by assessing:

- Existing farming systems in the Bekaa valley;
- On-farm irrigation practices currently employed by farmers in the Bekaa;
- Interventions practiced on both farm and scheme levels;
- Localized use of ICTs (linked to access to information);
- Existence and reliability of extension services;
- Knowledge level regarding key terminology of water use; 7. Access to relevant information and use of technological tools;
- Needed information to improve yields and water use.

A research methodology was tailored to the specific characteristics of the Bekaa agriculture and a survey was conducted between January and March 2018. The aim of the research was to reflect on the present and future role of ICT in on-farm irrigation management, to identify potential use cases for the WaPOR data, and to identify capacity building needs to support this. This was addressed through the following questions:

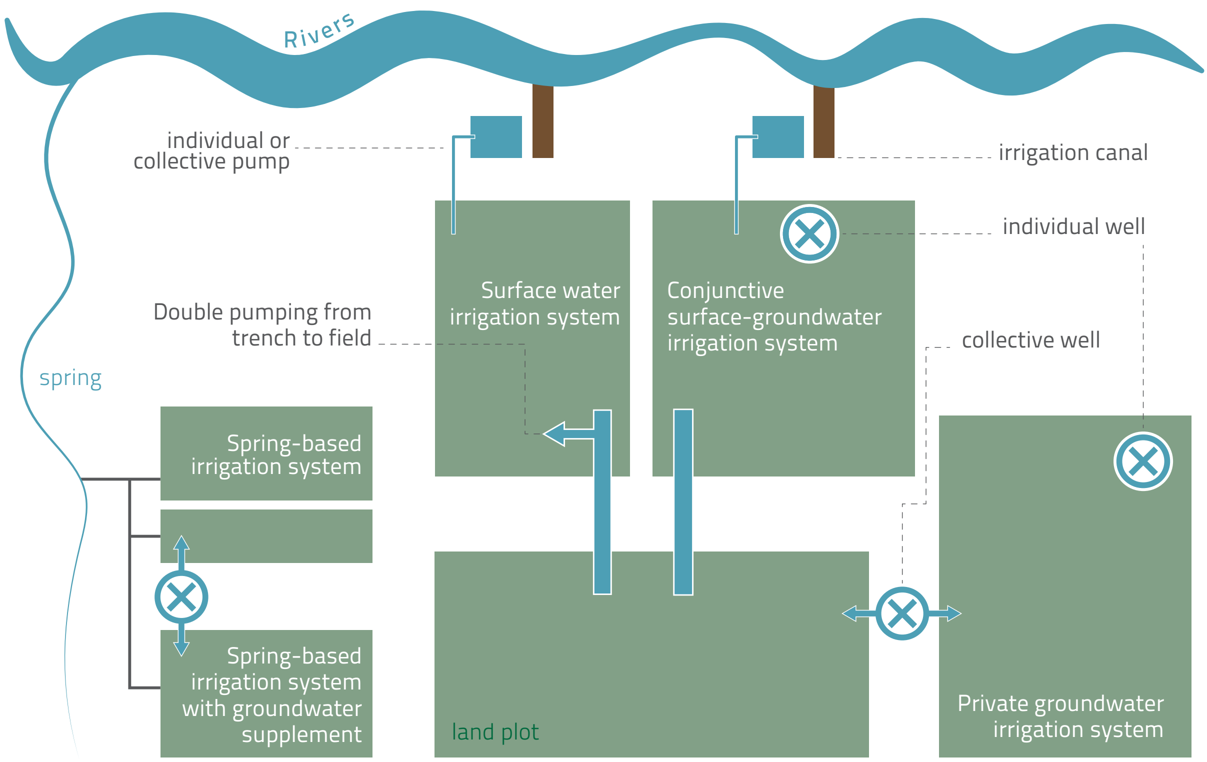
- What is the current role of ICT tools in farming and irrigation practices in the Bekaa?
- What are these tools, where and by whom are they used?
- What are the individual, community and state incentives for using ICT tools?
- What are the constraints for such use?
- What are the opportunities to expand the use of ICT tools in the future and in what areas is capacity building needed to address these?

3.1.2 Sampling methodology

The Bekaa includes a large diversity of irrigation systems and farming practices. Private and communal irrigation systems have developed around different types of water sources (surface and groundwater), and include different types of infrastructure (Figure 7). On each side of the plain, gravity collective canal systems have developed around mountain springs (Anjar, QabbElias, Berdaouni, Chtaura and others). In the plain, farmers abstract water from rivers using individual or collective pumps.

In areas where surface water is not available, farmers irrigate from private wells, used individually or collectively. Individual wells are generally wells with small discharges, drilled in the alluvial aquifer (Quaternary aquifer covering the plain) which does not allow for large amounts of water to be pumped because of its alluvial nature (less than 10 l/s on average). Collective wells are found in the Karstic aquifers, outcropping from each side of the Bekaa valley, which generate much larger discharges (between 30-60 l/s) (Nassif, 2016). As seen in Figure 7, wells can

Figure 7. The diversity of private and communal irrigation systems in the Bekaa



also be used conjunctively to surface water sources when the latter are not sufficiently available.

Although most of the agricultural area in South and Central Bekaa was planned to be equipped by public irrigation schemes (23,000 ha), only a small portion of the plan has been implemented. The same goes for the case of the planned state irrigation system for North Bekaa. Two state systems exist, “Canal 900” in West Bekaa, managed by the Litani River Authority,[14] and the Yammouneh Project in North Bekaa, partly managed by the Bekaa Water Establishment.[15]

Canal 900 is a 2,000 ha pressurized irrigation system fed from the artificial Karaoun lake, formed by the Karaoun dam (Figure 1). However, since its operation in 2001, farmers have kept using their existing wells partially because of a deficient water supply in the scheme (Merkley, 2010; Nassif, 2016); and since 2014, this system stopped being operational because of water quality problems in Lake Karaoun. Today, all of Canal 900 command area is supplied by wells. The Yammouneh irrigation system, an open-canal irrigation system supplied by the Yammouneh spring in North-Bekaa, is also supplemented by private wells.

The Bekaa also includes a large diversity of farming systems, crop types, and a large array of farm sizes with large farms hiring professional expertise and using advanced machinery and technology, and very small traditional farms where professional expertise and technology are more limited (MoA and FAO, 2010).

The survey undertaken for the purpose of this project focused on Central and West Bekaa, and included the three main categories of the Bekaa irrigation systems:

- one state system, Canal 900 in West-Bekaa, where 11 farmers and one key informant were included;
- one spring-based community managed system, Anjar in Central Bekaa, where 10 farmers and one key informant were interviewed; and
- private wells used in different regions of the Bekaa, for which nine farmers were interviewed. In the latter category (private wells), both collective and individual well systems were included.

Two of the collective well systems were found to be used by five farmers respectively. While only well owners of these systems were interviewed, this allowed us to consider the general farming practices used by these farmers as well and also their use of ICT tools.

This means that the number of individual farmers included in the sample was 40. However, the statistical results will be given for the 30 farmers individually interviewed. In each of the three categories, special attention was given to include different farm size and cropping patterns.

14 The Litani River Authority is an autonomous water authority working under the supervision of the Ministry of Energy and Water. It was established in 1954 to implement and manage irrigation and hydroelectric infrastructures on the Litani River Basin. In the Bekaa (and also in other regions), only a small fraction of the planned schemes was implemented, which is Canal 900 (2,000 ha).

15 The Bekaa Water Establishment (BWE) is one of the four Regional Water Establishments in Lebanon which are responsible for water and wastewater management at regional level, under the supervision of the Ministry of Energy and Water. They have been implemented in 2000 by law 221 and have a mandate in delivering domestic and irrigation water as well as wastewater treatment services. However, to this day, the BWE is not involved in irrigation management. The only irrigation scheme it partly supervises is the Yammouneh since the local "Office de l'eau du Yammouneh" was merged in the BWE by law 221.

Table 4. Sample description

System	Description	Water supply	Region in the Bekaa	N° of Interviewees
Anjar Irrigation System	Community-based,collective irrigation system, supplied by Anjar spring and groundwater (recently).	Spring and Karst-ic aquifer	Central, left Bank of the Litani	10 farmers and 1 Key Informant
Canal 900 System	State-system, supplied by Karaoun Lake (until 2014)	Karaoun Lake until 2014; Groundwater currently.	South, left bank of the Litani	11 farmers and 1 Key Informant
Private wells	Collective (large) and individual wells (small)	Karstic and alluvial aquifers	Central and South Bekaa	9 farmers

3.1.3 Questionnaires

Two types of questionnaires were developed (See Annex 1 and 2). The first was addressed to farmers and aimed at collecting data at individual farm level, and covered the following information:

- Farmer information: bios data and educational level;
- Farm information and farming practices: types of crops, farm tenancy, water source, type of irrigation system, etc.
- Use of ICT in farming practices;
- General access to ICT (Computer, smartphones, internet).
- General problem s in agriculture and irrigation.
- General access to information: links to public institutions and other stakeholders, links to information channels.

The second questionnaire was addressed to key informants and aimed at understanding the general functioning of the respective irrigation scheme. The "key Informant" questionnaire was only conducted for the two collective systems covered (Canal 900 and Anjar irrigation systems).

Figure 8. Field interviews with Anjar farmers

3.1.4 Interviews

Farmer contacts were available from recent studies conducted in the Bekaa (USAID-LRBMS, 2012; Nassif, 2016; Molle et al. 2017) and interviews were mostly conducted in the field. In the case of Canal 900 and Anjar Irrigation Systems, eight to 10 farmers were met collectively and interviewed first as a group, and then individually (Figure 8). The "focus group" form of the meetings allowed us to present the study's objectives to the farmers group; and also to understand farmers' problems as a community and their collective perception of ICT tools as a solution for their farming and irrigation practices.

In the case of private wells systems, interviews were conducted individually. Due to time constraints, some farmers were interviewed over the phone or were sent the questionnaire by email. This was done for farmers for whom information was available from previous projects and for which farming systems, irrigation practices and general socio-economic characteristics were already well understood.

3.2 Results

3.2.2 Farmers' characteristics

Farmers' age and education are two important characteristics to understand when analysing the use and willing ness to use modern technologies. 67% of interviewed farmers were between 50 and 70 years old. The rest belonged to a younger age category, equally distributed between two sub-groups: 17% were between 20 and 35 years and 17% between 35 and 50 years old (Figure 9). This suggests that farming as an economic activity is not appealing to young people, and is explained by several factors: the relatively low revenues generated by farming as compared to other sectors (Riachi and Chaaban, 2010); good access to education in the Bekaa which opens other job opportunities; and the high rate of urban and international migration (Amery, 1992; Bennafla, 2006).

As shown in Figure 10, the majority of farmers have benefited from basic education. Only one farmer (belonging to a Bedouin community) did not receive any school education at all. However, more than half of the farmers (57%) have only received an elementary school education, while 10% were high school graduates, 10% postgraduates (different disciplines not related to agriculture), and 20% were agricultural engineers.

Figure 9. Age of farmers

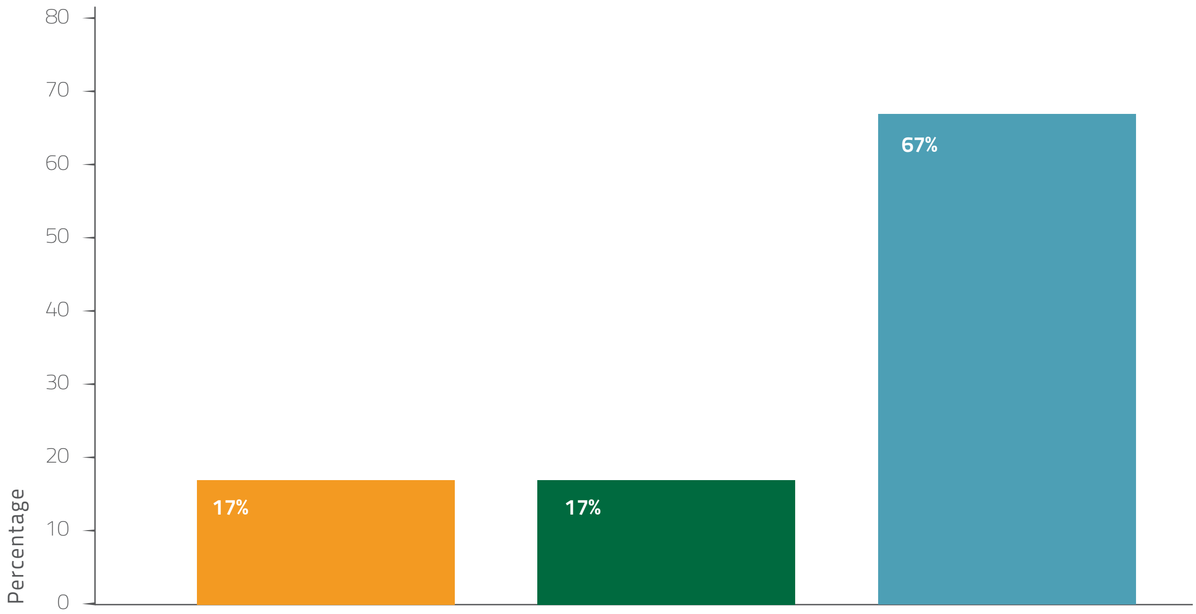


Figure 10. Education level of farmers

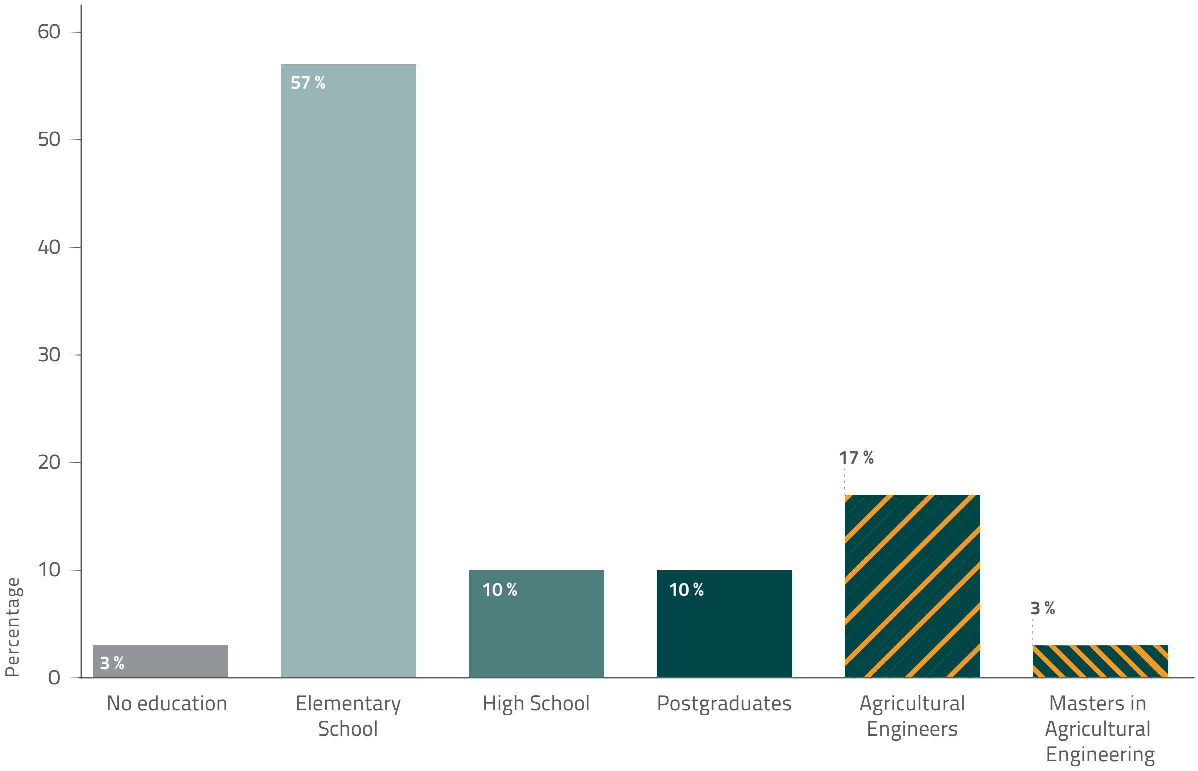


Figure 11. Distribution of farmers' age according to their education level

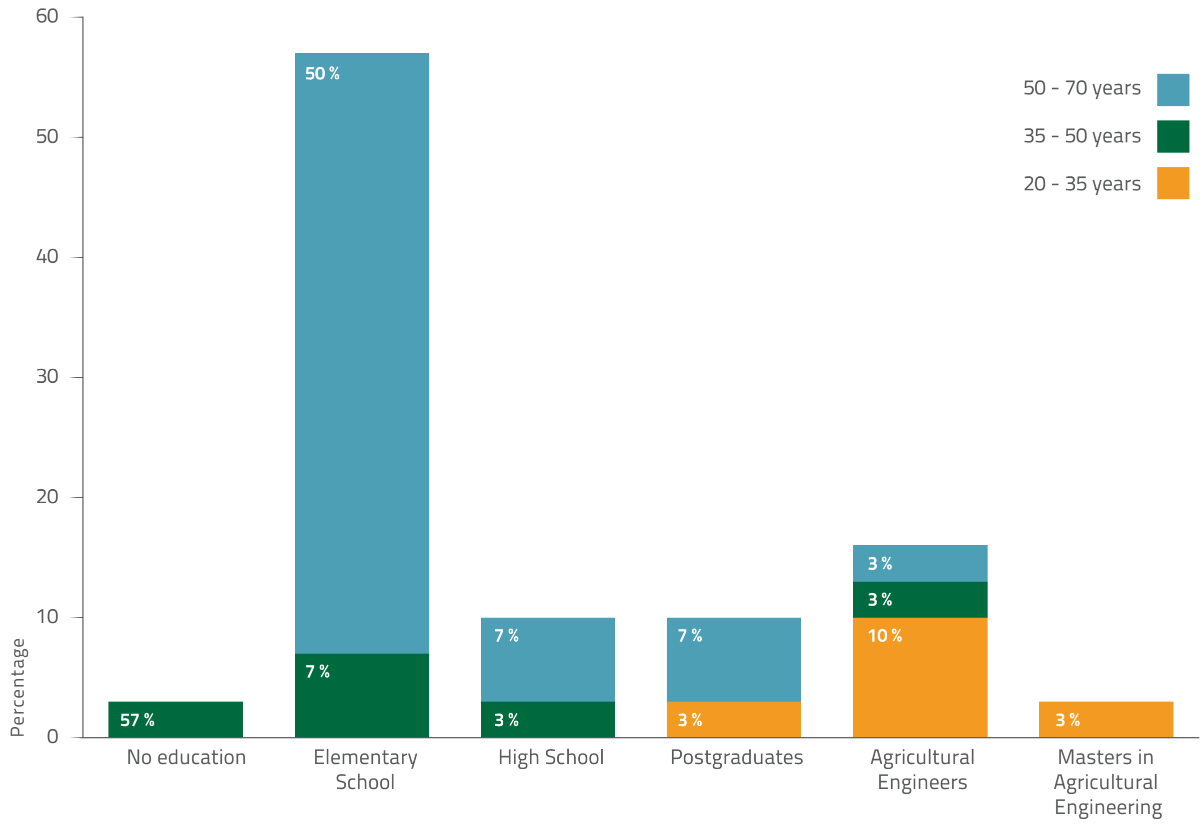
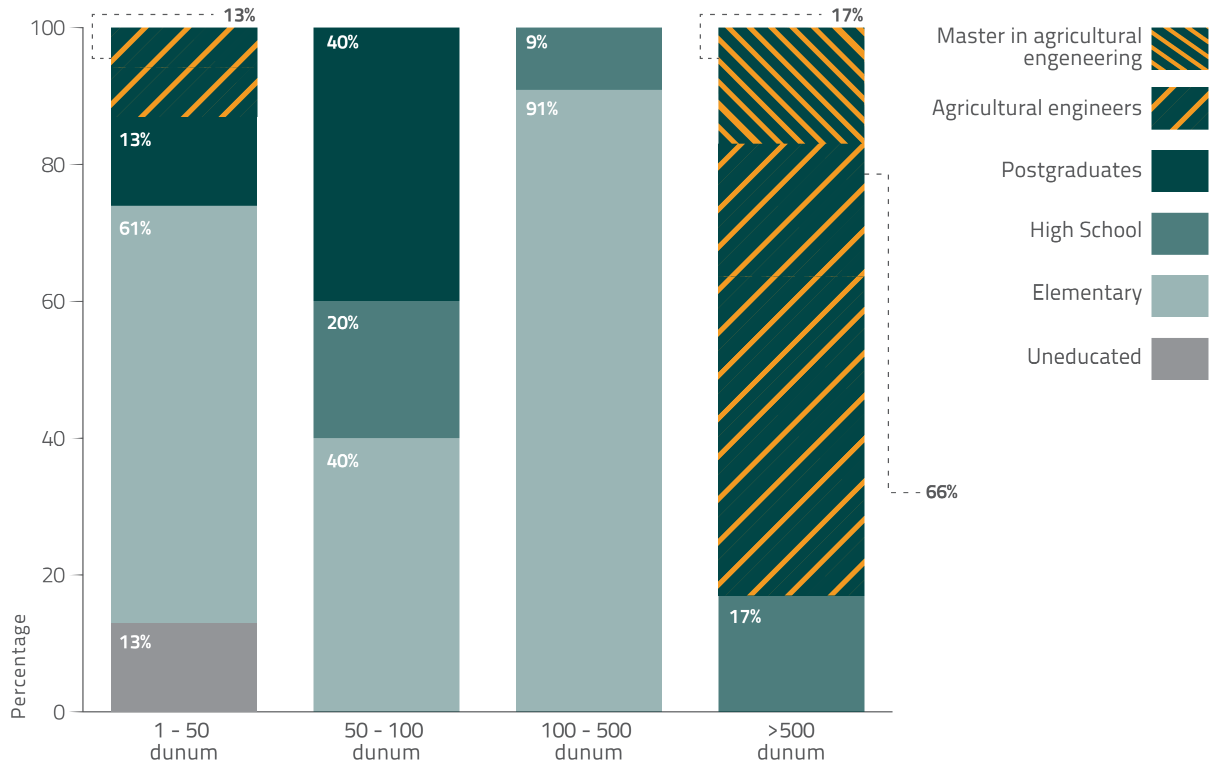


Figure 12. Relation between farm size and farmer's education



When education categories were crossed with age, most agricultural engineers were found to be between 20 and 35 years old (Figure 11); and as shown in Figure 12, most of them are linked to the big farms of the Bekaa (> 500 du[16]). Out of the six agricultural engineers, two are managers in two big wineries in West Bekaa, and two are managers of large vegetable farms (located respectively in West and Central Bekaa).

The two other farmers are managing their own farms, one in a large vegetable farm (1,300 dunum) and the other a small table grapes farm in Central Bekaa (50 dunum). In fact, most of the big farms are managed by agricultural engineers (70% of the large farms). Based on these results, we can note that the education level of most farmers may be detrimental to the use of ICT tools in agriculture and irrigation. However, the fact that most of the large farms are managed by agricultural engineers is a positive finding. This is because it was also found that agricultural engineers had started to look at ways to reduce water consumption (see section 3.2.5 below). For the other education categories, no particular correlation with farm size was found. Farmers with elementary school education, (the majority of the sample), were found to be well distributed between the three other categories of farm size (1-50 du; 50-10 du and 100-500 du).

3.2.3 Farm size and their relation to irrigation systems

Depending on physical characteristics (e.g. access to water), historical factors (e.g. remnants of the feudal system), or more recent economic transformations (e.g. capitalist investment in land ownership), the size of farms varies from as little as one or two dunums to as large as 10,000 dunums (Nassif, 2016). Different farm sizes were included in our sample, and could be divided in four categories: 1) small farms (1-50 du), representing around 27% of the sample; 2) medium size farms (50-100 du) represent 17% of the sample; 3) large farms (100-500 du) represent the largest part of the sample (37%); 4) very large farms (>500 du) represent 20% of the sampled farms. It is relevant to note that the smallest farm of our sample is 15 du and the largest one is 4,500 du (Figure 13). These categories are representative of the different farm sizes in the Bekaa. However, the distribution of farms in these categories is highly dependent on the sub-region in the Bekaa and the different factors cited above.

For example, the relationship between farm size and the sub-region in the Bekaa is apparent in our sample. In the Anjar Irrigation System, the majority of farms are of small and medium size (60% and 30% respectively), while large size farms represent only 10% of the sample and very large farms (more than 500 du) are inexistent. The reason is due to the land organization in Anjar, designed and built under the French Mandate in a way to allocate small plots (7 dun) to each family of an Armenian community that was displaced to Lebanon in 1939 under World War 2 (Nassif, 2016). According to the director of Anjar Irrigation Committee, most of the farms remain of small size[17], although transformations have occurred (transmission by heredity, land selling and renting).

In the Canal 900 area, 82% of the farms are large (100-500 du), while medium and small size farms constitute only 18% of the sample (9% each). In this region, the history of land organization is different, and varies among the 5

16 The dunum is a unit commonly used for farms' area measurements. 1 dunum = 1, 000 m2 = 0, 1 ha.

17 It is relevant to note that small and medium size farms are commonly found in the other spring-based systems of the Bekaa. The latter are communal systems that were developed in the Bekaa a long time ago and whose lands were divided among a large number of families.

Figure 13. Farm size categories

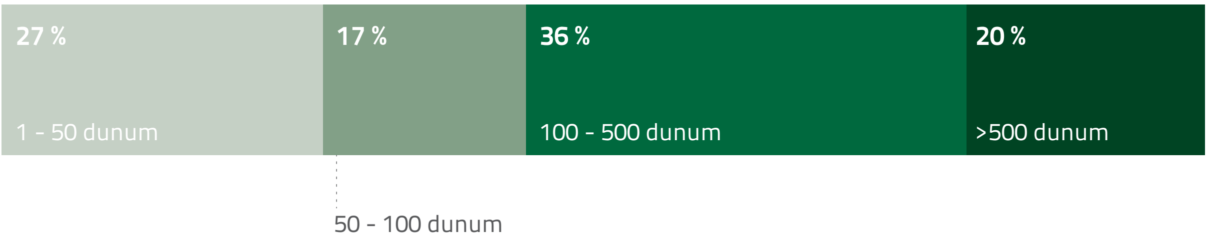
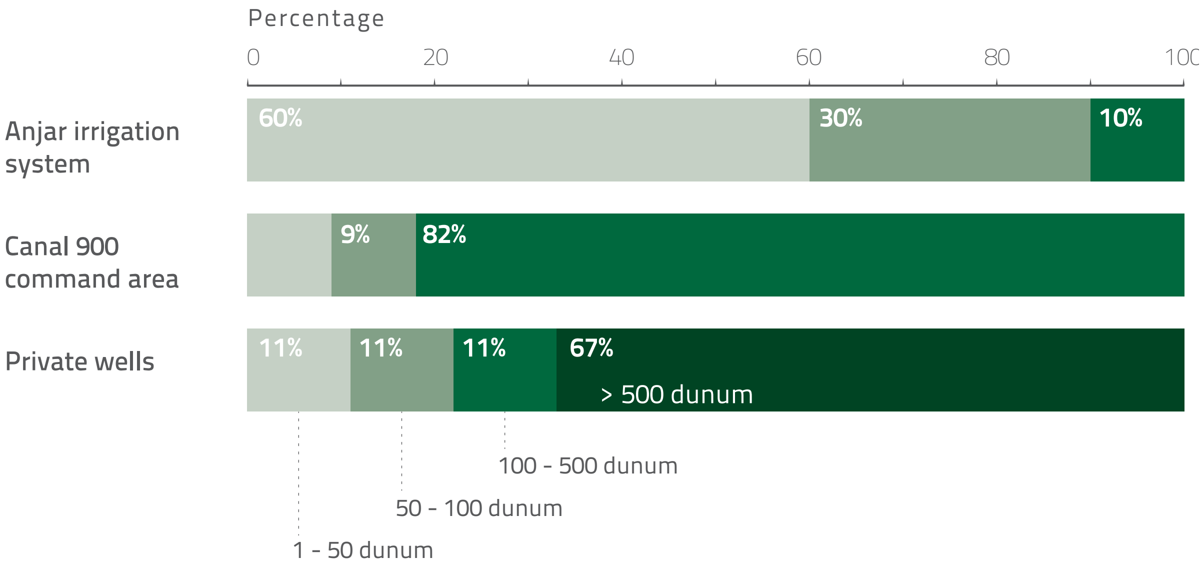


Figure 14. Distribution of farm size categories in the different irrigation systems



villages covered by the system. In general, plots are also of small size but were subject to local land arrangements around Karstic wells in order to reach mediumsize farms. In fact, Karstic wells started to be drilled in these villages since the 1960's in the Eocene and Cretaceous aquifers. Since these wells provide high discharges (up to 40 l/s in this region), land-arrangements occurred around these wells in order to rationalize the availability of water from individual wells, hence the formation of large farms irrigated by these wells.[18]

As for private wells, the fact that 67% of the farms irrigated by these wells belong to the very large size category is because we intentionally targeted this category of farms. Because of the large volumes of water needed for irrigation, these farms are usually irrigated by karstic wells. These very large farms include 2 wineries in West-Bekaa (who grow their own grapes), 2 vegetable farms in West-Bekaa and 2 vegetable farms in Central-Bekaa.

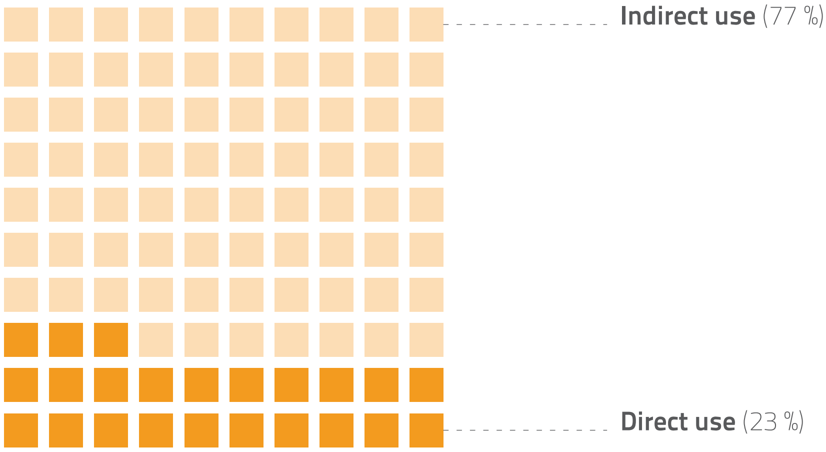
18 Information obtained from Marie-Hélène Nassif, PhD student working on water governance on the Upper Litani River Basin.

3.2.4 Land tenure

Around half of the Bekaa agricultural lands are under tenancy agreements (formal and informal). According the last FAO and MoA census (FAO and MoA, 2010), the rate of land tenancy in the Bekaa was 48% in 2010. However, according to a recent study conducted by IWMI in the Central Bekaa, this rate seems to be increasing in the last decade (Nassif, 2016). In fact, additionally to the general problems of the Lebanese agricultural sector (e.g. high costs of inputs, poor state policies in protecting local products and promoting export), market access possibilities were further reduced following the Syrian crisis and the closing of the Syrian borders (Rujis, 2017). This pushed many farmers to rent out their lands instead of cultivating them, in order to ensure stable revenues. In fact, land-rental is quiet expensive in the Bekaa, and varies between 100 and 300 USD/du (depending on access to water, soil type, social factors and others). This represents one third to half of the production costs.[19]

Land tenancy was found to be widely practiced in our sample. As shown in Figure 15, 77% of the farms included in our sample were under indirect use, with only 23% being directly cultivated by their owners. As shown in Figure 16, direct-use mostly concerns small plots (1-50 du) while indirect use is mostly common in the case of larger farms. This is why land tenancy was found to be more common in the case of Canal 900 and private wells (67% and 100%), while it was more limited in Anjar (60%), where plots are of smaller size. In fact, large farmers rarely own the whole area they cultivate and often rent out several plots from different owners in order to reach large farms.

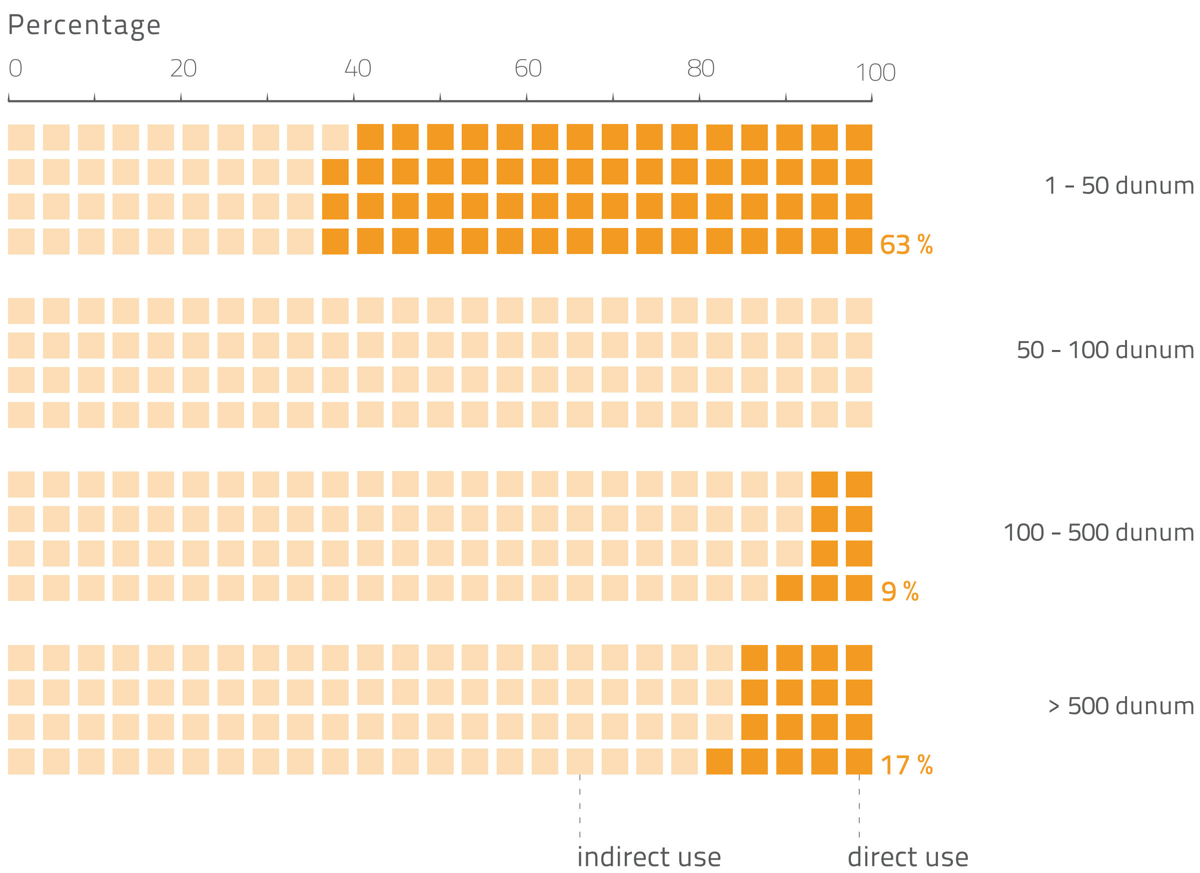
Figure 15. Land tenure



Nevertheless, in some places in the Bekaa, some families own large amounts of land. This was the case of one of the very large fruits and vegetable farms included in our sample (4,500 du), owned by an old notable family. Another example is a smaller vegetable farm (1,300 du), which is owned by a middle-class family who was able to

19 Estimation given by the manager of a winery in West Bekaa, interviewed on 30-1-2018.

Figure 16. Land tenure according to farm size



progressively buy plots with the revenues collected from irrigated agriculture in the 1960s.[20] In both cases, these vegetable farms were not entirely cultivated by their owners. It was found that parts of them were leased to other farmers, along with the access to water. In fact, tenancy arrangements were often linked to water-use arrangements as we will see below.

Generally, land rental arrangements can be divided in two main types. The most common type is when the tenant pays a fixed rent per year to the land owner. The tenant pays for all production costs and collects all revenues generated. The second type, which is less common, is when the owner provides access to land and water while the tenant provides the labor and other production costs and the revenues are divided between owner and tenant (Nassif, 2016). In both cases, land rental is considered to be expensive and was underlined as a problem by most of the tenants we interviewed.

20 This information was obtained from the respective farmers, interviewed on 30-1-2018 and 17-2-2018.

3.2.5 Water fees and water and land use arrangements

The cost of access to water and the type of arrangement organizing the relation of users to the water source are crucial to assess users' incentives to make an efficient use of water. In our sample, different arrangements and water tariffs were found.

In the Anjar system, farmers are subscribed to the irrigation service provided by the Anjar Irrigation Committee. Typically, in collective canal systems, water is provided through irrigation turns organized by employees working for the committee. Water is conveyed to plots by gravity. There are two types of tariffs depending on the types of crops grown. Vegetable (and cereal) farmers pay a flat rate of 500 USD for the entire irrigation season (April-October), for each 7dunum plot. Fruit tree farmers pay a rate of 50 USD for each irrigation, and for each 7-dunum plot. Generally, farmers irrigate 4 or 5 times depending on climatic conditions, type of crop and water availability. This means that the water fee for vegetables is around 70 USD/dunum/season and between 30 and 35 USD/dunum/season for fruit trees. According to the director of the Anjar Irrigation Committee, Anjar farmers tend to over-irrigate because water fees do not depend on water consumption.

When Canal 900 was still operational, farmers used to subscribe to the irrigation service provided by the Litani River Authority. They used to receive pressurized water through hydrants located on the plots, to which they would connect their own irrigation systems. Water was available day and night from the hydrants but the discharge was limited to 1 l/s for 8 dunums (1.2 l/s/ha) (Hill, 2010). In the last couple of years of operation, farmers used to pay flat rate of 60 USD/dunum. In the first years of the system's operation, the LRA attempted to implement volumetric tariff and equipped some hydrants with water meters. However, the experiment did not work, mainly because the material was regularly clogged due to water quality problems. LRA also reported that some farmers intentionally broke the meters on purpose fearing to pay higher water fees. Here too, farmers were accused to over-irrigate their crops (Merkley, 2010). As seen above, farmers currently use private wells in Canal 900 command area.

Different types of well-use are found in our sample (and more generally in the Bekaa). They often come hand in hand with land-use arrangements and could be simplified into 6 clusters:

- *Cluster 1*: the farmer is the direct owner of his well (and generally of his land). In this case, the cost of access to water is equal to the cost of water pumping (in addition to the investment of drilling the well).
- *Cluster 2*: the farmer rents out access to a well (generally along with the land). In this case, he pays the access to the well and is responsible for the pumping costs.
- *Cluster 3:* the farmer purchase water from another well, paying a fixed rate per hour.
- *Cluster 4:* the well owners who rent out access to their wells (generally with plots they own). These well owners are usually farmers as well, using part of their wall water to irrigate, but can also be only trading with water and land.

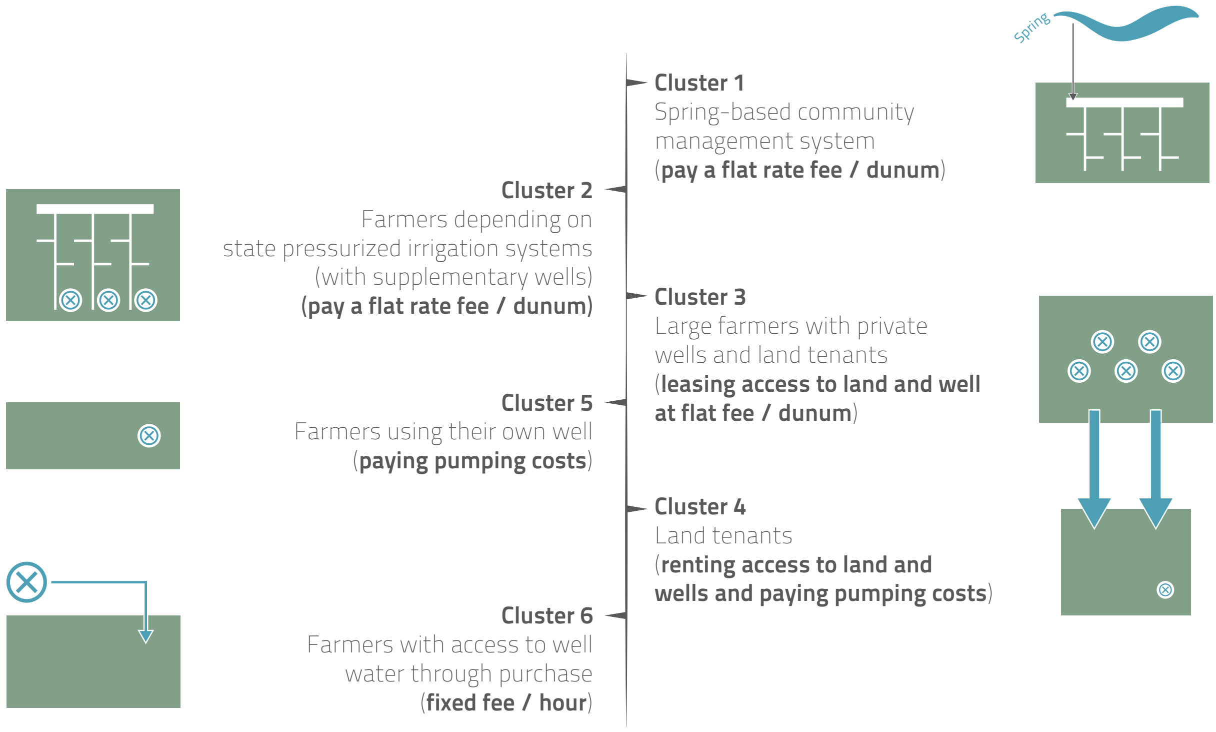
Pumping costs are variable and depend on the volume of water abstracted, water level in the well, the distance between the well and the plot and the types of conveyance system (earth canals or pipes). They are difficult to estimate since water levels are variable and depend on the types of aquifers and the degrees of their exploitation. In Canal 900 area, a study estimated the cost to vary between 45 USD and 389 USD/dunum for irrigation requirements varying from 550 to 1,500 m^3/dunum and depth to water table of 60 to 180 m (Hill, 2010).

The cost of well-rental is often included in the price of land-rental. In West Bekaa, the cost of renting 1 dunum of land with access to the well varied from 150 USD to 250 USD (not including the pumping costs).

The fixed rate per hour for purchasing water is also variable. According the director of Anjar Committee, well owners in Anjar[21] sell water at a fee of 40 USD/hour

- *Cluster 5:* farmers using their own well and paying pumping costs.
- *Cluster 6:* farmers with access to well water through purchase.

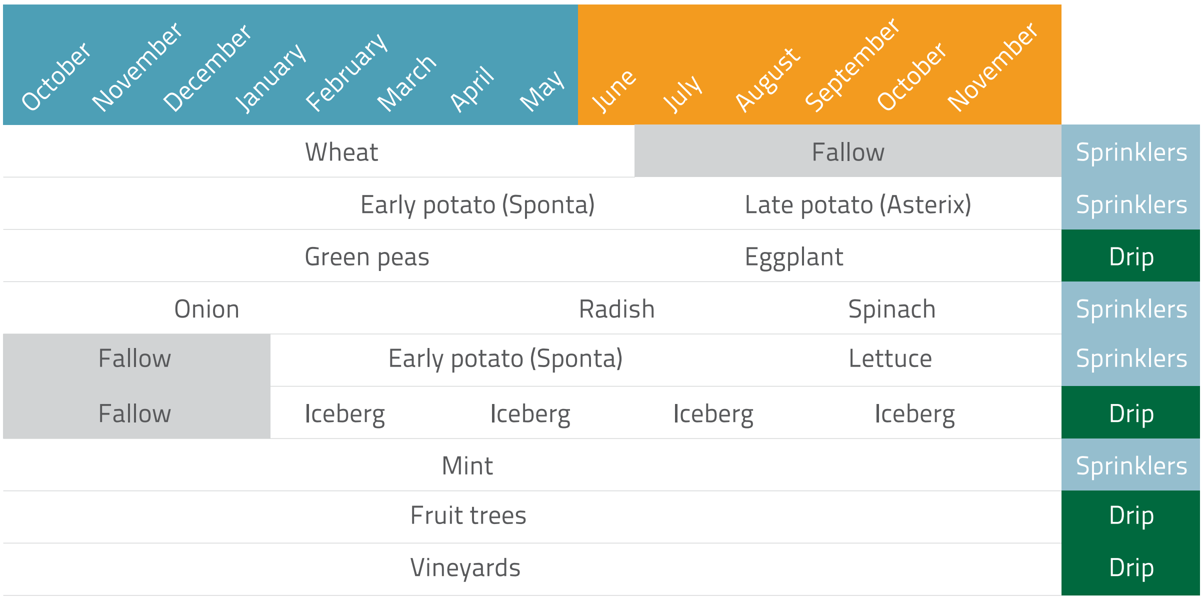
Figure 17. Arrangements around water use



21 These well owners have their wells outside of the collective system.

In West Bekaa, we interviewed two farmers belonging to category four, where high discharge wells and a large amount of land were respectively owned by the same individuals (or family). In both cases, part of the land (around 20%) was directly cultivated by land owners and the rest of the land was leased to several farmers with access to water (category 2). The arrangement consisted of paying a fixed rent (per du and per year) to benefit from the use of land and well(s). In one case, the cost of pumping was covered by the tenants and in the other case (the largest irrigated farm, 4,500 du), farmers had to pay for the cost of conveying water to their plot (second pumping) while the well owner paid for the cost of groundwater pumping. In the latter case, the fixed rate paid for land and well was higher than the first case (respectively 400 and 200 USD). In Canal 900 area, where farmers currently rely on wells, the same mechanism was observed, as all farmers reported to be renting the access to land and water from other well-owners. In these cases, tenants were also responsible to pay for pumping costs. On general, it was reported during our focus groups that arrangements where tenants pay themselves for pumping costs are more common in West Bekaa. Similar land and water tenancy arrangement were observed in Terbol and also concerned very large farms irrigated from Karstic wells. In this region, we also observed cases where farmers exploit their land and water under direct use, in fact, this type of arrangement was found to be common around wells found in the Quaternary aquifer of Terbol and concern small to medium farms (Nassif, 2016).

Figure 18. Example of agricultural calendar in the Bekaa



Source: Nassif, 2016.

In summary, we can note that there is a large diversity of economic mechanisms for water-use use in the Bekaa (Figure 17). Generally, farmers pay flat rate water fees in community and state collective systems. When wells are used (the case of more than 65% of the Bekaa area), farmers can be direct well-users or land-tenants using the well and paying for its operation. Water purchase from wells also exists but is more limited. In this case, farmers pay a flat fee/hour depending on the well discharge. All these arrangements are important to unpack when one wants to reflect on incentives for improving water efficiency.

3.2.6 Cropping patterns and agricultural calendars

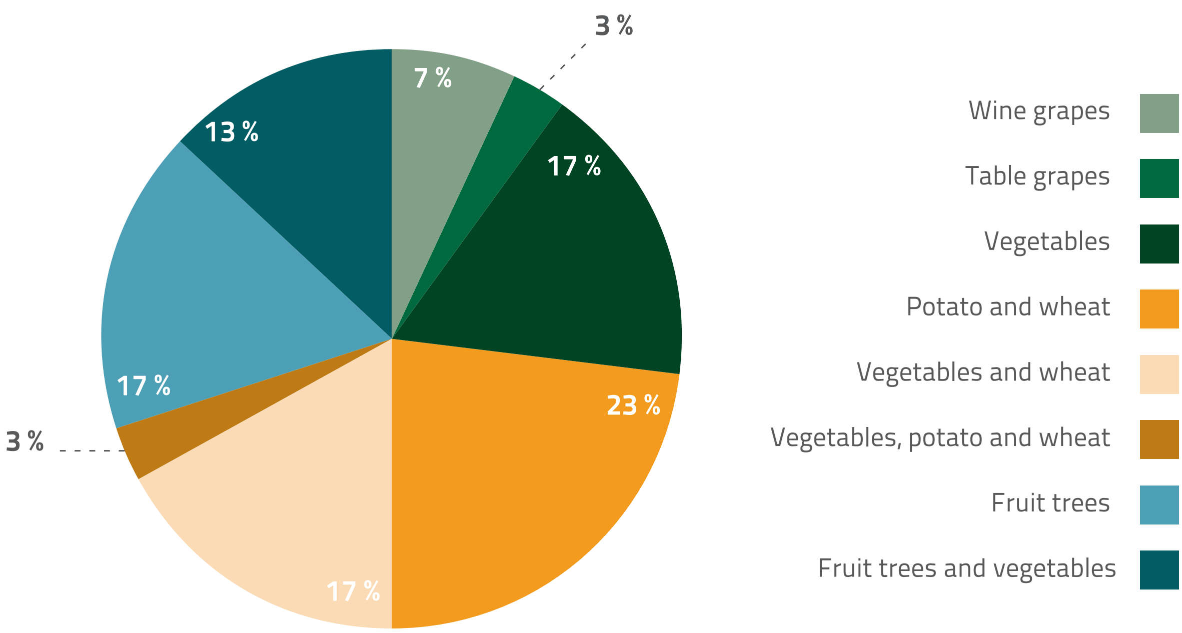
Identifying cropping patterns and agricultural calendars is crucial to estimate the amounts of water used by farmers. First, each crop has specific water needs, and second, there are different ways to organize crop rotation in the same plot, affecting the total crop water needs per dunum.

In the Bekaa, choices of cropping calendars were observed to depend on different factors: a) soil types and water availability; b) farmers' investment and/or technical capacity; c) market access opportunities and market prices; d) land tenure characteristics (Nassif, 2016). The most cultivated crops in the Bekaa include wheat, fruit trees, grapes, and field crops (vegetables, potato, beans, etc.). Although it does not provide high revenues (100 to 200 USD/du), wheat provides a stable income since it is subsidized by the state. It is subsequently cultivated in large areas every year.

Generally, wheat is rotated every other year with vegetable crops and is not followed by another crop. This crop rotation is widely practiced by farmers in the Bekaa and considered crucial for letting the land rest after intensive vegetable cropping. Wheat is generally irrigated but only requires supplemental irrigation in April and May. (It does not require more than 200 to 250 m^3/dunum.

Fruit trees such as apple, plum, peach and pear are also widely cultivated in Central and West Bekaa. In 2011, they occupied 17% of the Upper Litani River Basin's agricultural area (USAIDLRBMS,2012b). Grapes are also widely found. They are mostly used to produce wine, an important industry in the Bekaa and generally grown on large areas in West Bekaa. Table grapes are also commonly found and generally provide high revenues (around 1,000 USD/du). Vegetables include a wide variety of tuber and bulb crops (potato, garlic, onion, radish and turnip), leafy vegetables (lettuce, cabbage, cauliflower, spinach, mint, parsley and others), fruit vegetables (tomato, cucumber, eggplant, watermelon and melon), leguminous crops (green peas, fava beans and other types of beans)

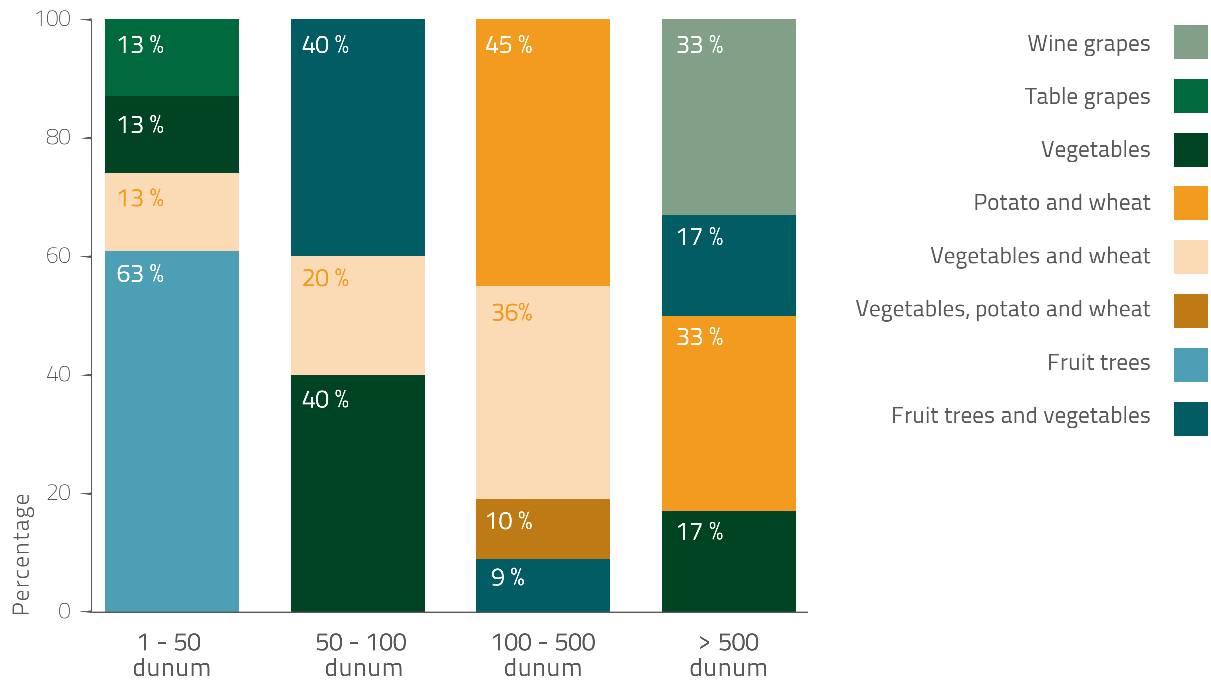
Figure 19. Cropping pattern practiced by the interviewed farmers



and corn, which is cultivated both for human consumption and as a fodder crop (Nassif, 2016).

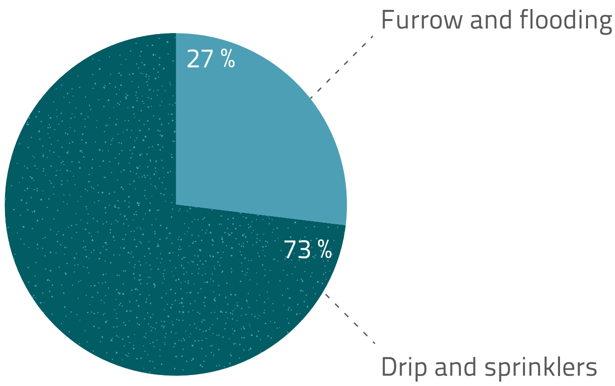
Several types and combinations of cropping patterns are practiced in the Bekaa (as shown from the survey in Figure 19). Generally, wine grapes and table grapes are cultivated as a monoculture, while wheat is rotated with vegetables and potato. Vegetables such as tomato, garlic, onion, lettuce and other leafy vegetables can also be practiced without a rotation with wheat. However, farmers who only practice vegetables tend to rent different plots each year and look for lands cultivated with wheat in the precedent year.

Figure 20. Distribution of cropping pattern categories according to farm size



Fruit trees were generally found in plots under direct use by their owners since land rental contracts are mostly done for one year only. Thus, as shown in Figure 20, they are mostly concentrated in the smaller plots (1-50 du). Wheat, potato and vegetables tend to be planted in larger farms. Potatoes are known to generate good income (850 USD/du/cycle) and are generally cultivated twice a year on the same plot (spring and summer season). However, as it has been indicated by our interviewers, important financial losses occurred for potato farmers in the last couple of years due to a drop of their selling price on the domestic market (2016-2017). The reason is related both to the over-production of local potatoes and the high competitiveness of the imported potatoes (mainly from Egypt). Another profitable crop is iceberg lettuce. It can be planted on the same plot up to four times a year and can generate up to 3,000 USD/du, and was found as a monoculture in a large professional farm in Terbol. Similar to other vegetables, it has to be rotated with less intensive crops in order to give good yields. Thus, as explained by one farm manager, different plots have to be rented each year to practice the crop rotation with wheat.

Figure 21. Irrigation techniques in the interviewed sample



These findings provide several insights into the potential use of ICT. First, they underline a large diversity of cropping patterns and agricultural calendars which have to be well understood to be able to target the most water consumptive farms. Second, the fact that plot rotation is a common practice can be detrimental to the use of systematic ICT tools. For farmers rotating plots from one year to another, the land characteristics are not fixed (soil type, climatic conditions), and the water source might also change. This is to be taken into consideration when it comes to implementing ICT technologies (such as smart irrigation applications) at farm level.

3.2.7 Irrigation techniques and practices

As shown in Figure 21, most farmers use drip and sprinkler irrigation systems. Sprinklers were observed to be used on wheat and potato crops, while drip irrigation is practiced on vegetables. Gravity irrigation was only found to be practiced in the Anjar Irrigation System, where water is conveyed by gravity to the plots. In the latter case, farmers pay a fixed fee per unit area and do not have incentives to reduce their water consumption. Additionally, switching to pressurized techniques would require important financial investments (including the cost of irrigation systems, pumps and on-farm reservoirs). According to the Director of Anjar committee and to the interviewed farmers, these costs are too high for farmers. For farmers using groundwater, the use of drip and sprinkler systems is wide-spread because of the incentives of reducing their pumping costs. This was observed in Ryak and Terbol regions (Nassif, 2016) and in Canal 900 (Karaa et al.2004). Sprinklers and drip systems were observed to be used by farmers pumping water from rivers in Central Bekaa (Nassif, 2016). Globally, we can say that gravity irrigation is only practiced in spring-based irrigation systems, where water is derived to plots by gravity and where the incentives and financial possibilities to adopt modern techniques are low.

3.2.8 Current use of ICT in irrigation management

As shown in Figure 19, current irrigation practices are largely dependent on traditional knowledge and irrigation methods. In all three types of irrigation systems (Anjar spring-based system, Canal 900, and private wells), and for all types of farm sizes, farmers explained that they adopt the "Eddan" method for scheduling their irrigation. This consists a traditional irrigation scheduling based on local know-how. For example, potato plots are commonly irrigated every 6 to 7 days, vegetables are irrigated every 4 to 5 days, and fruit trees are irrigated every 10 to 12 days. As described by farmers, the decision to irrigate is also carefully taken based on soil type and dayto-day observations of climatic conditions.

For example, all farmers look for changes in soil texture and manually check soil humidity. Typically, they dig the soil with their hand at 10cm of depth and test the soil humidity. Agricultural engineers also stated that they rely on field observations to decide when and how much to irrigate. The manager of one of the wineries included in our sample explained that she studies the colour and size of the grapes to decide whether it is the right moment to irrigate. She stated that the need to irrigate is highly dependent on day-to-day climatic conditions. She also

Figure 22. Decision making methods used for on-farm irrigation

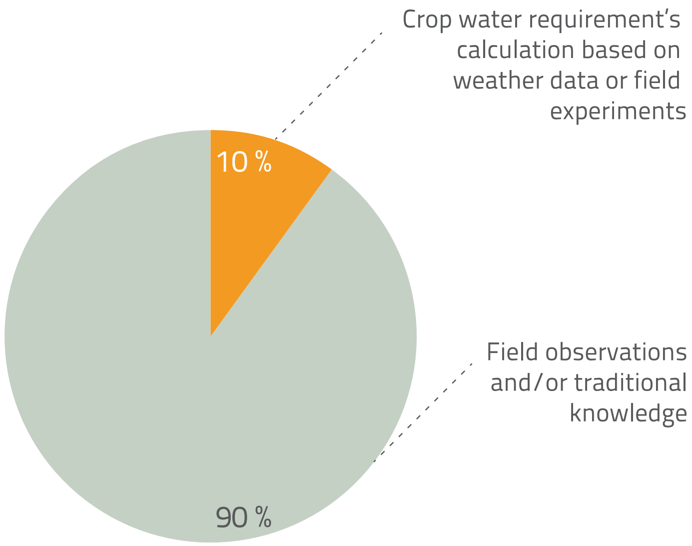


Figure 23. Irrigation decisions according to education level

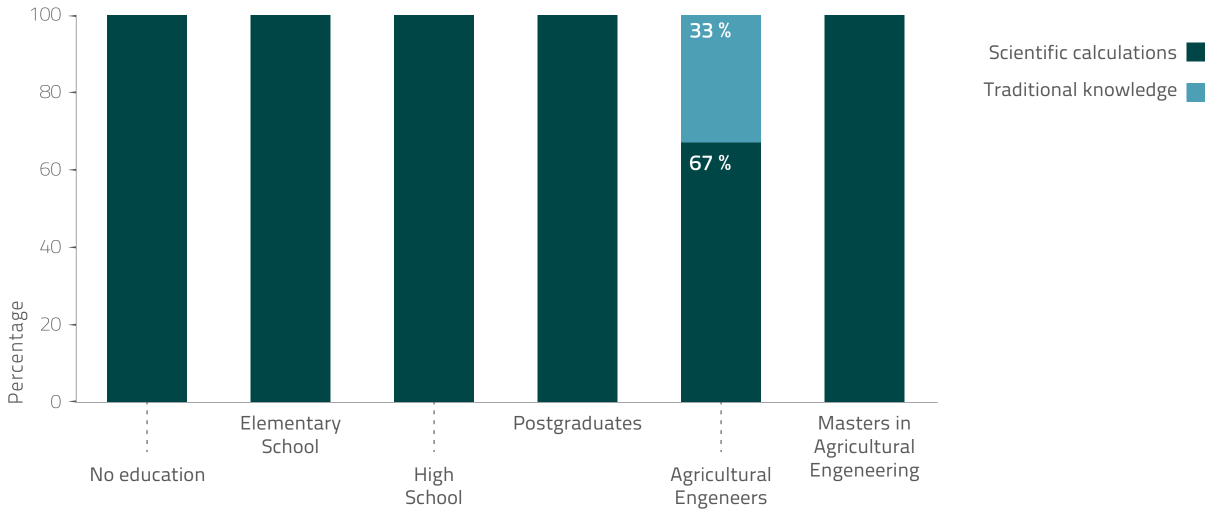


Figure 24. Irrigation decisions according to farm size

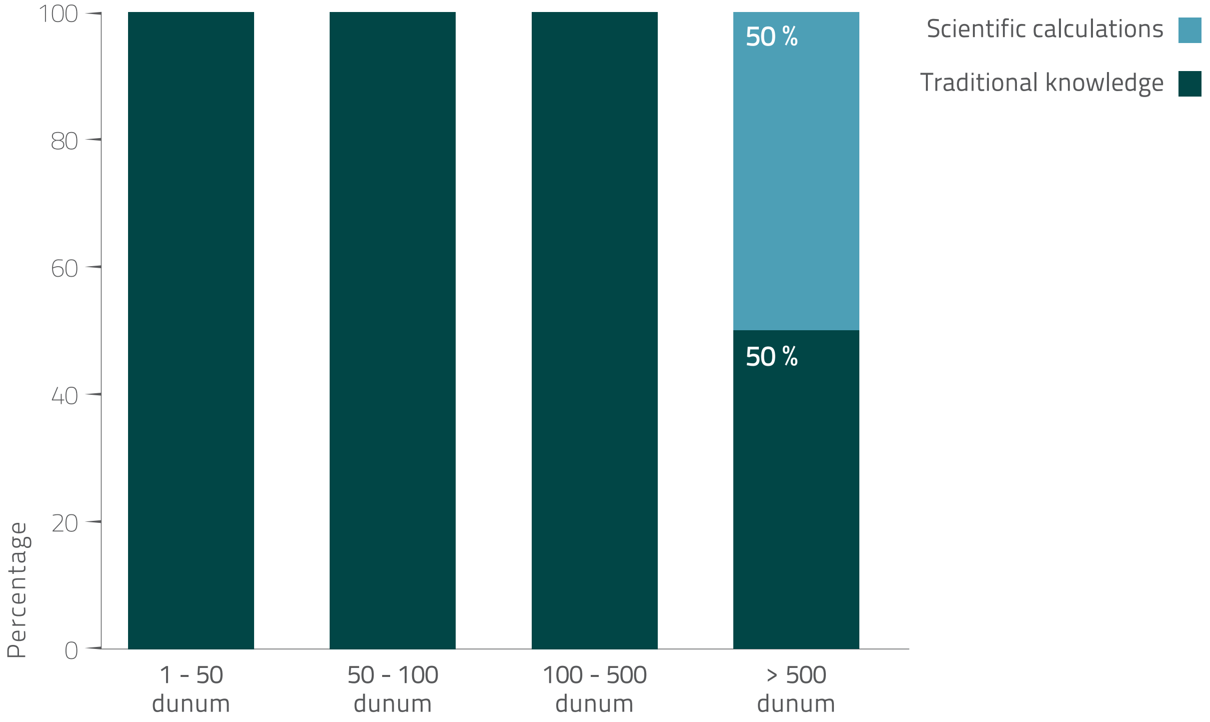


Figure 25. Irrigation decisions according to types of irrigation systems

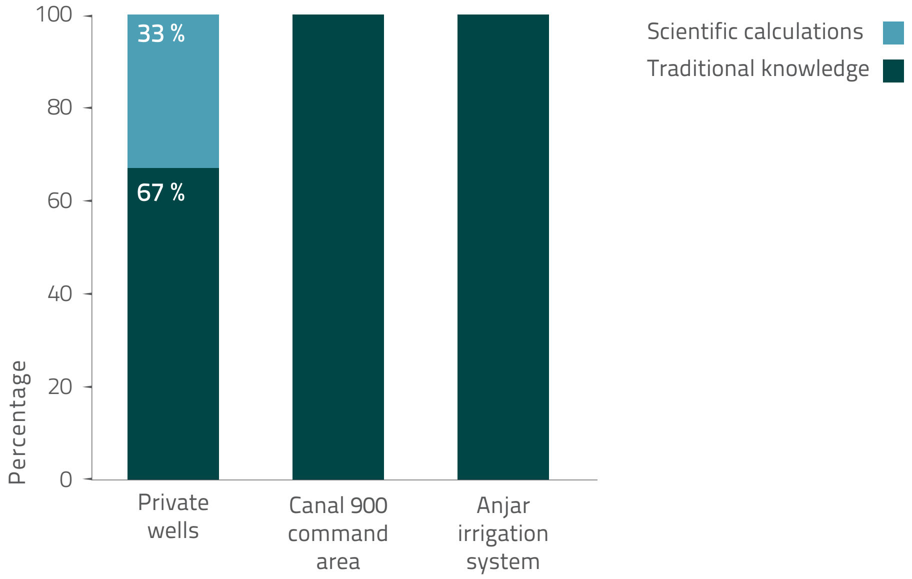


Figure 26. Irrigation decisions according to types of cropping pattern

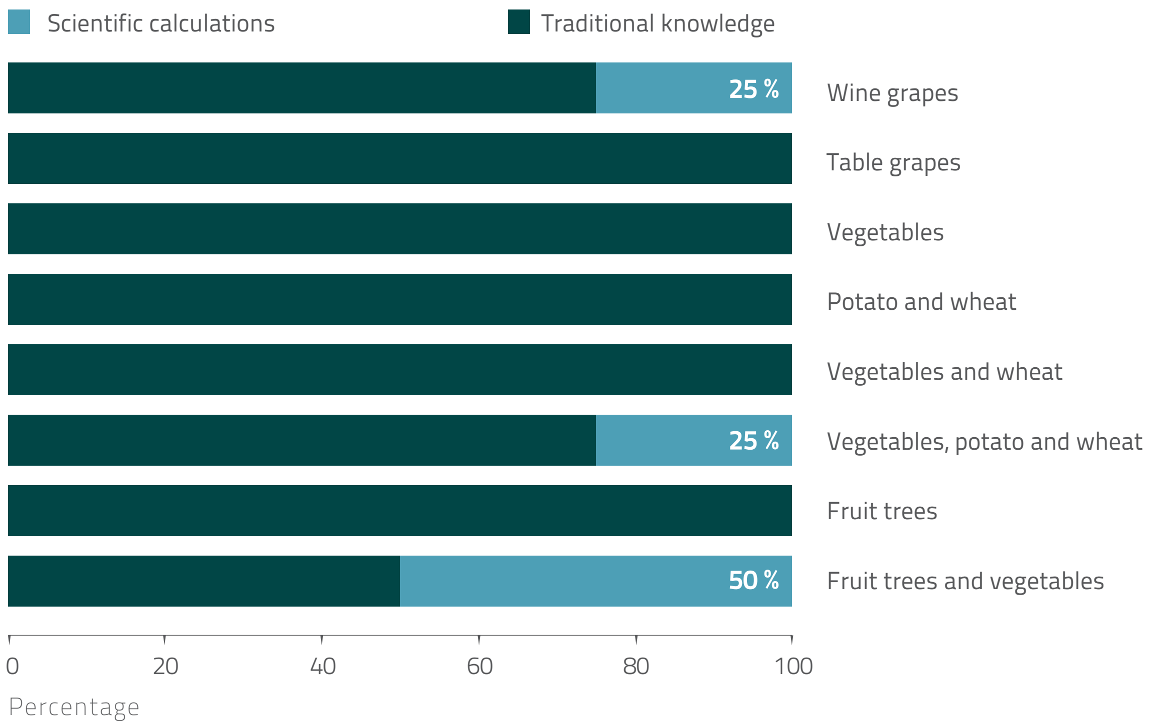
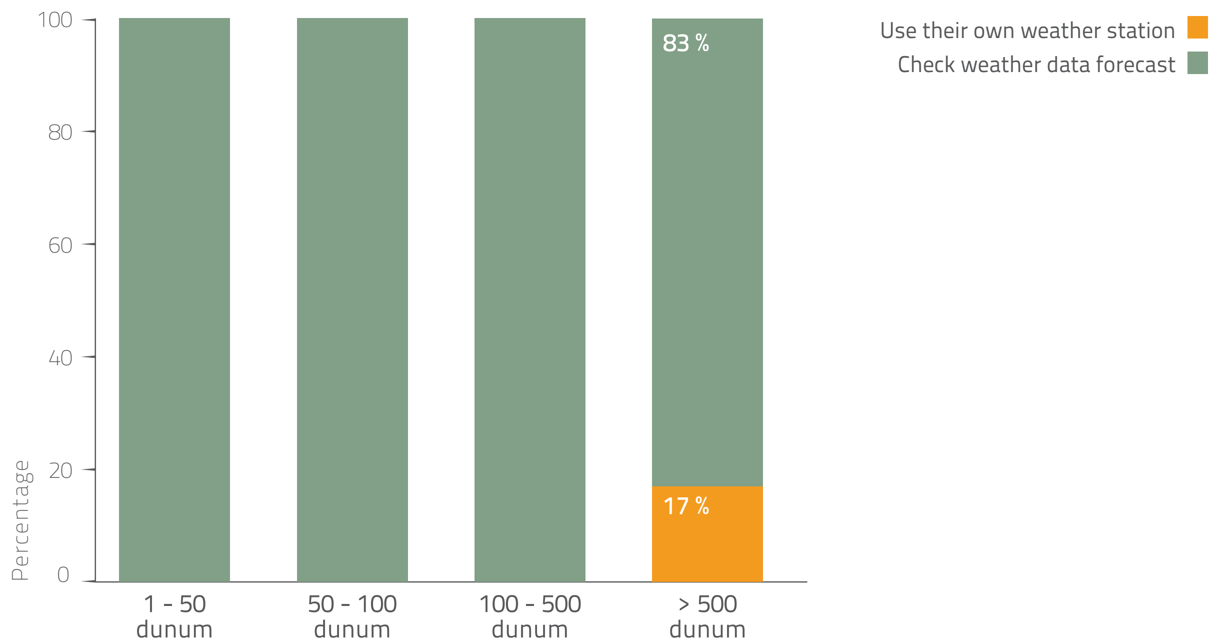


Figure 27. Use of weather data



explained that it depends on the quality of the grapes they wish to obtain, which is in turn dependent on the type of wine that will be produced. For example, less water is to be given to obtain a high sugar concentration in grapes.

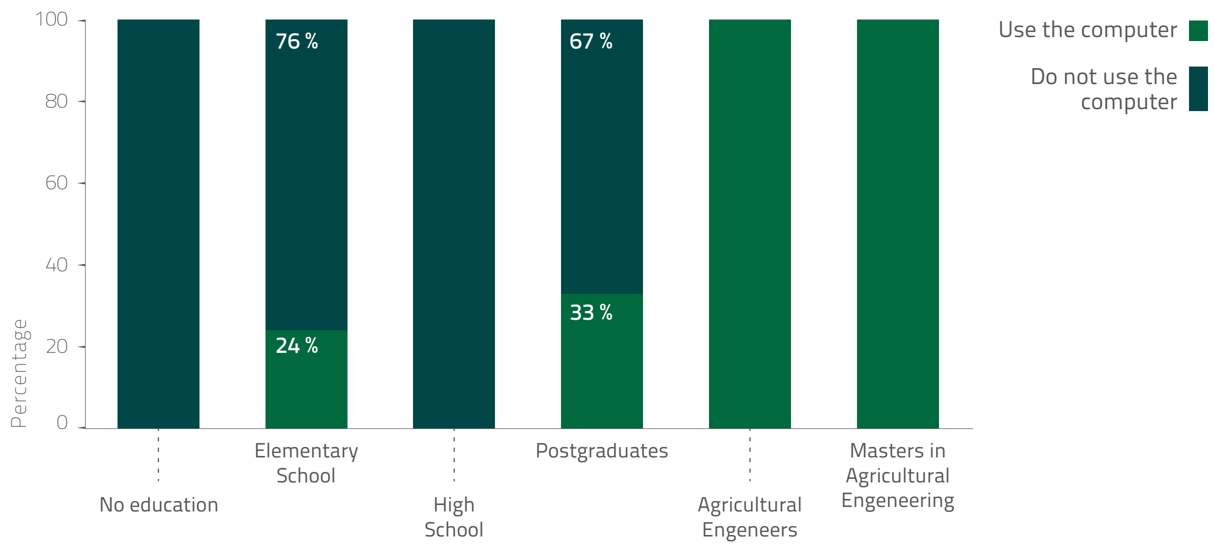
Only two farmers were found to rely on scientific calculations to schedule irrigation timings and decide the amount of water to provide. Both farmers were agricultural engineers and managers of large size farms using groundwater (see Figure 23 and Figure 24). The first was the manager of a larger winery in West Bekaa. In order to have a better understanding of the local climatic conditions, he recently took the initiative to buy two weather stations (located at different locations in the property since it is a large farm). In this case however, wine grapes were only irrigated during the first two years after planting and rainfed in the following years. The weather stations, as he explained, aimed particularly at monitoring changes in rainfall rates, as rainfall was observed to substantially decrease in the last decade. The second was the manager of a large iceberg farm in Central Bekaa. He explained that he relies on evaporation pan measurements to assess the local evapotranspiration on the plots. We also noted the interest of a third agricultural engineer in developing more accurate scientific methods to better assess crop water needs. It was also the case of a large farm relying on groundwater, part of which was rented through land and well-use agreements (cluster 3 in Figure 17). He explained that water shortage problems in the last years, made him consider implementing water-saving measures. Since several other farmers use his wells, he wishes to develop a new pricing strategy, based on volumetric consumption, instead of the traditional fixed fee tariff. For this, he will equip the inlets of their irrigation systems with water meters. It is important to note that water meters were not found to be used in any other farm in the Bekaa.

All interviewed farmers were found to regularly check the weather forecast. They explained that weather information was important for many decisions related to their farming practices, such as the date of ploughing, spraying, and harvesting.

Climatic conditions are also a big concern for farmers, as extreme natural conditions regularly occur in the Bekaa (high or low temperature, flooding or drought). Most farmers were found to check the daily weather forecast on their smartphones (mainly the "accuweather" application which is typically accessible with smartphones).

As shown in Figure 27, private weather stations were only found to be used by a significantly small share of farm-

Figure 28. Use of computer according to education level



ers. This is the case for example of the large winery described in the section above.

Despite the wide use of smartphones and a high rate of subscription to internet services (see following section and figures), none of the interviewed farmers regularly use the LARI mobile application. The main reason for

Figure 30. Internet service providers

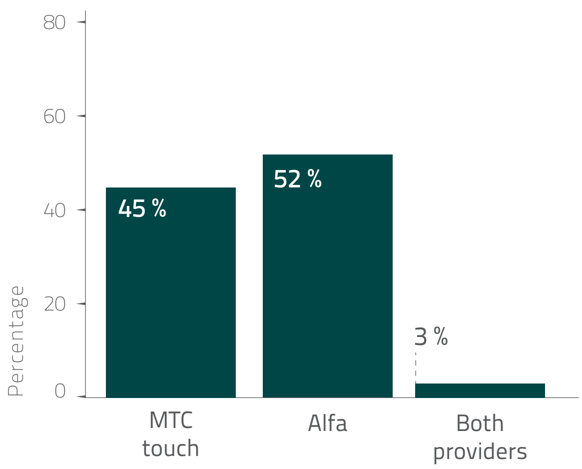
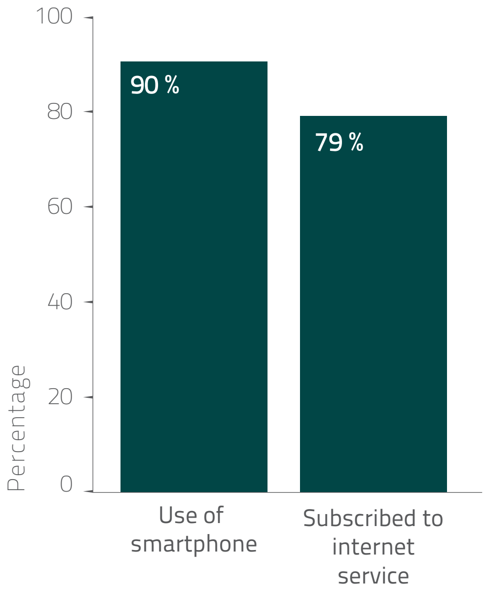


Figure 29. Use of smartphones and subscription to internet services



this is that most farmers were not even aware of the existence of the application - only a few farmers (agricultural engineers managing large professional farms) had already heard about this application. Another reason is that weather data (the main information transmitted by this app) and other information, such as the potential of pests' occurrence remain too general and not representative of local conditions. Farmers mentioned that they needed to have access to local weather data. The weather information currently given by the LARI app are not representative of the local conditions of the Bekaa.

3.2.9 Access to computer, mobile, and internet technologies

Computer and internet use is now very common in Lebanon. However, only 30% of interviewed farmers use computers, a fact related to their education level. As shown in Figure 28, most of the farmers using computers were agricultural engineers or post-graduates. Only 20% of farmers who received elementary school irrigation knew how to use a computer. Nevertheless, 90% of farmers who did not use the computer stated that their offspring uses one and benefit from an internet subscription at home. This is explained by the fact that computers and internet are widely used by the younger generation and accessible in the Bekaa which is now largely urbanized.

As opposed to the use of computers, smart mobile phones are regularly used by farmers. In fact, smartphones are today widely used in Lebanon by almost all socio-economic groups. Instant communication applications such as WhatsApp and social networks application such as Facebook are used on a daily basis by the Lebanese population.

As shown in Figure 29, 80% of farmers subscribe to internet services through their smartphones. There is also good data coverage in the Bekaa by the two mobile service providers (Mtc touch and Alfa). As shown in Figure 30, the two service providers have relatively the same popularity amongst farmers using mobile phones.

3.2.10 General access to information and extension services

If farmers are well connected to digital communication channels, their connection with public institutions was found to be very poor (Figure 33). While 37% of farmers interviewed have benefited from extension services, only a small share of them (less than 10%) received these extension services from state institutions.

Farmers explained that the only technical advice or support they receive come either from commercial agricultural enterprises who sell agricultural products and material, or nongovernmental organizations which provide technical trainings as part of development projects. It is important to note that the involvement of development organizations was observed mainly in the Canal 900 system and in the Anjar irrigation system, while it was less present in the case of decentralized private wells systems (Figure 32). This is explained by the fact that development programs are generally developed in cooperation with public institutions, such as state or municipal authorities. This is also related to the problems foundin these two irrigation systems. A seen above, Canal 900 failed at providing water to all of its command area, which pushed a number of development programs to develop studies and technical support programs to improve its performance, in cooperation with the LRA (Merkley, 2010; Hill, 2010). The Anjar irrigation system, although benefiting from a better service, has also been studied and monitored by several development projects in recent years. With the aim to improve the system's water efficiency, SPNL[22], a local NGO, trained farmers to practice furrow irrigation (instead of flooding). Also, two wells were drilled as part of another development program in order to compensate the reduction in Anjar spring discharge (Nassif, 2016).

Public institutions seem to have a very limited role and presence on the field. MoA, who has a local office responsible for extension services (in Zahlé), was found to have little contact with the farmers interviewed. The only MoA activity that was mentioned by farmers was conducted in Anjar system, aimed at improving pruning practices. LRA was found to be in touch with farmers only in West Bekaa, where it has two local offices: the Rural Development Center (in Kherbet Kanafar), and the Irrigation Department in Karaoun. However, farmers also stated that the extension services provided by these two offices are very limited and confined to NGOs initiatives that take place within LRA offices.

As for the LARI and the CNRS, the survey and interviews also found that they generally have a limited role in the field. However, we noted that the CNRS had recently developed a research project with a large winery in West Bekaa, consisting in assessing the vegetation health of vineyards using remote sensing technologies (described above). The goal was to identify the impact of climate change on the crops. However, such customized services are only provided by the CNRS at a cost[23] and can only be afforded by large professional farms.

22 La Société de Protection de la Nature au Liban.

23 Public institutions were also included in our study. Their exact scope, activities and constraints are detailed in the Section 'Results of Stakeholder Surveys'.

Figure 31. Access to extension services

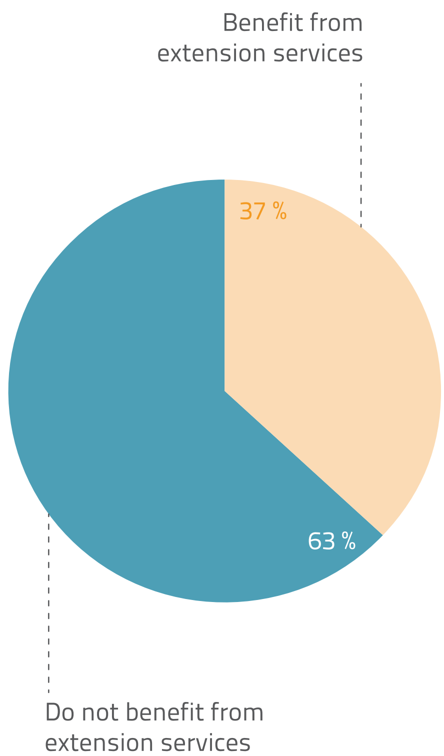


Figure 32. Access to extension services for the three irrigation systems

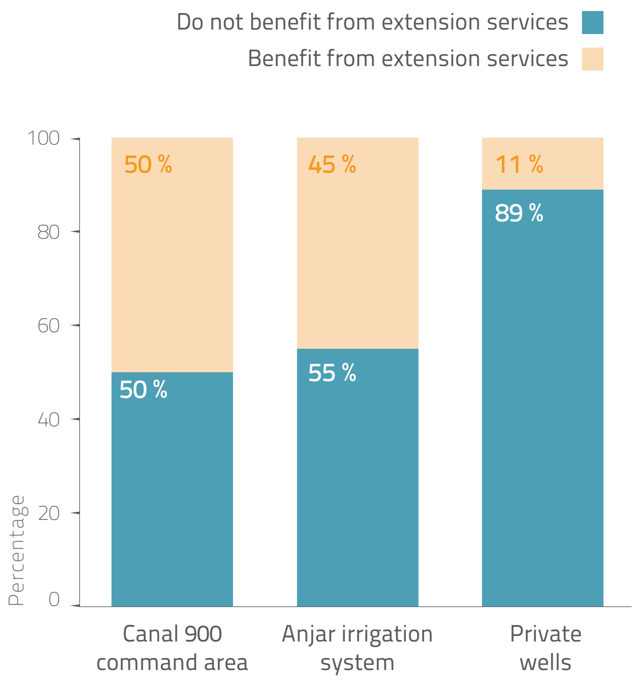


Figure 33. Access to extension services from the different stakeholders

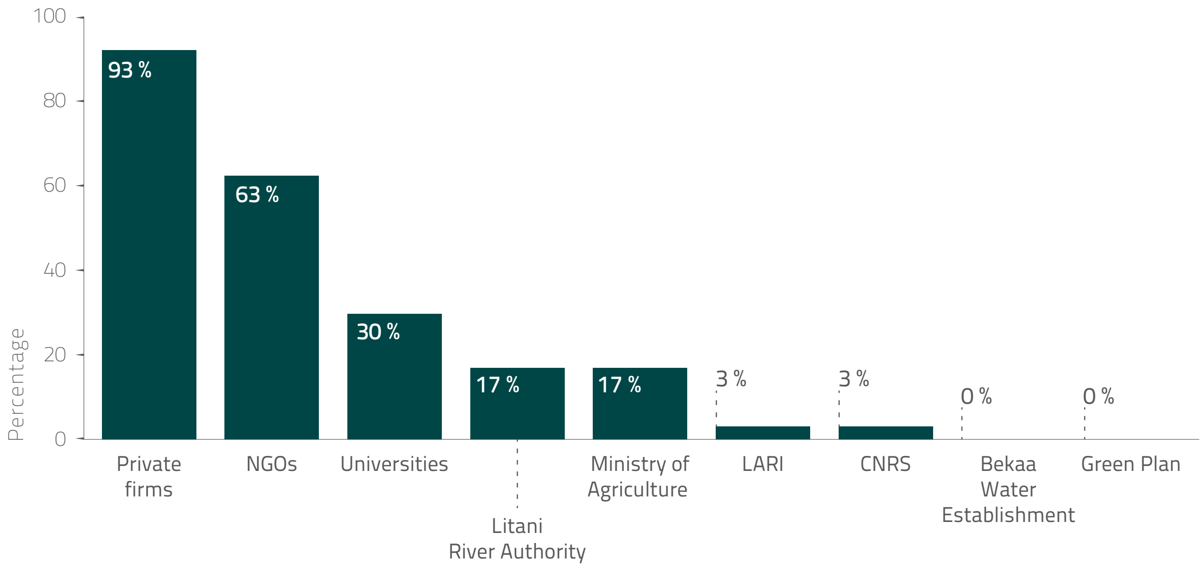
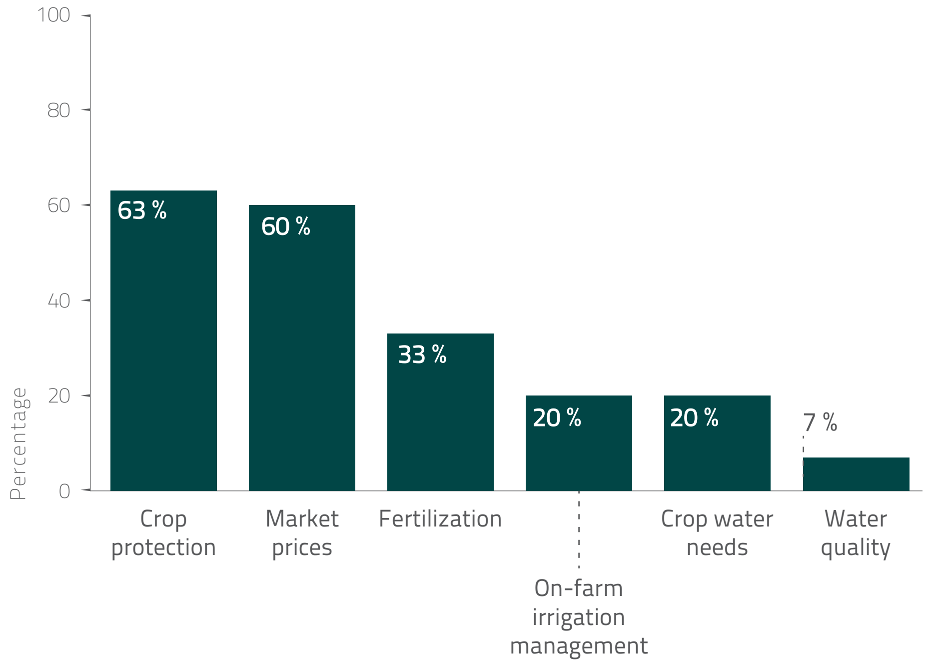


Figure 34. Types of Information needed by farmers



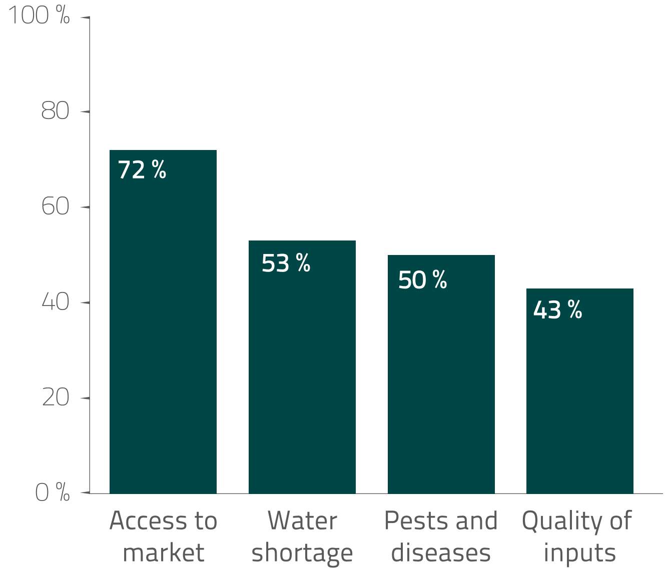
When asked about what type of information would be useful to improve their farming practices, farmers mainly underlined crop protection (63% of the farmers) and market prices (60% of the farmers) (Figure 34). Information on fertilization came third (30%). Other topics such as on-farm irrigation practices (how to use better irrigation techniques) and crop water needs were only considered to be needed by 20% of the farmers (respectively). Information on water quality was of interest for 7% of the farmers, which is explained by the fact that our survey included farmers using good quality water.[24] The other results are explained by the main problems that farmers face in the agricultural sector (Figure 35).

Information about crop protection and quality of inputs

Crop protection is a direct concern for farmers since pest attacks can highly reduce crop yields and sometimes threaten the whole production. As seen above, farmers receive limited extension services from public institutions, a fact that limits their awareness concerning pest risks and management, especially when it comes to farmers with limited education and access to the internet. If farmers receive advices from private input firms, the latter sometimes give them biased information aimed at selling them the most expensive products. The private sector was even accused of sometimes selling outdated products. In fact, focus groups in Anjar and Canal 900 areas revealed a recent problem with input quality, where a number of expired chemical products were sold to farmers (by changing the dates). This reportedly seriously impacted yields, causing important financial losses.

24 However, water quality is an important issue for farmers who irrigate from rivers. Also, When Canal 900 was operational, water quality was a big problem since it used to be provided through lake Karaoun which is highly polluted.

Figure 35. Problems in agriculture



Information about markets and commercialization strategies

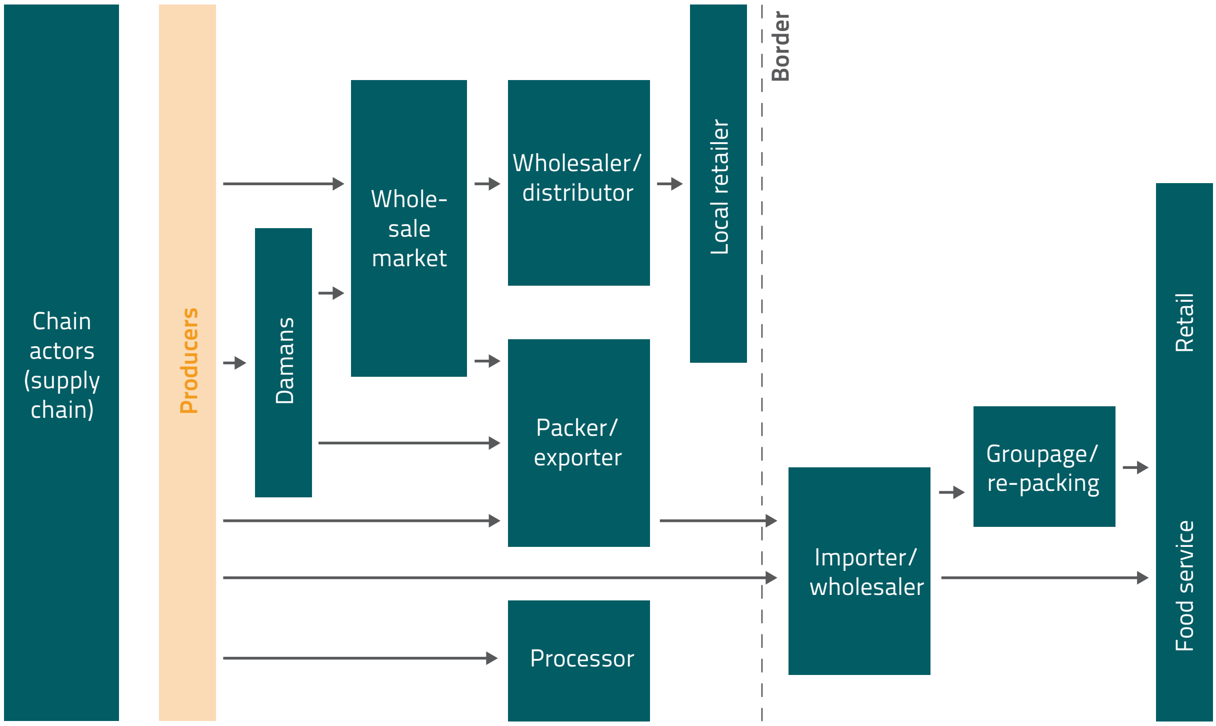
Access to markets is a structural problem for the Lebanese agricultural sector (Augiers et Blanc, 2009; Riachi and Chaaban, 2010). On the one hand, the liberal trade economy of Lebanon allows for international competitive products to be imported with limited restrictions and low protection of the domestic market (Riachi and Chaaban, 2010). On the other hand, Lebanon lacks an export strategy, which leaves farmers (mainly small ones) with no orientation linked to international markets' demands, required quality standards and packaging and marketing strategies (Rujis, 2017). Orientation is equally lacking with regards to adapting the choice of crops and agricultural calendars to domestic market demands. Local markets are often saturated which forces farmers to sell their products at very low prices. This was the case of potatoes which reportedly suffered from very low margins in the last couple of years, causing tremendous financial losses.

Another problem is the structure of the supply chain and the weak position of small and medium farmers in it (Rujis, 2017). As shown in Figure 36, there are several intermediary actors between farmers and local retail (domestic and international). Small and medium farmers rarely deliver their products to local retailers or even whole-sale markets. They have a limited power in setting their price (Rujis, 2017), and earn much smaller margins than the other actors in the supply chain (Riachi and Chaaban, 2010). Moreover, farmers rarely work together in cooperatives. Although a large number of agricultural cooperatives exist on the paper, they remain ineffective as a true solution to access better markets or decrease production costs (Rujis, 2017). As a matter of fact, interviews and focus groups showed that farmers operate alone. Farmers deplored the "individualistic mentality of the Lebanese farmer". Some farmers in Canal 900 used to be part of an agricultural cooperative but it was only established to receive funds and from an NGO and never functioned as a true tool of cooperation.

Other problems in agriculture

Another serious problem is the lack of agricultural banking credits. Due to the riskiness of the sector, bank loans to agriculture barely represent 1% of bank credits (ESCWA, 2009 in Riachi and Chaaban, 2010). In this situation, farmers are pushed to take informal loans. In the Bekaa, most farmers (small and medium to large) typically purchase their agricultural inputs on credit from local sellers, and pay them at the end of the season, once they have

Figure 36. Place of producers in the supply chain



Source: Rujis, 2017.

sold their products. But many times, revenues are lower than expected (due to market prices, climatic events, or other factors) and farmers cannot pay their debts. To pay their dues, they go to informal money lenders who grant them money at very high interest rates and from one bad season to another, they often become crippled by debts (Nassif, 2016).

The anger and frustration of farmers was clear during focus groups and interviews, where farmers complained about high rents, escalating input costs, low market prices, and the complete absence of state support. Many farmers found the topic of ICT irrelevant within this context, and constantly oriented the discussion towards these problems. These complaints are not exaggerated. A detailed study on the evolution of farming in the region of Terbol showed that due to money losses in agriculture, many families sold their farms in the last two decades, deciding to invest in more productive sectors (Nassif, 2016).

Need for information on water management

Although water shortage was mentioned to be an issue for 53% of the interviewed farmers, improved water management was a topic of interest for a limited number of them. On a global level, farmers said that "it's always good to learn new techniques for water management" but only few of them expressed a true interest in reducing their water consumptions.

As seen above, the majority of farmers, from all farm size classes and education categories (even agricultural engineers), use and trust the traditional knowledge they practice in irrigation (when and how much to irrigate). The "eddan" (time between two irrigations), traditionally applied in gravity irrigation before the introduction of pressurized systems, was adapted to these new techniques and is still widely used. These techniques are adopted by all farmers irrigating from groundwater because of the financial incentive. As described above, in most of water-use arrangements linked to wells, farmers pay for pumping costs and are thus economically pushed to reduce water consumption.

Anjar irrigation system is the only place where gravity irrigation is still practiced. This is explained by the type of water delivery in the system (drip and sprinklers require pressure), the pricing system (flat rate fee), the cost of switching to pressurized techniques, and the relative availability of water from Anjar spring. However, the spring's flow has been continuously decreasing since the 1960s which required from the Irrigation Committee to invest in pumps to convey water from the spring to the main canal, and to drill wells (recently) to supplement surface water supply (Nassif, 2016). According to the director of Anjar Irrigation Committee, this increased the cost of operations and translated into higher water fees to be paid by farmers. In his opinion, there is a need for water savings at plot level, and a need for a systematic monitoring of the spring's flow and the water table. Currently, the LRA has a flow meter at the level of the spring but there is no data sharing with the Irrigation Committee. He expressed his interest in having a water monitoring system at the local level to monitor the spring's variations. He stated that the committee lacks the technical knowledge and the financial resources to invest and develop such a monitoring system.

Another category of farmers (the very large farms using the Karstic aquifers) expressed a concrete interest in water monitoring and reducing water consumptions. This is explained by the drawdown of water tables in these aquifers which leads to increased pumping costs and threatens groundwater availability (at feasible costs) in the near future. This is an issue for both users directly irrigating from their wells or providing access to wells to tenants (at a cost). As described above, some farm managers have already started to implement new water monitoring techniques (in one case using remote sensing tools), while others are interested in developing new measures for water monitoring and reducing water consumptions. They stated to be interested in having information on localized weather conditions, and learning new irrigation practices based on scientific methods.

3.3 Farmers' needs assessment: key findings

The Bekaa valley, the largest agricultural area in Lebanon, suffers from serious quantitative and qualitative deteriorations of its water resources. Water courses are heavily polluted and water treatment remains very limited. Since the 1960s, many springs have dried, river flows substantially decreased and water tables have dropped in all aquifers. Irrigation consumes the largest share of water in the Bekaa. Groundwater is the largest irrigation source, supplying around 65% of the Upper Litani River Basin's agricultural lands while surface water sources (springs and rivers) irrigate around 35% of the lands. However, with the deterioration of surface water sources, groundwater is increasingly mobilized. Irrigation is mainly practiced within private and municipal systems. There are only two state systems, Canal 900 in West Bekaa and the Yammouneh scheme in North Bekaa. Together, they represent a negligible part of the Bekaa irrigated lands (around 5%). Moreover, these state systems are not properly operational. Canal 900 has stopped functioning since 2014 due to the pollution of its water source (Karaoun dam), and the Yammouneh scheme is supplemented by private wells.

Municipal systems are collective open-canal irrigation systems fed by springs where water is supplied on plots by gravity. They are managed by farmer committees under the supervision of the respective municipalities. Water is provided through water turns. Private irrigation systems rely on pumping from rivers or from aquifers (wells). They can be individual systems or collective ones. Individual systems use small pumps or low discharge wells while collective systems use larger pumps and high discharge wells. Our sample included 1 municipal system (Anjar); 1 state system (Canal 900) where past (state supply) and current (private) irrigation practices were assessed; and groundwater systems, including small individual and large collective wells.

Different types of water-use arrangements were found in these systems. In Anjar, farmers pay a flat rate water fee (per dunum per season) to Anjar Irrigation Committee who is in charge of operation and maintenance. In Canal 900, farmers also used to pay a flat rate water fee to the LRA when the system was operational.

In well-based systems, different arrangements exist and are closely linked to land tenure and landuse arrangements. Farmers can: 1) use their own well; 2) rent access to wells (generally with the land) at a fixed fee per dunum per year; 3) purchase water from another well, paying a fixed rate per hour; 4) rent out access to their wells (generally with plots they own). These well owners are usually farmers as well, using part of their well water to irrigate their own crops. With the exception of the case of water purchase, farmers directly pay for the pumping costs, even when they rent the well.

Pressurized irrigation systems (drip and sprinklers depending on the types of crops) are widely used in well-based systems to reduce pumping costs and optimize water availability throughout the season. Gravity techniques (flooding and furrow) were only found in Anjar, where water is supplied by gravity to plots. Since farmers pay a flat rate water fee, the incentives of using more efficient techniques are low.

The size of farms in the Bekaa is very variable and can go from as little as one or two dunums to as large as 10,000 dunums. Different farm sizes were included in our sample, and could be divided in four categories: 1) small farms

(1-50 du); 2) medium size farms (50-100 du); 3) large farms (100500 du) (37%); 4) very large farms (>500 du). Generally, small and medium size farms were common in Anjar system and around small individual wells, whereas large and very large farms are found around high discharge Karstic wells (including the case of Canal 900 where such wells are used).

Land tenancy is widely practiced in the Bekaa (around half of the area or more). In our sample, around 75% of the lands were under indirect use. Direct use is more common in the case of small and medium size farms and land tenancy is more common in the case of large and very large farms. Land rental arrangements often include the rental of well-use. The cost of rent is high. When it includes the cost of access to a well, it can go up to half of the production costs.

Crops include cereals (mainly wheat subsidized by the state), and a large diversity of vegetables and fruit trees, including table and wine grapes. Agriculture is intensive and mostly irrigated, with the exception of wine grapes that are usually only irrigated in the first couple of years. The choice of crops and agricultural calendars depend on different factors such as land tenure (direct or indirect use), water availability, know-how, and market opportunities.

Crops are sold on both domestic and international markets. However, with the lack of adequate state commercialization policies (protection of domestic markets, export strategies, coordination of crop calendars and choice of crops, support to marketing, etc.), access to markets is difficult and unstable. Small and medium farmers are the most negatively impacted and have the weakest place in the supply chain.

It was found that irrigation management decisions (when and how much to irrigate) are mostly based on local traditional methods. Farmers organize irrigation schedules based on the "Eddan" method. For each type of crop, a specific number of days are counted between two irrigations. The number of irrigation hours provided varies along the season and is also decided based on traditional knowledge. Daily field observations play a big part in these decisions (visually and manually testing the soil and the plants). These methods were found to be used in almost all the farms, including the large farms managed by agricultural engineers. Only in one case, the manager of a large vegetable farm was found to use evaporation pan measurements to calculate crop water requirements.

Most interviewed farmers were found to use smartphones (90%) and around 80% of them have a mobile internet subscription. In the last five years or so smartphones have become widely used in the Bekaa (as in the rest of Lebanon) with farmers checking daily and hourly weather information. This information is used to plan their agronomic practices (irrigation, ploughing, spraying). Despite the use of technology, none of the interviewed farmers use the LARI smartphone application, stating that weather and pest management information provided were too general and not customized to local conditions.

Although half of the farmers suffered from water shortages during the summer months, few expressed a true interest in learning new water management techniques to reduce their water consumption. This is explained by several factors: first, farmers have been practicing local irrigation methods, a know-how they trust, crafted on local conditions and transmitted from one generation to another. Second, they already consider to be using water efficient techniques, since most of them already switched to drip and sprinklers; third most farmers are not aware of what other techniques can be used, and the associated economic and water saving benefits to these techniques. A fourth factor is the fact that farmers suffer from many other problems that they judge more relevant (high rents, escalating prices of inputs, commercialisation issues, complete lack of extension services, etc.).

In two cases however, there was a concrete interest in learning new water management methods to reduce water consumptions and monitor water availability variations. The Director of Anjar Irrigation Committee expressed his interest in following the flow variations of Anjar spring discharge (which has significantly decreased in the past years). The Committee does not have access to the data recorded by the LRA flow meter. The director underlined the need to switch from gravity to more efficient techniques but acknowledged that farmers do not have incentives to do so. The second case concerns a very large vegetable farm (4,500 du) supplied by Karstic wells, part of which is rented with access to water to tenants. The manager of this farm underlined his worry regarding drops of water levels and increasing pumping costs (in this case pumping costs are included in the fixed rent). He was interested in techniques that would help him reducing water abstraction without compromising the yields, and in implementing water meters to incentivize tenants of using less water.

For large farmers and managers of collective schemes, water shortage is reaching a critical point pushing them to consider reducing water consumption on farm level. In this context, ICT can help with optimizing water applications without compromising yields. A recent scientific experiment conducted by LARI in the Bekaa showed that the use of a smart irrigation application (Blue Leaf) can save up to 20% of water compared to the traditional methods used by the Bekaa farmers.

3.4 Conclusions and recommendations

Unsustainable use is putting pressure on the water resources in the Bekaa, Lebanon's largest agricultural area. In order to meet the growing demand for food in a sustainable manner, improvements in water management at the national level are critically needed, as is a sound agricultural extension service in the key production areas. The potential and the need to improve agricultural water management at farm level has been highlighted through past reports and through the work reported here for the Bekaa region in particular. For farmers, problems of overirrigation, over-use of fertilizers, and use of polluted water are identified here as the main challenges, exacerbated by the absence of sound water and agricultural policies at the level of the public sector.

While the opportunity exists for significant improvement in both on-farm irrigation management and other agricultural practices (such as fertilizer use), farmers do not have the financial resources to be able to adopt the new technologies proposed through previous initiatives. Although half of the farmers interviewed suffered from water shortages during the summer months, few expressed a true interest in learning new water management techniques to reduce their water consumption. As farmers pay a flat rate water fee, the water-related financial incentives of using more efficient techniques are low; incentives to improve water use and water productivity thus need to focus instead on the potential to improve yield and on low cost interventions to reduce water consumption. Improving water productivity in the Bekaa thus needs to focus on both water savings and improved production.

As excessive use of water against the situation in the Bekaa of increasing water shortages has been identified as an issue, along with the fact that most farmers are not aware of what other techniques can be used and the associated economic and water saving benefits of these, our recommendations for both smallholder farmers and managers of collective schemes and larger farms include:

- Capacity building programs for farmers and farm managers in general concepts of water use efficiency and water productivity

- Capacity building to improve farmer understanding of the crop water requirements and the potential to improve yield through improved irrigation water application (in terms of both timing and quantity)

- Identification of low cost interventions to reduce water consumption (through improved irrigation water application) at the field level and training for farmers in the use of these

- Identification of improved agricultural management techniques (e.g. appropriate fertilizer application) to improve yields

- Capacity building in relation to the above should focus on the benefits of reducing water application on yields, and in simple, low cost solutions to achieve this which are sustainable beyond the life-cycle of the current project.

LARI was found to be actively working on communicating weather information to farmers with on-going efforts being conducted to improve and customize the Early Warning System (regarding crop diseases and extreme weather conditions) of LARI app. LARI is a public institution with decentralized offices in the different rural areas of Lebanon and have close access to the field and good knowledge of farming practices. LARI manages a large network of 35 weather stations from which only 4 are used to convey data to the app. A useful approach would consist on building on LARI's efforts and support them in upgrading and promoting their app in order for it to be more useful for farmers in practice.

Concerning irrigation for example, it should incorporate larger sets of geo-referenced weather data that would allow for calculating local Evapotranspiration and ETc for the main crops. It is also recommended to translate the scientific data in "farmers' language", i.e. giving clear and simple recommendations on how much to irrigate, using the technical terms used by farmers. A pilot experiment is recommended to assess the feasibility of this intervention both on the level of LARI and the farmers. It is recommended to be done in the Bekaa, the largest agricultural region in Lebanon and given the existence 12 weather stations managed by LARI in this region.

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Annex 1. Survey 1: Farmers (semi structured field interviews)

Date of interview:	Casa/District:
Farm location (town/village, GPS):	Irrigation source: (eg. pumping from Litani; using Anjar collective system; individual well; collective well)

I. Farmer info

1. Name ____________________

   Middle name ____________________

   Surname ____________________

2. Town of origin ____________________

3. Age ________

4. Gender

   M ☐

   F ☐

5. Education level:

   Uneducated ☐

   Elementary school ☐

   High school ☐

   University degree ☐

   Postgraduate studies ☐

II. Farm info

6. Total surface (dunum) ____________________

7. Crop types ____________________

8. Ownership:

   One owner ☐

   Several owners (specify number) ☐ ________

9. Rented land:

Contract length (in years) ___________

Name of landlord __________________

Rental type ____

10. Main water source for irrigation:

a. Rainfed ☐

b. Groundwater ☐

Aquifer (to be identified by interviewer)

____

Well discharge (inch or l/s)__________________________________

Water level/height (m b.g.l.)_________________________________

c. Surface water ☐

Pumping from River (please specify which river) ☐

____

Collective canal system (please specify) ☐

____

Please specify pump(s) capacity ____________

d. Other ____

11. Is your water source reliable?

No ☐ , please specify the reason(s)____

Yes ☐ , please specify the reason(s)____

12. What is the type of use of the irrigation water source?

- Individual pump (on rivers) ☐
- Collective pump or rented pump ☐

Please specify the type of arrangement between owner and tenant

____

- Individual well ☐
- Collective well or rented well ☐

Please specify the type of arrangement between owner and tenant

____

- Community-based spring system ☐
- Public system ☐

13. Are you member of a Water Users Association?

No ☐

Yes ☐

- please specify o Date of membership (year) __________________
- Name of WUA ____

III. Farming practices (including irrigation)

14. Agronomic practices

a. Cropping pattern/cycle

Monoculture ☐

Multiculture ☐ , please specify

	Season 1 (spring)	Season 2 (Summer)
Plot 1		
Plot 2		
Plot 3		
Plot 4		
Plot 5		

b. Do you grow crops outside of the main irrigation season?

No ☐

Yes ☐, please specify crop type(s) and irrigation source ______________

c. Fertilization method

Manual ☐

Fertigation ☐

d. What are the main problems/challenges you face in growing your crops?

Pests and diseases ☐

Water shortage ☐

Climatic conditions ☐

Water quality ☐

Quality of inputs ☐

15. On-farm irrigation practices:

a. No irrigation (rainfed) ☐

b. Irrigation system used:

- Drip ☐
- Furrow/surface ☐
- Sprinkler ☐

c. Do you face problems with your irrigation system?

No ☐

Yes ☐ , please specify___________________________________

d. Irrigation scheduling:

i. How do you plan/schedule on-farm irrigation? (please specify if water turns or rotations apply)

____

ii. Do you use technological tools for irrigation events?

No ☐

Yes ☐, please specify ___________________________________

iii. Do you use technological tools for irrigation scheduling?

No ☐

Yes ☐, please specify___________________________________

e. Crop water requirements:

i. How do you estimate your crop water requirements?

No estimation ☐

Use of traditional methods ☐ , please specify

____

Use of extension services ☐ , please specify

____

Use of technological tools ☐ , please specify

____

16. Water storage:

On-farm ☐

Other ☐ , please specify ____________________________________

17. Water metering:

- Existence of water meter(s)

  No ☐

  Yes ☐ , please specify type and location

  ____

- Purpose

  ____

18. Do you use any technological innovation in your farm?

No ☐ , please indicate reason____________________________________

Yes ☐ , please specify ____

19. Do you use the computer?

No ☐

Yes ☐

20. Is there anyone in your family who can help you use the computer?

No ☐

Yes ☐

21. Do you navigate the internet?

No ☐

Yes ☐ , please indicate what type of information related to agriculture do you seek

____

22. Do you check weather bulletin?

No ☐

Yes ☐ , please indicate the mean through which you check the bulletin

____

23. What kind of information/expertise you think you need most?

Irrigation water management (irrigation systems) ☐

Estimation of crop water requirements ☐

Water saving ☐

Crop protection ☐

Fertilization ☐

Market prices ☐

Other ☐ , please specify ______________________________

24. Which technology do you think would help you must to improve your production?

____

____

25. Do you benefit from extension services?

No ☐

Yes ☐ , please specify:

- Public ☐
- Private ☐
- Name of the institution ______________________________
- How often? ______________________________
- For what purpose? ______________________________

26. Are you in touch with any of the following public institutions? and what information do you receive from them?

- Ministry of Agriculture

  Please specify the local office location in the Bekaa ____________________

  Please specify what information you receive ____________________

  Do you trust these information? No ☐ Yes ☐

- LARI

  Please specify the local office location in the Bekaa ____________________

  Please specify what information you receive ____________________

  Do you trust these information? No ☐ Yes ☐

- Litani River Authority

  Please specify the local office location in the Bekaa ____________________

  Please specify what information you receive ____________________

  Do you trust these information? No ☐ Yes ☐

- Green Plan

  Please specify the local office location in the Bekaa ____________________

  Please specify what information you receive ____________________

  Do you trust these information? No ☐ Yes ☐

- Bekaa Water Establishment

  Please specify the local office location in the Bekaa ____________________

  Please specify what information you receive ____________________

  Do you trust these information? No ☐ Yes ☐

- Others

Please specify the local office location in the Bekaa ____________________

Please specify what information you receive ____________________

Do you trust these information? No ☐ Yes ☐

27. Are you in touch with any of the following other institution?

Please specify name and types of information you receive regarding use of technology, and whether you trust the information you receive

- Universities ______________________
- Private firms ______________________
- NGOs ______________________
- Regional office of the ministry of agriculture ______________________

28. Were you ever involved in experimental campaigns regarding irrigation management?

No ☐

Yes ☐

29. Were you provided with technological tools to better monitor water? (Tensiometer, others).

No ☐

Yes ☐ , please specify ______________________

30. Do you use a mobile phone?

No ☐

Yes ☐, please specify:

- Is it a smartphone? ______________
- Brand ______________________
- Reason(s) for choosing the brand ______________________
- Operator ______________________
- Reason(s) for choosing the operator ______________________
- Plan type: Prepaid ☐ Postpaid ☐
- Do you have internet subscription? No ☐ Yes ☐
- Do you use the internet on your phone? No ☐ Yes ☐
- How much do you pay monthly for your phone subscription? __________
- Is the service reliable?
  - No ☐ , please indicate reason(s) ______________________
  - Yes ☐

31. Do you use LARI-LEB App?

No ☐

Yes ☐

- Do you find the service helpful?

  Yes ☐

  No ☐ , please indicate reason(s) ________________________________

- How often do you read extension messages/forecast?

  Daily ☐

  Weekly ☐

  Monthly ☐

  Seasonally ☐

32. What information services provided through mobile do you think would help you with agriculture?

____

____

____

____

____

33. Would you trust paying for services through your phone?

No ☐ , please indicate reason(s)________________________________

Yes ☐

Annex 2. Suvey 2: WUA-Decentralized Irrigation Groups, Irrigation Authorities, Irrigation Scheme Managers

Date of interview:	Location:

Personal information

1. Name ____________________

   Middle name ____________________

   Surname ____________________

2. Name of institution/WUA (if member) ____________________

3. Position ____________________

4. Hire date/date of membership ____________________

5. Professional status

   Permanent staff of public institution ☐

   Daily contractor (mouyawem) ☐

   Other ____________________

   Who pays your salary?

   ____

6. Age ________

7. Gender

   M ☐

   F ☐

8. Education level:

Uneducated ☐

Elementary School ☐

High school ☐

University degree ☐

Postgraduate studies ☐

I. General information related to the irrigation scheme command area

9. Total surface (dunum) covered ____________________

10. Number of farms covered ____________________

11. Number of farmers ____________________

12. Main crop varietie(s) ____________________

13. Water source(s) for irrigation:

    a. Rainfed

    b. Groundwater

    Aquifer (interviewer)

    ____

    c. Surface water

    Pumping from River (please specify which river) ____________________

    Collective canal system (please specify) ____________________

    d. Other ____________________

    e. Proportion of water use per source (% or volume)

    Rainfed ____________

    Groundwater ____________

    Surface water ____________

14. How reliable is(are) the water source(s)?

- Groundwater:

Not reliable ☐ , please indicate reasons and corresponding period

____

Reliable ☐ , please indicate reasons and corresponding period

____

- Surface water:

Not reliable ☐ , please indicate reasons and corresponding period

____

Reliable ☐ , please indicate reasons and corresponding period

____

15. What is the type of use of the irrigation water source in the scheme?

Individual pump (on rivers) ☐

Collective pump or rented pump ☐

Individual wells ☐

Collective wells ☐

Community-based spring system ` ☐

Public system ☐

16. Is there any water storage in the scheme?

No ☐

Yes ☐ , please specify type and location ______________________________

II. Water management information

17. How do you monitor water use at the level of the scheme?

- Flowmeters ☐ ,please specify type and location within the scheme

  Digital with data logger ☐

  Digital with online/GSM transmission ☐

  Digital without data storage ☐

- Spring ☐
  - Main canal ☐
  - Secondary canals ☐
  - Drainage canals ☐
- Visual monitoring of water levels in the reservoir ☐

18. By whom (public institution(s), NGOs, others) were they put in place?

____

19. How do you monitor water use on farm level

No monitoring ☐

Yes ☐ , please specify type (digital or manual) and location ____________

20. Do you consider that water meters are useful for water management in your scheme?

No ☐

Yes ☐ , please indicate reason(s)

____

21. How do you assess agricultural water demand at scheme scale?

- No assessment ☐
- Estimation based on local, traditional knowledge

(based on climatic observation for example) ☐

- Based on in-house land use/cropping pattern maps and climate data ☐

22. Who provides the expertise to assess agricultural water demand?

- Own expertise ☐
- With the help of research institutions or NGOs ☐ , please specify____________
- With the help of private experts (consultants) ☐ , please specify____________

23. Would you like/need to have more expertise in this area?

No , please indicate reason(s)____

Yes , please indicate reason(s)____

24. Are you familiar with these terms? How do you understand them?

- Water efficiency

  a. Plant level

  ____

  b. Field level

  ____

  c. Basin or scheme level

  ____

- Water productivity

a. Plant level

____

b. Field level

____

c. Basin or scheme level

____

25. What interventions do you practice, or you would like to practice, to increase water use efficiency and water productivity?

a. At scheme level

- Canal lining ☐
- Monitor canal operation ☐
- Cropping calendar (constraints on certain crops, keep fallow lands) ☐

b. Farm level

- Constrain farmers on using more water efficient technologies (sprinker, drip) ☐
- Impose fines on famers that are provoking water losses ☐
- Raising awareness ☐

26. Do you consider that you need more expertise/tools in this area?

No ☐

Yes ☐

27. Which measures are implemented in a dry year?

____

____

____

____

28. Do you provide extension services to farmers?

No ☐

Yes ☐ , please indicate which ______________________________

29. How do you communicate/transmit information to users? Please indicate frequency

Public Meetings	☐	Frequency ______________
Public announcement	☐	Frequency ______________
Phone call	☐	Frequency ______________
SMS	☐	Frequency ______________
Texting and voice apps (e.g. Whatsapp©)	☐	Frequency ______________
Social networks	☐	Frequency ______________
Informal discussion (de bouche à oreille)	☐	Frequency ______________

30. Do you consider you need expertise in other areas of irrigation, water management and/or agricultural production?

No ☐ , please indicate reason(s) ______________________________

Yes ☐ , please indicate which ______________________________

III. Access to information related to ICT

31. In your opinion, what are the crucial information required to be able to manage water more efficiently in your scheme?

____

____

____

32. What are the missing information in your case?

____

____

____

33. Which ICT tools would be helpful to you?

Sensors for climatic data ☐

Sensors for flow monitoring ☐

Sensors for water level ☐

Remote sensing hardware and software ☐

GIS for crop use maps ☐

Soil moisture sensors ☐

None of the above ☐

Other(s) ☐ ____

34. Who do you think should provide you with these tools? Ministry of Agriculture

Ministry of Energy and Water ☐

Bekaa Water Establishment ☐

NGOs ☐

Research centres and universities ☐

35. Are you in touch with universities regarding this topic or others topics related to water management and agriculture?

No ☐

Yes ☐

Please indicate the name of the institution _______________________________

Please specify what information you receive _______________________________

Do you trust these information? No ☐ Yes ☐

36. Are you in touch with NGOs working in agriculture development and/or water management?

No ☐

Yes ☐

Please indicate the name of the NGO _______________________________

Please specify what information you receive ____________________________________

Do you trust these information? No ☐ Yes ☐

37. Did you ever conduct or participate in experimental campaigns or pilots regarding irrigation management? Please indicate whether it included the use of technological tools and usefulness

No ☐

Yes, with use of technological tools ☐

Yes, without use of technological tools ☐

Stakeholder mapping and needs assessment, Lebanon

Given the scarcity of land and water resources, global strategies to increase food production should focus efforts on increasing production per unit resources, i.e. the combined increase of production per unit land surface (yield expressed in kg/ha) and the increase of production per unit water used (water productivity expressed in kg/m³). The FAO portal to monitor WAter Productivity through Open access of Remotely sensed derived data (WaPOR) uses satellite information to compute and map key variables related to water and agriculture, such as evapotranspiration, biomass production, and water productivity. The provision of near real-time information through such open access data portal enables a range of service providers to assist farmers to attain more reliable yields and to improve their livelihoods; irrigation operators have access to new information to assess the performance of systems and to identify where to focus investments to modernize the irrigation schemes, and government agencies will be able to use the information to monitor and promote the efficient use of natural resources.

This report presents the work undertaken to identify key stakeholders in the agriculture and Information and Communication Technologies (ICT) sector and the capacity needs of farmers to improve water productivity in a sustainable manner, through two components; the first surveys the role and capacities of various stakeholders in the ICT and agriculture sector in Lebanon, and the second presents and analyzes the results of a survey into the capacity needs of farmers in relation to the use of ICT in agriculture in the Bekaa valley.

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