Lebanese Agriculture
Research Institute

ClimaSouth
Technical Paper 1

EARLY WARNING SYSTEM IN THE BEQAA VALLEY, LEBANON

Needs Assessment

May 2016

Low carbon development
for climate resilient societies

A project funded by
the European Union

EARLY WARNING SYSTEM IN THE BEQAA VALLEY, LEBANON

Needs Assessment

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LIST OF ACRONYMS

AWS: Automated Weather Station

CC: Climate Change

DIAM: Department of Irrigation and AgroMeteorology

ENPI: European Neighbourhood and Partnership Instrument

EWS: Early Warning System

IEWCS: Increasing Farmers Resilience through Early Warning and Advisory Climate Service

GDCA: General Directorate of Civil Aviation

LARI: Lebanese Agriculture Research Institute

LMS: Lebanese Meteorological Service

MOA: Ministry of Agriculture

MOE: Ministry of Environment

MOPWT: Ministry of Public Works and Transport

SNC: Second National Communication

TNA: Technology Needs Assessment

UAA: Utilised Agriculture Area

EXECUTIVE SUMMARY

BACKGROUND: CLIMASOUTH PROJECT

Under the ENPI, Lebanon is benefiting from ClimaSouth, a regional European Union funded project tackling climate change. More specifically, the project is intended to:

- reinforce dialogue and cooperation on climate change between the European Union and the Southern and Eastern Mediterranean countries.
- support the transition of partner countries towards low carbon development and climate resilience, in a context of sustainable and democratic development.
- enhance regional cooperation, information sharing and capacity developments on climate change mitigation and adaptation, between the European Union and its Mediterranean neighbours.

The first meeting of the Steering Committee of the Project ENPI ClimaSouth, held in September 2013 endorsed the principle of a national activity by countries in the field of mitigation or adaptation to climate change (CC) to meet the needs expressed by partners, and within the Second National Communication (SNC) and Technology Needs Assessment (TNA) reports (MOE, 2010, 2012).

The original proposal of 'Increasing Farmers Resilience through Early Warning and Advisory Climate Service' (IEWCS) was the result of an initial field mission (Feb. 18th – Mar.2nd 2013) in addition to the needs expressed by Lebanese stakeholders. This proposal was described in a fact sheet that was approved by the Lebanese focal point, and shared furtherer with national concerned stakeholders as the Lebanese Agriculture Research Institute (LARI) and the Lebanese Meteorological Service (LMS) to collect their advice in to improve and update this proposal.

Initially, LARI has already developed a basic early warning system (EWS) to support farmers to improve their resilience to CC through better management of the impacts of climate variability on their activity. This adaptation measure to CC was meant to provide an agro-meteorological support- to share meteorological information via SMS. By 2015 this outreach system shifted from SMS to smartphone application and website and the subscribers to this service increased from 2,000 to more than 14,000.

After the elaboration of IEWCS proposal, bilateral meetings and discussions amongst Lebanese key partners (the project focal point, LARI and LMS) and the ClimaSouth project led to the identification of the following priorities for the national activities under the IEWCS:

- training to enhance the LARI early warning irrigation system
- training to improve forecasting capacity at local scale
- training for climate data analysis
- seasonal forecast training
- training to enhancing the LARI early-warning plant-protection system

The main objective of this task is to develop a detailed assessment of the LARI EWS and of the coherence between farmer demand and information provided to be a key input for the preparation of the project proposal for the enhancement of the LARI EWS, as shown in **Errore. L'origine riferimento non è stata trovata.**.

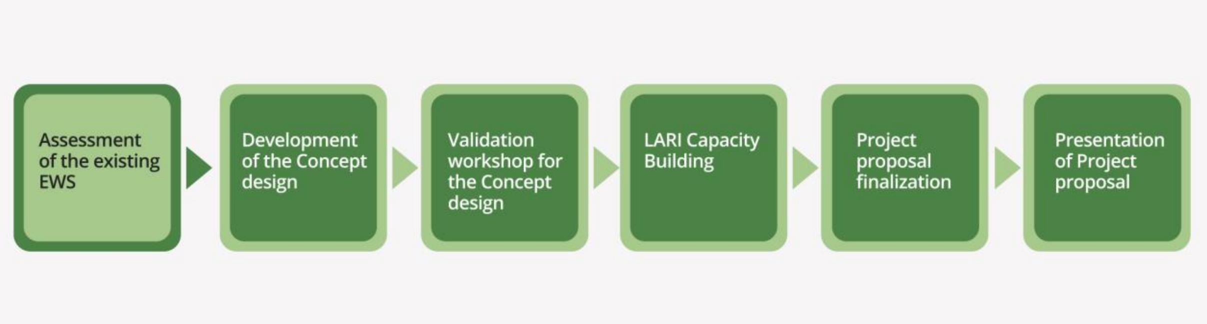

Figure 1. Series of Actions in the national activity "Project Proposal to Enhance the LARI EWS in the Beqaa Valley

The first action in this process "Assessment of the existing LARI EWS" was to:

i) Analyse the EWS under the three components:

- meteorological: stations and forecasting data are processed to track the weather evolution over a given area at an appropriate agronomic scale generating either a weather extreme event alert or a dataset for input in agro-meteorological models;
- agronomic: climate data and field data are input for agro-meteorological models (irrigation and pest management), which in turn generate agronomic data output for a specific crop to allow crop risk assessment; and
- information: crop risk assessment is transformed in information products apt to allow farmer to take a decision; the information product should be in format and content appropriate for a specific crop and for a specific typology of farmer and on time for farmer action.

ii) Evaluate farmers' reactivity to the transmitted information in terms of content and format.

METHODOLOGY OF WORK

In order to analyse the three components of the EWS, the assessment relied on direct interviews and meetings with the key partners of the project.

As for the farmers' responses, we conducted a field survey with 100 farmers distributed along the Beqaa Valley. Descriptive statistics were further used to analyse the results.

Based on the series of meetings and the results of the field survey, we developed sections 4, EWS priorities and needs of the Beqaa region.Sustainability of EWS in Lebanon

In particular, the assessment thoroughly reviewed the following information as per the terms of reference:

- the LARI meteorological station network in the Beqaa Valley: stations models, data collected and format, validation procedure, length of data series, data-acquisition procedure, data storage and retrieval, data processing, LARI human resources and equipment;
- LMS forecasting: data provided and format, integration procedure for collected data and forecasting data, agrometeorological data set, timing for data set availability;
- crops monitored, water stress and pest management farmer strategies, tools, techniques and simulation models for the evaluation of water stress and pest risk, data, and information produced;

FORMAT OF INFORMATION PRODUCTS FOR DIFFUSION TO FARMERS

- farmers' characteristics;
- response from farmers and actions taken by farmers; and
- efficiency of the mechanism to allow farmers' demand for information to reach LARI and to facilitate LARI and interaction by farmers.

1. CONTEXT

1.1 MAJOR CROPS AND THEIR ECONOMIC IMPORTANCE

According to the Agricultural Census 2010, the total agriculture land area in Lebanon is estimated at 332,000 hectares, of which 231,000 hectares are cultivated (almost half, 113,000 hectares, is irrigated), with an average land holding size of 1.36 hectares (1.23 hectares for irrigated holdings). Around 41% of the utilised agriculture area (UAA) is located in the Beqaa Valley with its two districts: Baalbeck-Hermel and Beqaa.

Agriculture and food products exports witnessed a remarkable improvement during the period 2010-2013, registering an increase of 4.02% between 2011 and 2012, and 17.74% between 2012 and 2013. The slow growth is attributable to the Syrian crisis as 50% of the total agricultural products were exported to Syria or through Syria to other Arab countries and the Gulf States (2010), while a figure of just 35% was recorded in 2013. Consequently, agriculture in the Beqaa faces difficulties.

The 2010 agricultural census showed that there are 170,000 farmers or holders, the average age of which is 52 years and half of whom depend exclusively on agriculture for their livelihoods.

1.1.1 PERENNIAL CROPS

Pome fruits (apple and pear) are planted mostly in the Baalbeck-Hermel district. The area of plantation in the Beqaa Valley reached 4,575 hectares or 32% of the national cultivated area. Apples are largely predominant, covering 4,216 hectares. The Red Delicious group constitutes the majority of the production, followed by Golden Delicious, Granny Smith, etc. Contrastingly, the Coscia is by far the major pear cultivar, followed by California, Comice, Louise-Bonne, etc. All pome fruits are irrigated. Apples are an exportable crop; however, due to the Syrian crisis, the export routes have been disrupted.

Stone fruits (almonds, apricots, cherries, plums, peaches and nectarines) are widely planted in both districts of the Beqaa. The Baalback-Hermel district alone has more than half of the nation's total area of production. The total cultivated area in both districts is 15,418 hectares. Apricots are almost exclusively produced in Baalbeck-Hermel. Orchards benefit from irrigation, and most cultivars are local. Almonds are rain-fed and mostly planted in Baalbeck-Hermel. Cherry follows the same trend, even if this crop may benefit from some irrigation in certain areas. Most cultivars are local. Plums are the least cultivated in the Beqaa Valley amongst stone fruits, while both districts embed half of the area cultivated with peach and nectarine at national level. They are evenly distributed between Baalbeck-Hermel and Beqaa districts. Plums, peaches and nectarines are irrigated, thus benefitting from a massive introduction of new cultivars. A small percentage of stone-fruit production is exported.

Grapevine is a major economical crop for the Beqaa. The area of production is 7,640 hectares, or 72% of the national cultivated area. Vineyards for industrial use (wine, arak) constitute 30% of the total area of production, mostly in the Beqaa district, while table grapevines are almost evenly distributed between both districts. Table grapevines benefit from irrigation and are raised on pergolas, while industrial grapevines are rain-fed. The latter is showing a continuous increase trend in exportation of wine.

Olive tree has been recently growing in importance in the Beqaa Valley. In the north dry areas of Baalbeck-Hermel, it's irrigated, whereas it's rain-fed in the southern parts of the valley. Olive grows are less than 7000 hectares, and constitute 13% of the nation's total area of production.

1.1.2 FIELD CROPS

The major field crops in the Beqaa Valley are cereals (mostly wheat, followed by barley and, to a lesser extent, corn). They cover a UAA of 30000ha, or 65% of the country's total cereal-grain production area. Most of cereals are rain-fed, or benefit from supplementary irrigation (12,800 hectares, mostly in Beqaa Mohafaza (district)). Most cereals are planted in crop rotation with each other, with legumes, potato, or vetch.

Vegetables are mainly produced in the Beqaa districts. Vegetables include leafy vegetables and fruit vegetables. The UAA dedicated for these crops is around 24,000 hectares (60% of the national UAA for vegetable production). Leafy vegetables (cabbage, lettuce, cauliflower, parsley, artichoke, etc.) are mostly produced in the Mohafaza of Beqaa while fruit vegetables (tomato, cucumber, watermelon, melon, eggplant, bell pepper, etc.) are mostly cultivated in Baalbeck-Hermel. The majority of vegetables are irrigated, and approximately 18% is in greenhouses or tunnels; however, this share is insignificant in the Beqaa. Vegetables are cultivated either following a rotation or in monoculture.

Potato remains economically the most important field crop in the Beqaa, with almost 7,800 hectares, or 70% of the nation's total area of production. About 10% of the production is dedicated for the industry, while the monoculture of the cultivar Spunta characterizes the production for domestic consumption. Potato production has been improving and yields reach 60t/ha, due to appropriate crop rotations, and improvement of irrigation techniques and other agriculture practices. A share of the production is exported; however, with a diminishing trend due to the export route disruption in Syria.

1.1.3 IRRIGATION SCHEMES IN THE BEQAA

Almost half of the UAA in the Beqaa is irrigated (31,700 hectares in Baalback-Hermel and approximately 30,000 hectares in Beqaa, according to the agriculture census of 2010). Drip irrigation is predominant, while sprinkling is used for field crops such as cereals, legumes, fodder crops, and potatoes. Two-thirds of the irrigated schemes rely on underground water and the reaming is covered by surface water from natural springs and rivers (Figure 2). In western Beqaa, part of the water is supplied by the channel 800m from the Litany River Authority. The water is supplied through open air channels, which hinders the development of pressurised system. Water meters are absent in the Beqaa. As a result, water efficiency is less than 50% in the Beqaa, as water losses occur in open channels (evaporation, leakage), in irrigation system practices (sprinkler system, surface irrigation), and the inadequate farmer practices regarding the frequency and quantity of irrigation. In fact, irrigation schedule and quantity is ruled by fixed calendars and the amount of available water rather than by the nexus crop and climate water demand and soil characteristics.

For instance, one hectare of potatoes, for which water demand in central Beqaa is estimated as being between 5,000 and 6000m^3, would consume approximately 10,000m^3 of irrigation water. With a continuously lowered water table, increased shortage in surface water, farmers are forced to improve water efficient use at farmer level or to pay an increasing bill for pumping. The efficiency of irrigation for winter crops such as barley and wheat is even lower.

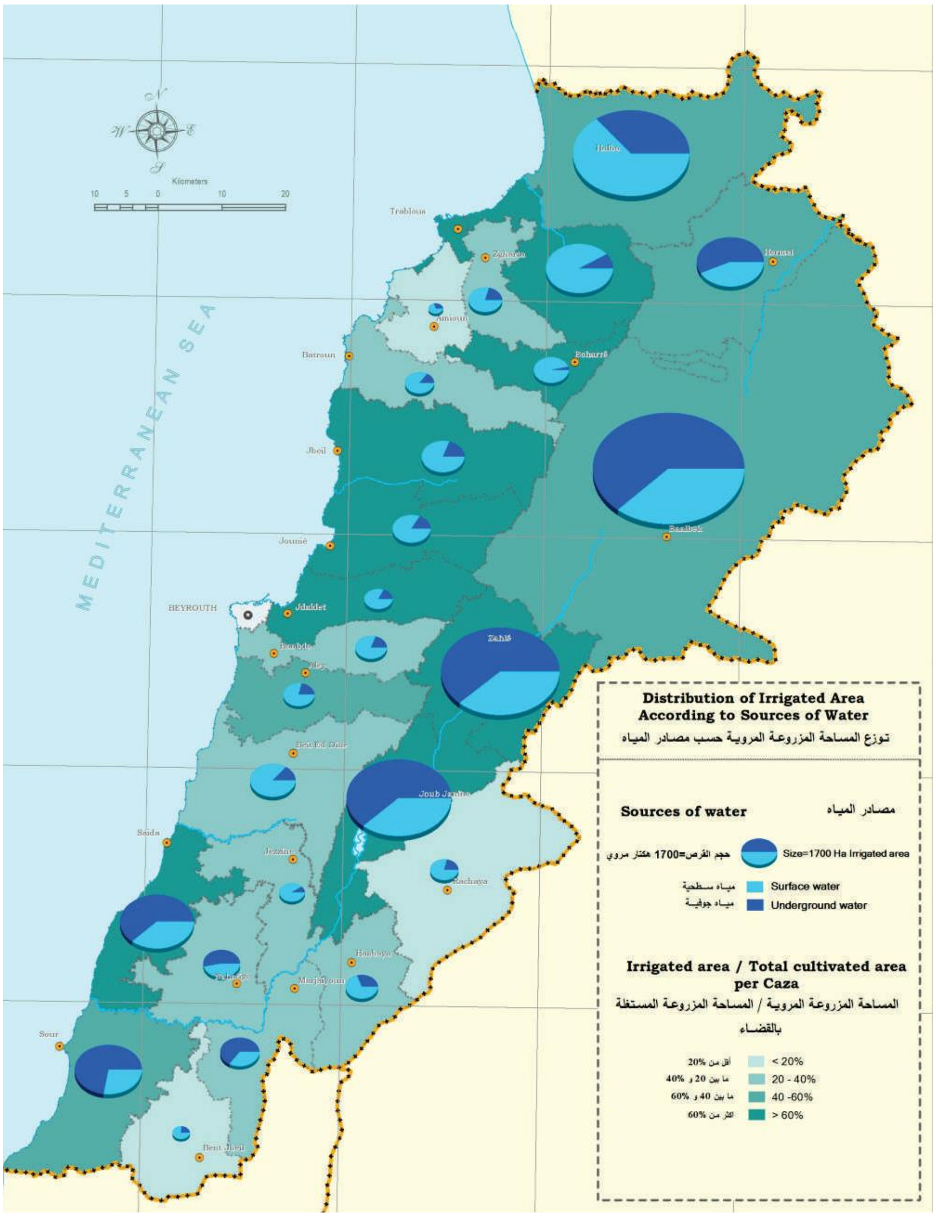

Figure 2. Distribution of irrigated area according to resource of water (Agriculture Atlas)

Note: The figure shows that irrigated crops percentage is also high in other districts, particularly northern Mount Lebanon, and the southern coast. Similar rates exhibiting low water efficient use are noticed in these zones. In Mount Lebanon and the North, irrigated fruit *orchards (apple, pear, peach, plum, etc.) are predominant, while citrus and bananas prevail in the south.*

1.2 MAJOR CLIMATE-DRIVEN RISKS IN THE BEQAA REGION

1.2.1 CLIMATE EXTREMES

The SNC described the foreseen climate variability for Lebanon, following the IPCCC scenarios. Amongst the results, drought will increase due to an expected reduction of annual rainfall by 20% to 40%, coupled by an increase in annual average temperature by 1˚ to 4˚C by the end of the century. The drought period is expected to increase by two weeks. Extended and recurrent drought will have a direct impact on rain-fed annual crops; however, the most vulnerable crops will be irrigated fruit trees.[2]

Heat waves are expected to increase in frequency and intensity causing seasonal abnormalities of temperature. Heat waves can damage pollination and fruit setting for fruit trees (cherry, apple) and fruit vegetables (tomato), as well as the leaf development for leaf vegetables.

Frost is common in Beqaa; however, the risk of spring frost may be exacerbated due to CC and result in direct damage to all crops.

Flood risk is higher on the lower basin of the Litani River. With expected increase with climate extremes, floods are likely to increase in frequency and intensity, causing direct damage to winter crops.

Flash floods are periodical but rare and occur in spring in the northern Beqaa, in the downstream of dry creeks of the Anti-Lebanon. However, they cause physical damage to agriculture summer crops.

1.2.2 PEST OUTBREAKS: INSECTS AND DISEASES

Pest outbreaks aren't necessarily climate-driven, and can occur due to a complexity of factors including bad agriculture practices such as monoculture of vulnerable cultivars, the trade and plantation of infested seeds and seedlings, the misuse of pesticides and fertilizers, the destruction of the habitat of natural predators, etc.

However, climate plays an important role in increasing the frequency of these outbreaks. Amongst these outbreaks, we mention the wheat brown and yellow rust that are frequent in the Beqaa and can jeopardize the production of this strategic crop.

[2] MOE/UNDP. 2011. Second National Communication to Climate Change for Lebanon.

In wet springs with late rates, additional serious disease can cause important economic losses for different crops in the Beqaa; these include apple scab and fire blight on apples, and downy mildew on grapevines, which were observed in spring 2016.

<u>Note:</u> *Outside Beqaa, some diseases are more frequent and induce more damage on crops (i.e., apple scab and fire blight on apple in Akkar, North Lebanon and Mount Lebanon). Late blight can cause severe damage to potato production in Akkar.*

2. CURRENT SITUATION OF EWS IN LEBANON

2.1 ROLE OF LMS IN WEATHER FORECAST AND EWS

The Lebanese Meteorological Service (or department) is under the General Directorate of Civil Aviation (GDCA) within the Ministry of Public Works and Transport (MOPWT). It is located within the headquarters of the GDCA at Beirut Rafik Hariri Airport. The mission of LMS is "observing and understanding weather and climate, and providing meteorological, hydrological and related services in support of relevant national needs". These needs are well defined and include:

- Protection of life and property
- Safeguarding the environment
- Contributing to sustainable development

Promoting long-term observation and collection of meteorological, hydrological and climatological data, including related environmental data

- Promotion of endogenous capacity building
- Meeting international commitments
- Contributing to international cooperation[3]

The LMS is structured into three divisions:

(i) the Forecasting Division, which encompasses the EWS;

(ii) the Observation Division, which measures and monitors miscellaneous weather parameters;

(iii) the Climatology Division, which is responsible for archiving and analyzing climatic data.

The LMS has currently a major legal constraint which hinders the recruitment of technicians in order to improve the services of the department. The LMS was dissolved in order to be replaced by a higher committee for meteorology; nonetheless, the latter was never created or put into action for different political reasons. Currently the LMS is a *de facto* entity which keeps providing the minimal possible of the national needs mentioned above.

[3] http://www.dgca.gov.lb/index.php/en/meteo-en

The LMS, which has currently 40 technicians, isn't able to conduct the additional recruitments which are necessary in order to fill the vacancies of the department, which comprises 129 positions.

Under those circumstances, the department head sees that the LMS can have a complementary role in agriculture EWS, even though this activity is within its original mandate (protection of lives and properties, safeguarding the environment, etc.).

This role can be resumed in the information dissemination of climate risks, through media or direct contact with concerned stakeholders (email or phone text message).

Precisely, the LMS can forecast weather with three days with confidence and four additional days with less confidence.

The LMS is currently measuring a series of weather parameters including: temperature, wind velocity and direction, relative humidity, precipitations, snow pack, etc. ETP was removed due to the lack of adequate technical, human and financial resources. In collaboration with LARI, soil surface and in depth moisture and temperature were also measured. Unfortunately soil moisture and temperature sensors were damaged by rodents, and these parameters are no longer measured.

LMS has in total 35 stations, including seven in the Beqaa: Zahle, Dahr el Baydar, Rayaq, Hermel, Deir el Ahmar, Qaraaoune and Kfar Qouq. In addition, there is one damaged station in Douris. Some stations require upgrading, spare parts, and other maintenance requirements.

In addition, LMS is currently seeking to procure two radars, in order to improve the estimates regarding the forecast of amount of rainfall, continuously and nationwide. This will improve the confidence of forecast and estimation to 80%. Nonetheless, such equipment costs more than 1 million USD. The process is being slowed down due to the lack of funds.

Collaboration between LMS and LARI is possible, when it comes to installing meteorological stations for LMS in LARI stations. Climatic data for these stations can be shared. However, data sharing in general (other stations and stored data) is hindered by legal constrains; LMS can't provide LARI EWS with climatic data, as these information is priced by law.

The forecast messages are partially given to concerned stakeholders (approximate information), namely for the media. Nevertheless, if there is a climate induced risk, the information is disseminated to media as well as to the Disaster Risk Management Unit at the Prime Minister cabinet.

Initially, the LMS has the mandate to send early warning messages, but due to the limitations in terms of human resources, and limited experience of the existing staff in agriculture, they don't currently provide such service. Hence, the LMS can't provide LARI with climatic information due to legal constraints. If those legal constraints are eliminated, the LMS can provide LARI with climate data, but not disseminate technical messages or measures to farmers.

2.2 LARI ACTUAL EWS

The EWS at LARI is managed by the Department of Irrigation and AgroMeteorology (DIAM), although EWS is a cross-cutting topic for different departments (irrigation, phytopathology, etc.)

The process for releasing an early warning goes through the following system (Figure 3):

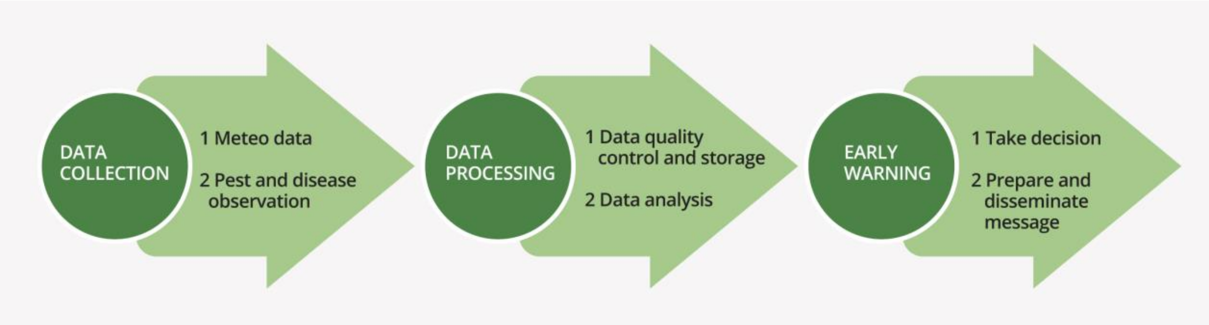

Figure 3. Early-warning process at LARI

If data collection and data processing are conducted by the concerned departments, the early warning message is released only by the Irrigation and Agro-meteorology department (DIAM). In the following sections we will describe the EWS process, the available infrastructure and technical and human resources.

2.2.1 DATA COLLECTION

LARI has 53 automatic weather stations (AWS) distributed nationwide, with 17 in the Beqaa Valley as shown in Figure 4. Among these we cite: Tal Amara, El Kaa (two stations), Ras Baalback, Jabbouleh, Mansoura, Douris, Btedii, Mcheytiyeh, Kfardan, Talia, Haouch Omara, Terbol, Bar Elias, Ammik, Khorbet kanafar, and Saghbine. Out of the 53 stations, only 35 stations provide continuous data, due to the quality of the existing stations that aren't heavy-duty (PESSL model iMETOS 2 and 3). PESSL stations software are designed mostly for autonomous farmers who would like to have their own stations, but therefore not optimal for an advanced EWS. These stations may suffer from reception problem, stop functioning when it snows, and require periodic maintenance and battery substitution.

All stations measure multiple climatic parameters including temperature, wind speed and direction, relative humidity, atmospheric pressure, total solar radiation and precipitations. In 20 stations, soil moisture and temperature are also measure, as in the remaining stations, instruments were damaged by rodents. In major stations. (For example, the Class A station of Tal Amara in the Beqaa leaf wetness and ET_0 are also registered. ET_0 measurement requires accuracy assessment as confirmed by officials.)

LARI is launching currently a bidding process to procure five additional AWS nodes of a higher-quality brand. One of these stations will be installed in Tal Amara; this would allow to compare data generate by both stations, in order to assess their accuracy/error.

One full-time contracted technician is responsible for the maintenance of these stations (one visit/month/station). In addition, there are eight to 12 technicians that are responsible over these AWS, each in his region. Nonetheless, these technicians aren't qualified, nor are their terms of references clear in regards to the maintenance of the stations, which reduces the effectiveness of their supervision and maintenance over those stations.

LARI disposes of a bench for the reparation and maintenance of the AWS. Yet, it requires upgrading and an electrician is necessary to operate it. Spare parts are procured through annual bidding process, following a predefined tender dossier for the spare parts.

The institute has also direct communication with mobile providers in Lebanon; LARI recharges GPRS SIM on yearly basis, through a procurement process.

These stations are linked to PESSSL and DACOM software in order to provide weather forecasts, and, beginning in June 2016, to METEOS software as well.

LARI relies on its own AWS to provide weather forecast messages for the general public through its website and application (free smartphone application).

Data collection for pest and disease outbreaks is collected by the fruit trees and the phytopathology departments in Tal Amara (for pests and diseases respectively).

Data related to insects is collected by traps for insects or through direct observation. These are distributed within the Beqaa (and other regions, where other departments are involved). Nonetheless, traps and observation cover neither all of the Beqaa nor all the existing pests on different crops. The major insects include the Mediterranean fruit fly, olive fly and olive moth, apple codling moth, *Tuta absoluta* on tomatoes, suna-bug on wheat, grape worms, etc.

As for diseases, data collection is divided into two categories:

- Climate-related diseases, where temperature relative humidity, leaf wetness, precipitation are taken from the Class B stations. These include apple scab, potato phytophtora, grape mildew, fire blight, etc.

- Non-climate-related diseases, such as verticilium, fusarium, rely on direct observation in the field.

Quarantine pests (and diseases) require continuous monitoring on the border ports, in nurseries and in the field.

Currently, only six technicians are involved in data collection for pests and diseases (including staff from Fanar).

Regarding data collection for irrigation (crop water demand) is currently unavailable, due to the lack of essential information at local scale; data regarding ET_O, soil temperature, soil moisture, soil texture, are needed, in addition to the type of cropping system (crops, cultivars, density of plantation, plantation calendar, etc.). A field trial was conducted with four farmers, using AQUACROP. However, the results were not encouraging; the high variability of soil, climate, crop and agriculture calendars makes the EWS for irrigation (water demand) very complex, in turn making it difficult to provide AQUACROP with the required information to run the model. To counteract this, the experts tried to follow the crop stages and record results using ET_o computation through AWS or Class A pan. Only two researchers are dedicated to this task.

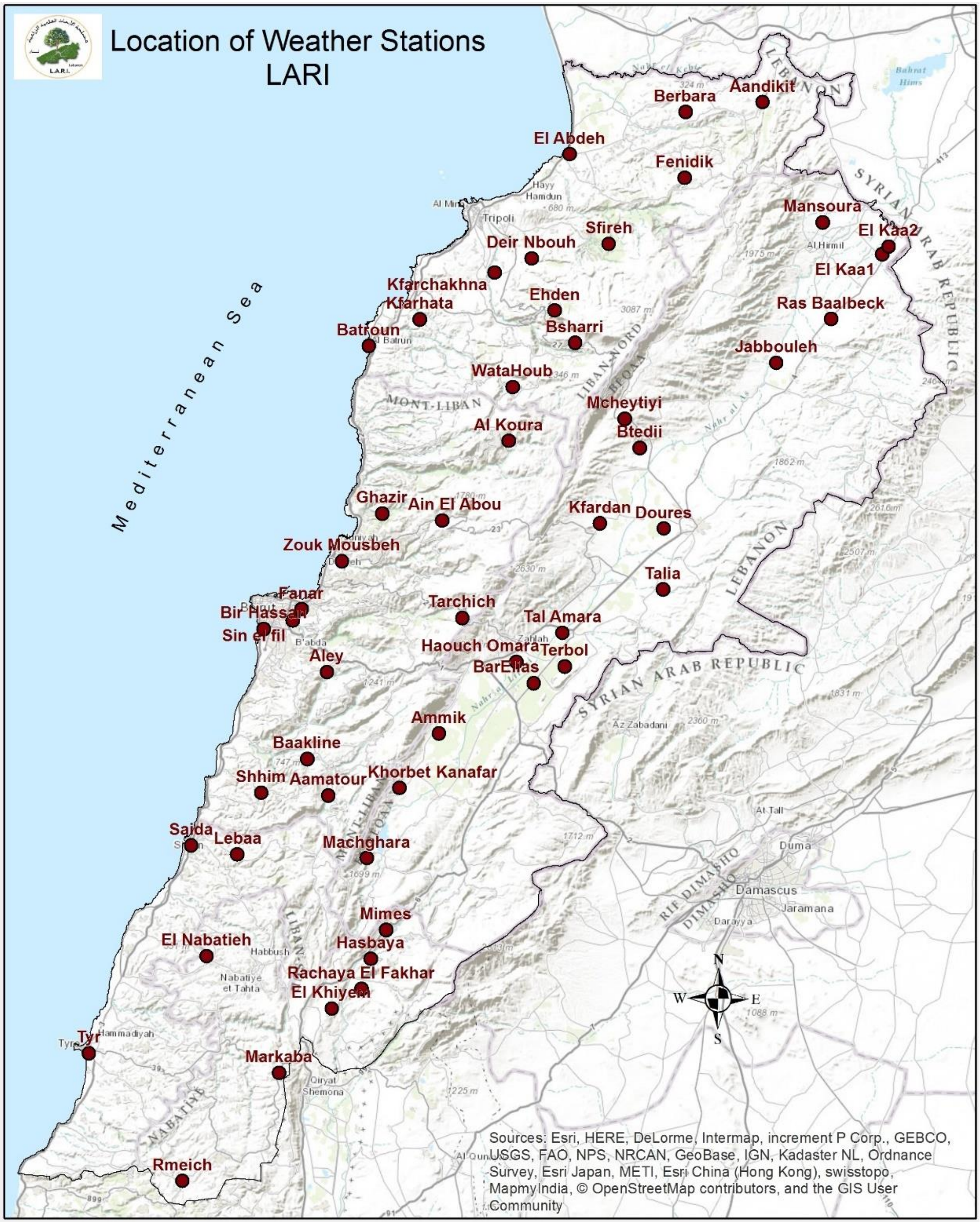

Figure 4. LARI AWS in Lebanon (source: Department of Irrigation and AgroMeteorolog; map prepared in 2015)

2.2.2 DATA PROCESSING

Climatic database is transferred directly to PESSL web service (www.fieldclimate.com). Hence, in order to access the database, and conduct quality control and processing, LARI climatology DIAM has to login to the website for data retrieving and storage. The responsible of the AWS accesses the database through PESSL web service. One technician is responsible to put the data in Excel format for offline use, in case data is needed for further study. Another technician runs data check and control, using Excel.

Data collected from the AWS is examined, to verify the quality of the data and the absence of technical problems during data measurement, and eventual outlying values. An initial check is conducted by the responsible of each station, and further also by a dedicated technician at the central level within DIAM in Tal Amara. Quality control does not rely on any software or program, but rather on the expertise of the staff.

Table 1. Types of messages delivered by the LARI app

LARI APP
The LARI application is a smartphone application which, on a daily basis, sends to farmers, fishermen, citizens, etc.: 1- weather forecasts for up to four days to a maximum of 10 days 2- updates of cumulated rainfall amounts (after every rainy day) with comparison on mean and previous rainy seasons 3- recorded maximum and minimum temperatures 4- alerts regarding heat waves for farmers, suggesting them to irrigate 5- alerts to farmers before expected frost, and suggesting to farmers to do practices to reduce the risk 6- windstorm alerts for farmers, fishermen, etc.

The actual technician in Tal Amara isn't qualified (in terms of climatology or data control) and therefore requires supervision from the department head.

AWS data is sent to the PESSL database, the technician (responsible of the AWS) in the region (or at central level in Tal Amara) downloads an Excel file of data, check it. Quality control is conducted in Tal Amara, where data from all stations are gathered in Excel format.

For weather forecasting, data is evaluated by the department head, in order to elaborate the EWS message as the institute doesn't rely only on the web service of PESSL (since DACOM and METEOS are also linked for weather forecast). Weather forecasting is generated for four to 10 days at the most, using the data of the four main AWS nodes around the country (Tal Amara, Abdeh, Fanar and Tyre).

As for pest outbreaks, no analysis is required, and the warning is released based on direct observation (i.e., presence or not; percentage of damaged leaves or fruits if an economical threshold is set). Evaluation is conducted by 3 to 4 experts (in entomology and horticulture) of the Institute.

Regarding diseases, special models or software are required in order to predict a risk of infestation. LARI procured in the past years a series of CDs for DACOM models which are dedicated for a series of diseases. Unfortunately, the models were ineffective as they were not calibrated for Lebanon, which means they gave false alerts, or did not detect any infestation when there was one. The major reason was that the model was procured, but no training was conducted for technicians in order to be able to adapt it to the local context (calibrate inputs related to type of cultivar, vegetation stage, pest life cycle, etc.). For example, the life cycle for certain pests is shorter in Lebanon than in the Netherlands, for which DACOM was calibrated. From another hand the cultivated varieties in Lebanon are different, and have different tolerance/susceptibility to diseases than those listed in the DACOM model. Consequently, the models were abandoned and the early warning for pests became only based on observation, which makes it ineffective.

2.2.3 EARLY WARNING

Experts that conducted LARI AWS data evaluation are responsible to develop the respective messages for dissemination. The messages are either of a warning/alert nature when climate extremes are expected, with preventive measures for action addressed to farmers. If the warning is related to pest or disease outbreaks, the measure can be either for control or prevention, with an eventual suggestion of pesticide active ingredients as shown in Table 2.

Once the EW message is approved or reviewed by the head of the administrative council of LARI, it's disseminated through the application by DIAM (through mobile text messages before 2015). One technician is managing the application. The process is resumed in the flowchart sotto:

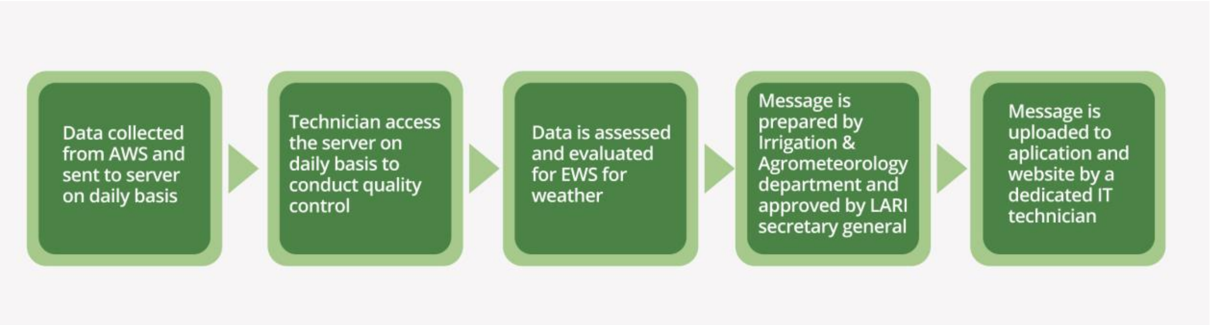

Figure 5. Flowchart for elaborating EWS by LARI (AWS collects data on an hourly basis)

2.3 LARI EWS AS SEEN BY THE FARMERS

Beginning in March 2015, the Lebanese Agriculture Research Institute developed a mobile application that provides daily information that is useful to all farmers. This information includes weather forecasts, advice in regards to irrigation periods and methods as well as alerts about pests and disease outbreaks and their respective measures of control. Until the beginning of this assessment, more than 13,000 participants were registered.

In this assessment we were interested in evaluating LARI application. We conducted a survey to evaluate the application visibility, its accuracy, its most used information, the information that farmers are most interested in receiving and eventually promoting the use of this application.

The survey methodology consisted of applied statistics analysing responses to a series of questions, of a group of individuals randomly selected from a given population (farmers of the Beqaa).

For this purpose, and due to time and budget constraints, we prepared a questionnaire of 10 questions varying between quantitative and qualitative nature, as shown in Annex I**Errore. L'origine riferimento non è stata trovata.**

We conducted personal in-home surveys and our sample consists of 100 farmers of varying ages, cultivating various crops and chosen randomly from different regions of the Beqaa. For analyzing the data obtained we used SPSS, which is a widely used program for statistical analysis in social science.

2.3.1 DESCRIPTIVE STATISTICS:

Based on our survey, farmers were distributed according to the following categories:

- 43.75% of the surveyed farmers have heard of the LARI application and use it;
- 6.25% of the surveyed farmers have heard of the LARI application but don't use it;
- 10% of the surveyed farmers haven't heard of the application but use the website;
- 10% of the surveyed farmers haven't heard of the application but after this survey they will download it;
- 30% of the surveyed farmers haven't heard of the LARI application and didn't show any intention of downloading it.

In the design of our survey, we intended to have a minimum of 40 farmers who have heard of the application (or the website: http://www.lari.gov.lb/WeatherForecast) in order to have valid statistical analysis. Therefore we can't evaluate the percentage of farmers that use the application.

However, 40% of farmers haven't heard of the application or the website, which shows that the visibility of the institute can be improved. Our survey showed that an improved visibility can increase the number of adherent farmers at least by 10%.

We believe that the 30% of farmers who haven't heard of the application or website but not interested to use them are basically old farmers, with minimal education or those who don't use smartphones.

2.3.2 FARMERS WHO HAVE HEARD OF THE APPLICATION

An estimated 65% of farmers who have heard of the application are of an age ranging between 40 and 60 years and 32.5% of an age ranging between 20 and 40 years (Fig.6) . This is coherent with the age distribution of farmers in the Beqaa, as per the Agriculture census of 2010. However, it's clear that farmers above 60 years old either have no smartphones, or simply aren't familiar with applications and how to use them.

An estimated 84.62% of farmers of a relatively young age (20-30) have heard of the application, with a decreasing trend with age. Only 25% of farmers of an age above 60 have heard of the application (Fig.7). This figure confirms the findings of the previous analysis by farmer counts according to age categories.

Among farmers who have heard of the application 32.5% grow vegetables, 20% are grapevine growers, and 15% are apple growers (Fig. 8). Farmers using crop rotation of different annual crops such as potato, onion, cereals and vegetables constitute 27.5% of the total number of farmers. If we combine farmers planting perennial crops together (grapevines, fruit trees and roses) they reach a share of 40%. Consequently, the type of cultivation does not significantly affect the percentage of farmers who have heard of the application.

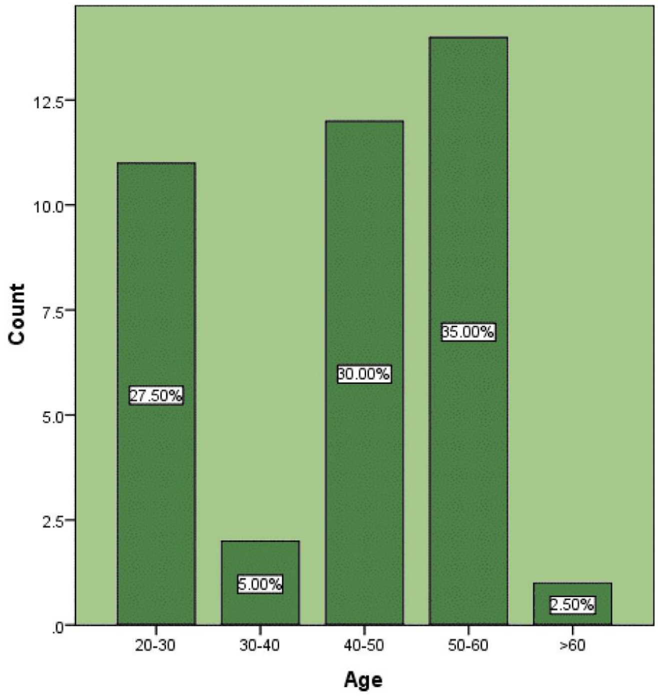

Figure 6. Age distribution of farmers who have heard of LARI application

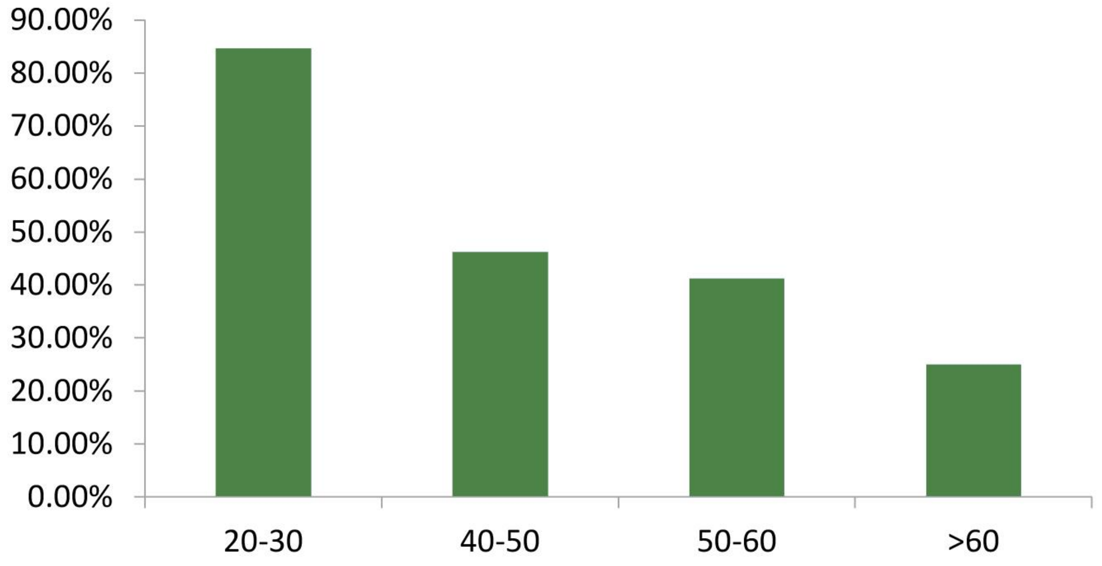

Figure 7. Percentage of farmers who have heard of the application relative to their age

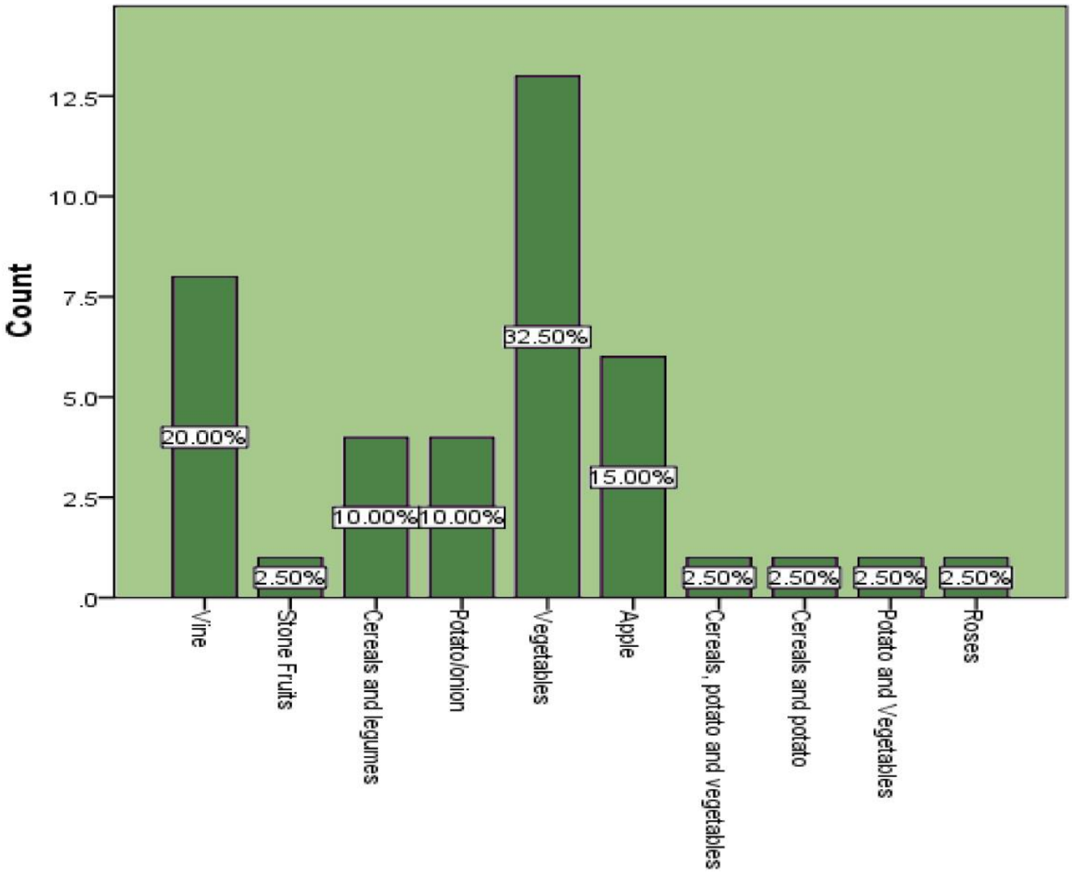

Figure 8. Distribution of farmers who have heard of the LARI application according to the crops they grow.

2.3.3 ANALYSIS OF FARMERS WHO HAVEN'T HEARD OF THE APPLICATION

About 50% of the farmers who haven't heard of the LARI application are of an age ranging between 50 and 60 years, 35% are between 40 to 50 years old, while only 7.5% of an age ranging below 40 (Fig.9). This information is important, since the average age of farmers is 52 years, based on the agriculture census. Consequently, if farmers between 50 and 60 years old haven't heard of the application, this would restrict the number of beneficiaries to the application based on the reasons mentioned above for Figure 6. Moreover, although we didn't ask the farmers about their educational backgrounds in order to avoid embarrassment, but the high percentage of farmers with minimal education in this category of age hinders the use of EWS application by many farmers. Nonetheless, many farmers who affirmed not having smartphones get their EWS messages through their children or siblings, who are more keen with this technology.

An estimated 77.5% of farmers who haven't heard of the LARI application cultivate vegetables and potato, while only 22.5% cultivate vine and fruit trees. It is obvious that farmers growing permanent crops are keener to get EWS information as they are more vulnerable to climate extremes (Fig.10).

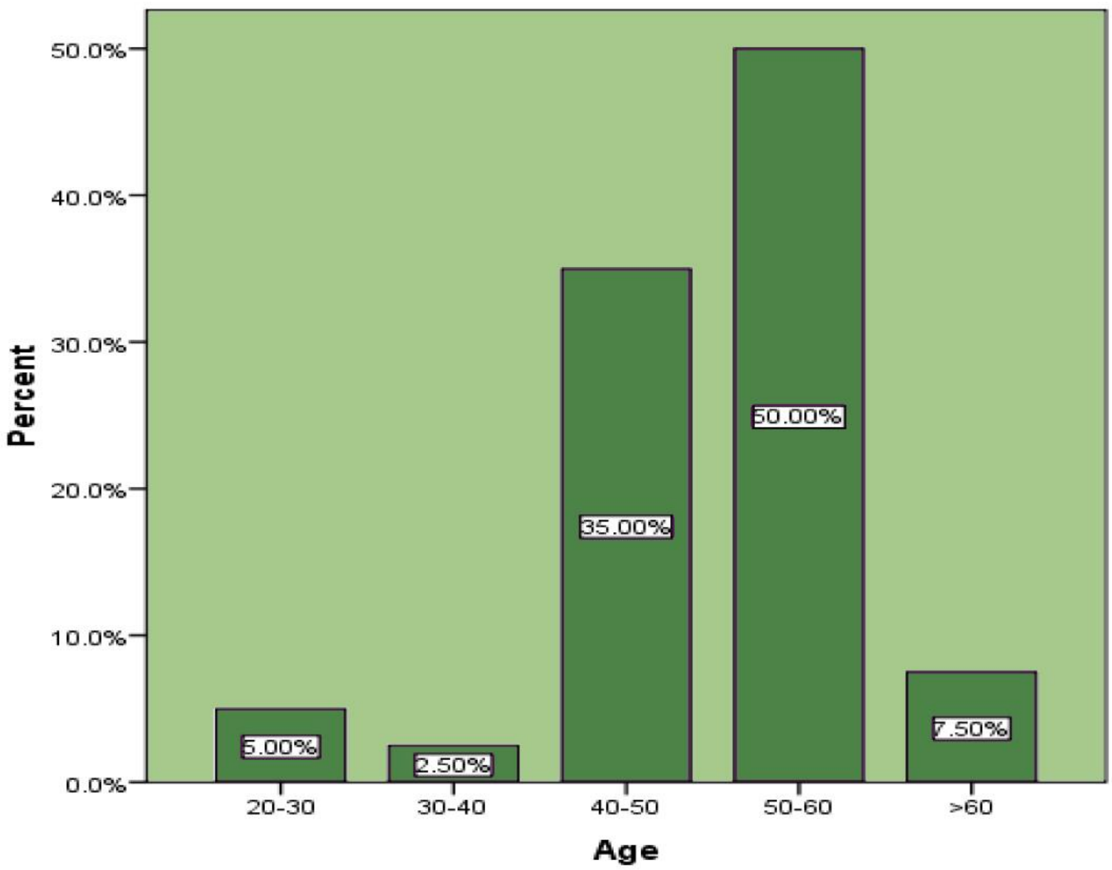

Figure 9. Age distribution of farmers who haven't heard of LARI application

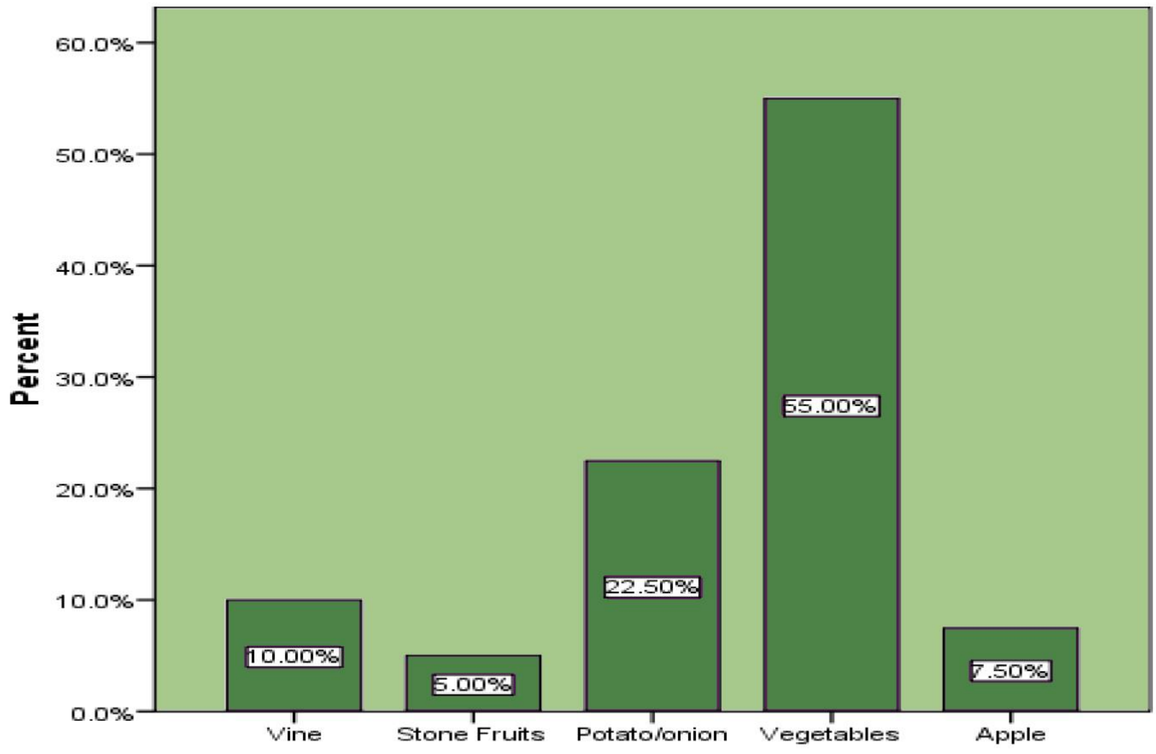

Figure 10. Distribution of farmers who haven't heard of LARI application according to the crops they cultivate

2.3.4 ANALYSIS OF FARMERS THAT USE THE APPLICATION AND WEBSITE

Half of the farmers use the application and website on a daily or weekly base, which indicates their confidence in it as shown in Fig.11. Nonetheless, the other half use the application sporadically.

Farmers that cultivate cereals, legumes, potato and apple use the application and website more often than those who cultivate vine and vegetables, which in turn use the application and website more often than those who cultivate roses and stone fruits (Fig.12).

Therefore, farmers who rely on supplementary irrigation (cereals and legumes) or weather forecast for conducting planting, harvesting or pesticide control (cereals, legumes and potato) are more interested in the application than vegetable growers who follow intensive production systems, but less affected by climatic risks. Rose and stone-fruit growers use the application on a seasonal basis, due to the short season of their crops, and the lower risk to certain climatic risks, or even the absence of certain services that are of interest to those growers. Although vine requires a lot of attention, and should be using the application at least on a weekly basis (similar to apple), they are refraining from using the application on a regular basis, due to a previous negative experience with some messages from LARI.

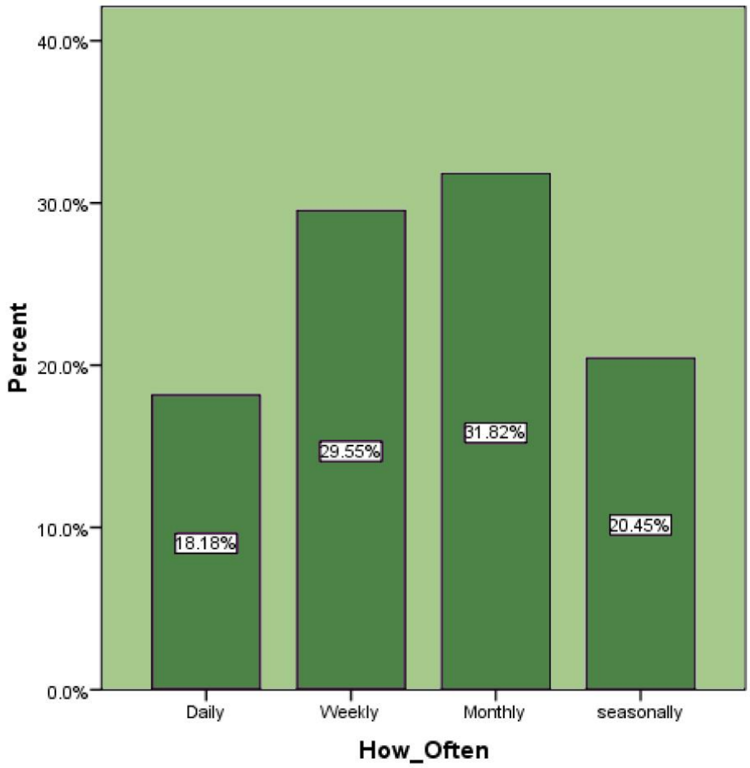

Figure 11. Distribution of farmers that use the application and website according to how often they use it.

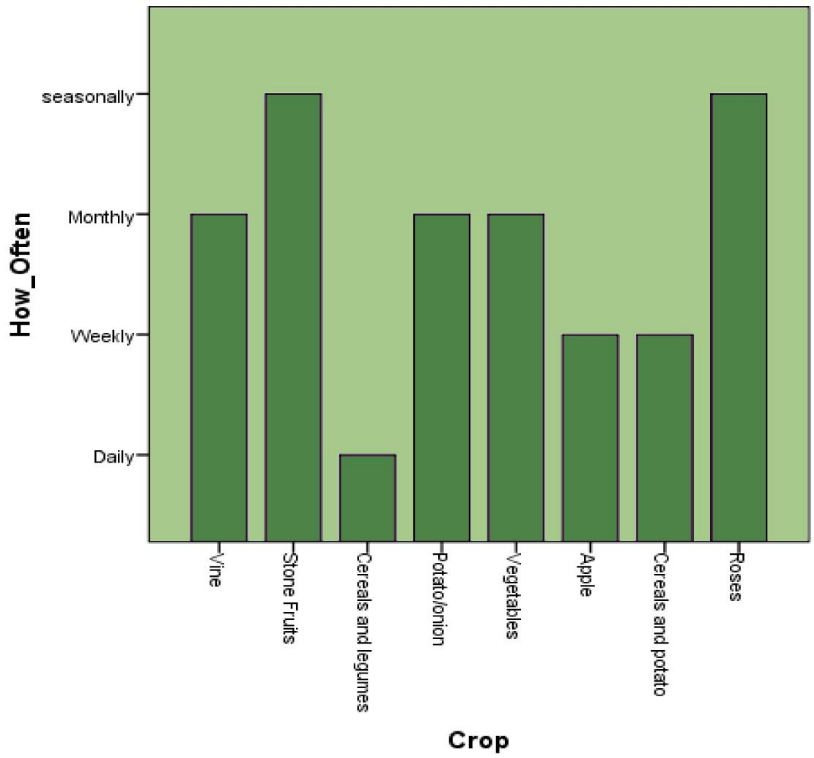

Figure 12. The mean of "how often farmers use the application and website" according to the crops they cultivate.

Almost 55% of farmers use the application only to check the weather forecast, but the percentage increases to 87% if we include farmers using the application for all purposes (including advice related to agriculture practices to protect plants from frost, drought or heat waves and to receive alerts about pest/disease outbreaks), thus demonstrating the importance of climate risks on agriculture in the Beqaa region.

Farmers who utilise the application only for pest outbreak control account for less than 14%, but the figure can reach 45% if we include those who use it for all purposes. This can be explained either by the lower relative importance of this risk or by the limited reliability of the EWS regarding pest in disease outbreaks. Note that there are no farmers using the application solely for irrigation, since this service isn't yet provided (Fig.13).

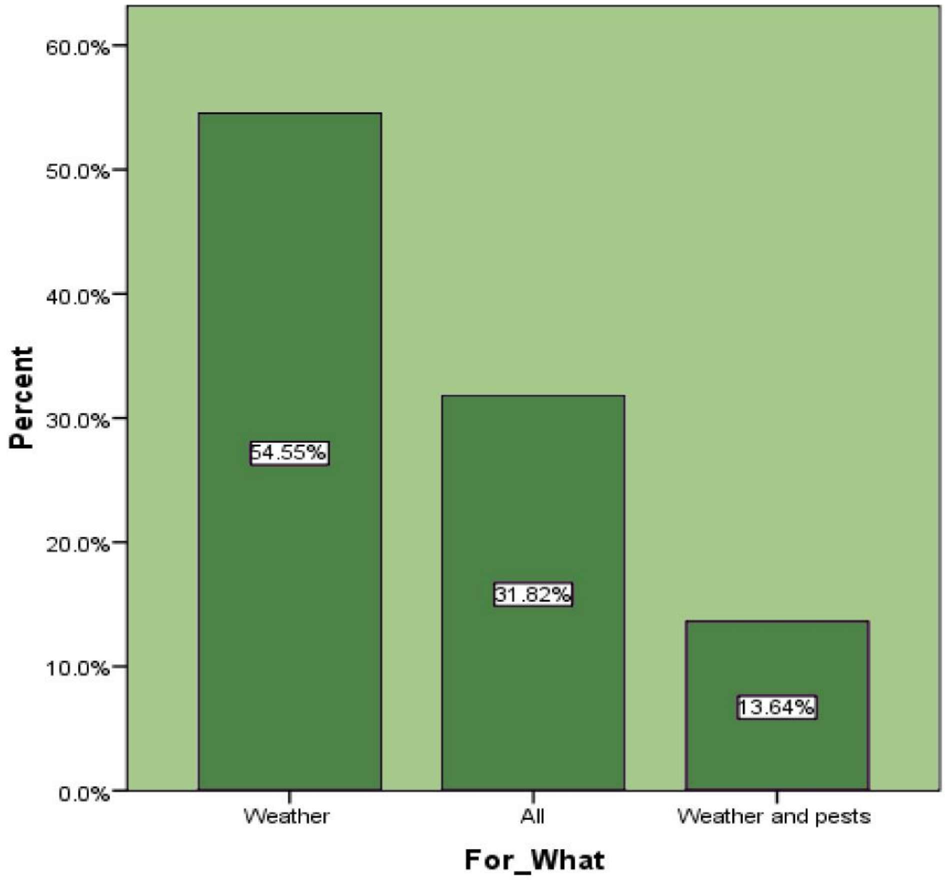

Figure 13. The information that farmers who use the application and website use the most.

Generally all farmers use the application mostly for weather forecasts whereas the farmers that cultivate cereals and legumes use it for pests, diseases and irrigation as well, which confirms the results on how often the application is used according to the type of crop (Fig.14).

When farmers were asked to rate the application (and website) based on their satisfaction degree, values varied between 6 as a minimum and 9 as a maximum, with an average of 7.25 (72.5%) showing general satisfaction amongst the farmers who use the application or website.

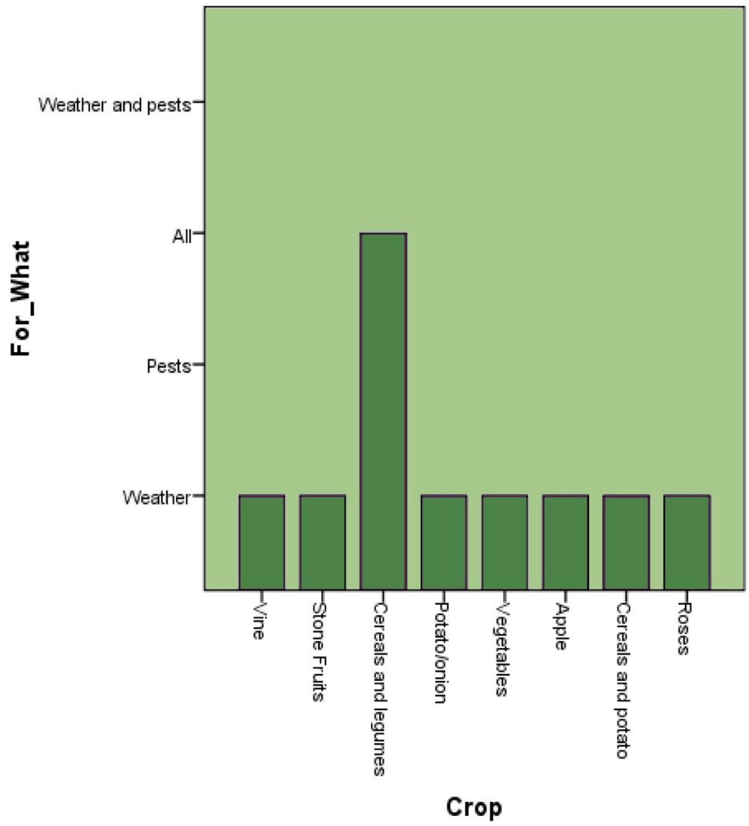

Figure 14. The mean of "for what do farmers use the application and website" according to the crops they cultivate.

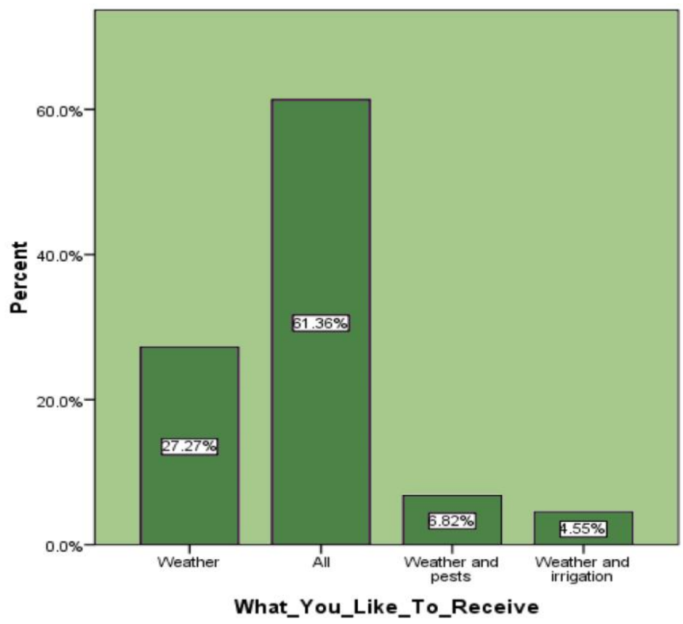

Figure 15. Percentage of farmers according to what kinds of alerts they're most interested in receiving.

Approximately 61% of farmers are interested in receiving all kinds of alerts that LARI can offer and approximately 27% are only interested in the weather forecast. This indicates a certain limit to the confidence of the farmers in the quality of the messages related to other services such as irrigation, pest control and so forth (Fig.15).

Farmers would like to receive all kinds of alerts, except for those who cultivate roses that were mostly interested in weather forecasts. This indicates the importance of EWS and the need for it by the majority of farmers in the Beqaa Valley (Fig.16).

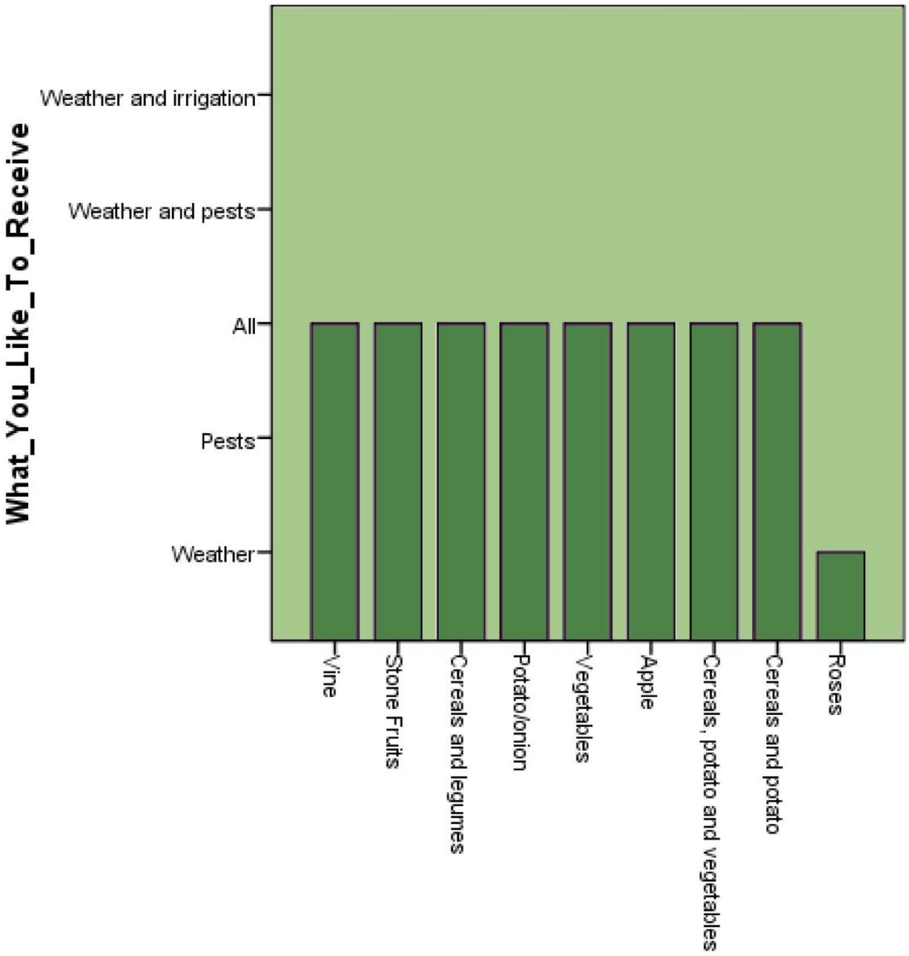

Figure 16. The mean of "what kinds of alerts would farmers like to receive" according to the crops they cultivate.

2.3.5 CONCLUSION

Most of farmers who have heard of the application use it on daily or weekly basis. This shows the importance of the LARI application and website for farmers in Beqaa. Even many of those who have not heard of it use the website or are willing to download it after this survey. As for the farmers who have heard of it but don't use it or don't intend to download it after this survey, their reasons varied between: (i) it doesn't provide important information, (ii) they aren't familiar with smartphones or (iii) considering that it's better for a farmer to depend on his experience but not on advice from a service who can't consider the characteristics at the parcel level.

Concerning the visibility of the LARI application, it isn't related to location since farmers who have heard of it vary between regions that are either very close (Rayak) or far (Ammiq) from the institute. According to our survey visibility is more related to the age of farmers and their environment, as young farmers are more educated and familiar with smartphones. In addition, older farmers who have heard of it, they got acquainted to it through their children, friends, siblings, their extension agricultural engineers, or through text messages from LARI.

In addition, in the last question of our survey we asked farmers if they had any comments or any advice that might help us improve the application and website. Their answers were mainly focused on improving the accuracy of the weather forecast taking into consideration the different microclimates in the Beqaa, giving more precise advice and instructions along with their warnings (particularly for irrigation and pest outbreaks), publishing more of their research information so that students and farmers can use it and stop sending irrelevant information or messages through the application.

In order to improve the outreach of LARI EWS application and its importance for farmers and the wider public, we suggest the use of social media, or send a text message to promote it to farmers by getting their phone numbers from the Chamber of Agriculture in the Beqaa.

2.4 SWOT ANALYSIS

The findings of both the bilateral meetings (with the different relevant experts and partners) and the survey conclusion enabled us to elaborate a SWOT analysis (Fig. 17).

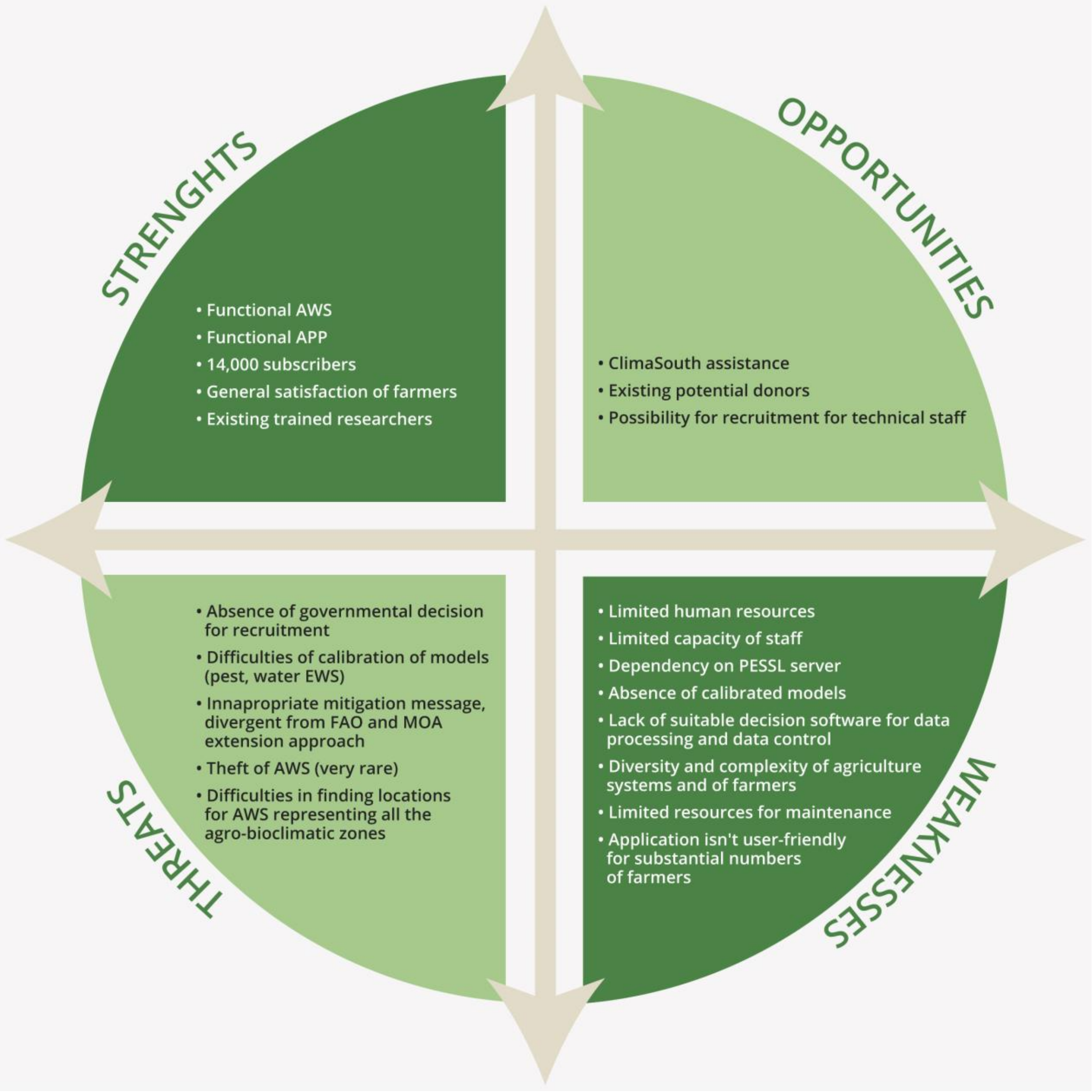

Figure 17. SWOT analysis for LARI EWS

3. EWS PRIORITIES AND NEEDS OF THE BEQAA REGION

3.1 PRIORITY CROPS

Our results show that cereals, potatoes, grapevines, vegetables, stone fruits, legumes and apples are the major crops of the Beqaa. Within the cereal category, wheat is largely dominant, followed by barley. The potato is by far the most important field irrigated crop, for both table and industrial uses. Grapevine is important for both table and industrial grapes, while amongst the other perennial crops, stone fruits are the most important; these include: almond, apricot, cherry, peach and nectarines. In our survey, we found that roses are also important on a local scale; however, rose growers aren't particularly interested in EWS.

Among fruit and tuber vegetables, tomato, onion and watermelon are the most cultivated crops, while for leafy vegetables cabbage is the most noticeable.

When we combine the most cultivated crops with their respective climate-related risks, including pest and disease outbreaks, and the result of our survey, we find that cereal and legume growers are of a great priority, followed by all the other above mentioned crops.

Priority crops for irrigation in Central Beqaa will be: potato, grape, wheat and tomato;

Priority crops and their respective diseases in the Beqaa include: wheat (brown and yellow rust) and grape (downy mildew).

<u>Note</u>: Dr. Elia Choueiri and Dr. Wassim Abi Habib consider that Akkar is another priority zone, where pest outbreaks are more frequent on different crops (fire blight and apple scab, late blight on potato, etc.). Moreover, in Akkar one person is dedicated and trained on DACOM and managed to use previously the model for late blight on potato, which was the only success story for EWS for disease outbreaks, without any calibration. Apple scab and fire blight are also more frequent in the North and Mount Lebanon. Dr. Marie-Therese confirmed the complexity of designing a big homogenous irrigated scheme as a pilot area for irrigation EWS, and suggest to rather work on smaller homogeneous schemes, with one crop each, but not necessarily confined to the Beqaa (i.e., Apple in Northern Mount Lebanon, Citrus in the South, winter crops in Akkar, Potato in the Beqaa).[4]

3.2 PRIORITY NEEDS

Based on the baseline study previously detailed, a list of priority needs can be developed. Needs are technical, financial or human resources. Nonetheless, for LMS legislative aspects hinder the enabling environment to develop a joint or mutual project on EWS with LARI.

[4] This note is to express the opinion of LARI experts met during the assessment.

These legal barriers are far beyond the frame of a project proposal, as they require law amendments and a revision of the legal status of LMS. Hence, we will continue in the following paragraphs with the priority needs of LARI, according to the major 3 axis: (i) climate adverse, (ii) water demand for irrigation and (iii) pest and disease outbreaks.

3.2.1 CLIMATE ADVERSE

LARI has no independent database, which is a major problem; all data is directly transferred to PESSL server, on an hourly basis which slows the process of EWS.

Hence, the institute needs an autonomous server in Lebanon, which would require a dedicated room, air conditioning, and electric power.

A program is required to decode the signal in order to be able to transfer data directly from the AWS to the local server, and use a research-based configuration instead of the actual farmer-designed software provided by PESSL, which isn't appropriate for weather forecasting for EWS. The required software should be in a manner comparable to those used by the California Irrigation Management Information System (CIMIS).[5] The software should be flexible and compatible with other software for different use (those for irrigation such as AQUACROP or any similar model, or for disease outbreak models similar to DACOM).

In addition, it's essential to establish a means of data storage with its specific software as well as a program for data quality management control.

The upgrading of the bench for AWS maintenance is a must.

The current dedicated staff is neither sufficient nor qualified to fulfil the tasks of an efficient EWS. Additional human resources are required, including:

- a technician for data control and management, with information technology and meteorology/climatology background in order to be able to take decisions;
- an electrician for AWS maintenance; and
- a technician with information technology (computer sciences) to develop, maintain and use new software for data storage, programming, etc.

In addition, all the existing and recruited staff would require training in the fields related to their respective tasks.

3.2.2 WATER DEMAND FOR IRRIGATION

Maps at 1/5000 scale are essential, with all the data related to the parameters mentioned in paragraph 2.2.1 collected. To conclude, the researchers of the Irrigation and Agro-meteorology department are convinced that EWS for irrigation is a very complex, and

[5] www.cimis.water.ca.gov/

requires on an initial phase a pilot project for the central Beqaa region, in a relatively homogenous zone, focusing on 4 major crops (potato, grape, wheat and tomato). In addition to those technical needs, human resources should be reinforced with additional assistants (agriculture engineers, with experience in irrigation and horticulture). A specific application for irrigation EWS (different from the existing LARI application) is required to outreach a target group of farmers that is involved in the pilot project.

3.2.3 PEST AND DISEASE OUTBREAKS

The previous models procured by the institute were not calibrated to be compatible with PESSL AWS and the local bio-climatic conditions. In order to conduct an appropriate EWS for pest and disease outbreaks, it's essential to purchase new models (i.e., DACOM) however, on the condition that the procurement is coupled with the calibration of the models based on the phonological stages of the local crops, the life cycle of the existing diseases in Lebanon, and the current PESSL AWS. For the Beqaa, the retained priority crops and disease are grape (downy mildew) and wheat (brown and yellow rust).

Hence, a consultant from the providing company is required to conduct calibration and test the models on the local scale. In order to scale up the service to outreach additional pest and disease on different crops, a preliminary evaluation of the cost effectiveness and efficiency of models is required.

Human resources are linked to the number of pests or diseases to be monitored for EWS. LARI head of phytopathology department estimates 2 field technicians for every 4 to 5 pests, with a similar number for diseases. These technicians are crucial for the development of the EWS and are a prerequisite; the existing staff in the concerned departments aren't able to dedicate time for EWS. The required technicians should have an agriculture engineer diploma, preferably in plant protection.

In addition, a technician with at a Master degree in agriculture or modelling and information technology or any related field is required, as well as an assistant for data entry in order to follow up the models and take the appropriate decisions (to send an alert or not).

All recruited technicians should benefit from a training to be able to conduct field inspection (identification of pest and disease, and their symptoms, etc.). Capacity building for the Information technology technicians is also essential; such training should be provided by a consultant from the provider company (i.e., DACOM).

The list of needs is resumed in Table 2.

Table 2. List of needs for LARI EWS

Type of Need	Cost (USD)
Equipment, software and tools	
autonomous server with dedicated room, air conditioning and electric power	
Decoding program and a research-based configuration for AWS software, compatible with other software needed for EWS	
Data storage and software for quality management control	
Updating the bench with missing spare parts and tools	
Digital soil and topography maps at 1/5000 scale	
Customised application for irrigation EWS for selected farmers	
Disease models calibrated to Lebanese (Beqaa) context in terms of vegetation stage, pest life cycle, etc., for the selected crops/diseases	
Human resources	
1 technician for data control and management (IT)	To be defined by LARI
1 electrician	
1 technician (IT) to develop, maintain and use new software for data storage, programming, etc.	
Engineers and technicians for the pilot irrigation project	
2 agriculture engineers with phytopathology background	
2 agriculture engineers with entomology background	
1 technician with at least a master's degree in agriculture or modelling or IT to follow up the DACOM models and make the appropriate decisions	
1 assistant for data entry of pest and disease	
Capacity building	
AWS maintenance; weather data quality control; data transfer and storage; EWS decision making; calibration of pest and disease software; data entry and decision making for pest outbreak EWS model; entomology and phytopathology for recruited technicians; training on water demand software, etc.	Depends on the background of the existing or recruited staff; the number of technicians involved and the software used. Estimated: 5 days/topic or 45 days in total.

4. SUSTAINABILITY OF EWS IN LEBANON

To ensure an enabling environment and sustainability of EWS in Lebanon, few points should be considered:

Human capacities of LARI (and eventually LMS) should be reinforced; contracted technical and administrative staff during the project period isn't a guarantee for the sustainability of this service. A prerequisite for a successful implementation of a EWS is the recruitment of the required technicians based on the terms of references identified by LARI interviewed personnel, through the appropriate administrative channels. This process is currently impossible for LMS due to legal constraints. Complementarity between LARI and LMS is currently the only mean of collaboration due to the legal constraints at LMS, which prohibits the department from sharing freely its data with other national actors.

Equipment procurement should not be reflected as the major outcome of the project; expendables for daily maintenance of the AWS, server, software and other equipment should also be considered.

Although EWS for irrigation is a crucial issue, it's difficult to reach in a short or medium term project due to the complexity and diversity of crops, soils, microclimates, and planting calendars in the Beqaa. Moreover, water isn't always pressurised, and water meters are lacking. In short, it's difficult to quantify the amount of water used for irrigation at farm level. If a pilot project in central Beqaa is retained, a farm-tailored EWS service on water demand for irrigation should be designed, in order to provide farmers with accurate information, rather than sending a unified message for all. Another option would be to discuss the possibility to split the pilot project into smaller homogenous zones with single crop but different regions (or agro-bioclimatic zones).

Regarding EWS for pest and disease outbreaks, any model should be compatible with the AWS, and calibrated to the Lebanese context (climate, crops, pests and diseases). Due to the high cost of the models, it's wise to examine which crops and related pests/diseases are cost effective, knowing that the Beqaa region suffers less from those climate-related pest outbreaks when compared to other regions.

Finally, for better effectiveness of the EWS outreach messages, it's essential to have AWS network covering all the agro-climatic zones of the country, and to collaborate with MOA and FAO on the measures to be delivered within the early warning messages, because they're part of the extension service of MOA,[6] and in order to avoid sending inappropriate messages. As an example, messages suggesting the use of a certain pesticide active ingredient should be verified in order to secure that this active ingredient isn't banned or is imported to Lebanon. In this regard, we suggested the use of technical small committees from LARI and MOA, which would periodically review the types of messages to be delivered according to

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6 MOA has an extension department at the directorate of coordination and studies. The department supervises the work of 24 regional extension centers. There is no direct coordination between LARI and the MOA extension service.

the risk and crop. Another issue is to overcome the technical barrier for a substantial number of farmers who aren't familiar with smartphone applications, by providing (in collaboration with MOA) a bulletin or a regular printout that can be distributed to farmers, or any other extension tool that would be suitable for an extended outreach service.

ANNEX I. SURVEY QUESTIONNAIRE

Name of Farmer: Date:

1. Farmer's age:

A: 20-30
B: 30-40
C: 40-50
D: 50-60
E: >60

2. What type of crops do you produce:

a-Vines b- Stone fruits (لوزيات) c- Cereals or legumes (حبوب)
d- Potatoes/onions and vegetables (خضار) f- Apples

3. Have you heard about the LARI mobile application (تطبيق مصلحة الأبحاث الزراعية)?

A: Yes
B: No

4. Do you use the LARI application or website?

A: Yes
B: No

5. If you know it and you don't use it can you tell us why?

6. If you use it, how often do you read extension messages/forecast ?

A: Daily
B: Weekly
C: Monthly
D: Seasonally

7. What is the information given that is interesting for you?

A: Weather (الأرصاد الجوية)
B: Irrigation (الري)
C: Information about pests and diseases (معلومات الأمراض و الحشرات)
D: Others (name them)

8. Rate its accuracy or quality of information from 1 to 10: __________

9. What kind of information do you like to receive:

A: Irrigation schedule and quantity
B: Alerts for weather forecasts (frost, heatwave, wind, rain, etc.) and how to lower the risk and impact (cover, irrigation, burning, pruning, etc.)
C: Alerts for pest outbreaks and the control measures to use (pesticide, mechanical control, biological control, etc.)
Other: ____

10. Do you have any recommendations for the improvement of the application and website?

ANNEX II. LIST OF NEEDS AND THEIR APPROXIMATE COSTS

Type of Need	Cost (USD)
Equipment, software and tools	
autonomous server with dedicated room, air conditioning and electric power	50,000
Decoding program and a research-based configuration for AWS software, compatible with other software needed for EWS	75,000
Data storage and software for quality management control	50,000
Updating the bench with missing spare parts and tools	5,000
Digital soil and topography maps at 1/5000 scale	?
Customised application for irrigation EWS for selected farmers	?
Pest and disease outbreaks models calibrated to Lebanese (Beqaa) context in terms of vegetation stage, pest life cycle, etc.	A total of up to 60,000 for all crops; however, there are only three priority crops/disease for the Beqaa.
Human resources	
1 technician for data control and management (IT)	To be defined by LARI
1 electrician	
1 technician (IT) to develop, maintain and use new software for data storage, programming, etc.	
Engineers and technicians for the pilot irrigation project	
2 agriculture engineers with phytopathology background	
2 agriculture engineers with entomology background	
1 technician with at a Master degree in agriculture or modelling or IT to follow up the DACOM models and take the appropriate decisions	
1 assistant for data entry of pest and disease	
Capacity building	
AWS maintenance; weather data quality control; data transfer and storage; EWS decision making; calibration of pest and disease software; data entry and decision making for pest outbreak EWS model; entomology and phytopathology for recruited technicians; training on water demand software, etc.	Depends on the background of the existing or recruited staff; the number of technicians involved and the software used. Estimated: 5 days/topic or 45 days in total.