The Water sector

Water sector

7.1. Sector Overview

Lebanon's Second National Communication to the UNFCCC has projected a decrease in precipitation and water losses due to evapotranspiration increase in the near future. With a temperature rise of 2°C, water resources are estimated to decrease by 450 Mm^3 per year (MoE/UNDP/GEF, 2011). The effect of climate change on snow, which is vital for water resources in Lebanon, is considerable. River flows would increase between December and February, however as snow melt decreases from April to June, river flows will dramatically decrease during periods of high demand for irrigation water.

Lebanon's water resources are considered to be under stress since the Ministry of Energy and Water puts the total renewable resources (drinking, industrial and irrigation) per capita per year at 926 m^3 which is slightly lower than the international benchmark of 1,000 m^3/capita/year. This situation will be exacerbated since the total renewable resources are projected to reach 839 m^3 by 2015 (MoEW, 2010b).

Lebanon has 16 perennial rivers and 23 seasonal rivers and total annual river flow is about 3,900 Mm^3, of which an estimated 700 Mm^3 flow into neighboring countries. 75% of the flows occur between January and May, 16% between June and July and 9% between August and October (Comair, 2010).

Most of the surface water used to secure supply comes from captured spring sources. Lebanon has some 2,000 springs. Their total yearly yield exceeds 1,200 Mm^3; however, less than 200 Mm^3 is available during the summer period. The total annual exploited volume is 637 million m^3 (MoEW, 2010b).

Lebanon has two dams, the Qaroun dam on the Litani River, and Chabrouh dam which captures runoff from rain and the Laban Spring. Their respective static storage capacity is 220 Mm^3 and 8 Mm^3 respectively. Currently, only 30 Mm^3 is being utilized from the Qaroun Dam for water supply and irrigation and the rest is used to generate electricity.

Current demand estimates vary with the source and assumptions. According to the national water sector strategy developed by the Ministry of Energy and Water in 2010, water withdrawal was estimated at 1,310 Mm^3, of which almost 60% was for agricultural purposes, 29% for municipal use and 11% for industry. Groundwater and surface water account for 53.4% and 30.2% of total water withdrawal respectively. Recycled irrigation drainage accounts for 12.6%, and reused treated wastewater for 0.2%. The share of water withdrawal for agriculture is likely to decrease over the coming years as more water will have to be diverted for municipal and industrial purposes.

Irrigation is a necessity for agricultural productivity in most parts of Lebanon, given its prevailing drought during the summer growing season. Irrigated surfaces reached over 104,000ha (MoA, 2008). Irrigation is the major factor enabling production intensification in agriculture. However, unsustainable water management practices, water governance shortcomings, and environmental risks including climate change are among the main obstacles facing the sector.

Over 50% of irrigation water comes from underground wells and boreholes while 80% of potable water comes from groundwater sources. In addition, private wells have increased greatly in the last few years, due to population growth, economic development and urban expansion (MoEW 2010b). Aquifers are being overexploited and wells are drying up or increasing in salinity.

Rivers, springs, and groundwater continue to be adversely impacted by raw sewage and other wastes, both domestic and industrial, being discharged without any regulation or control from establishments. While all the water resources are being impacted by bacteriological contamination, in the agricultural areas, the runoff and infiltration of residues from fertilizers and pesticides is exposing them to further environmental degradation. Furthermore, runoff from urban areas may contain heavy metals and hydrocarbons which could impact the quality of receiving waters. Generally, coastal wells are subject to severe salt water intrusion, and many are being put out of operation (Shaaban, 2009).

7.1.1 Actions at sectoral level

In order to increase water availability and optimize water efficient use, the MoEW developed a 10-Year plan to build dams and lakes that would add approximately 650 Mm^3 per year to the stock of available renewable freshwater resources mainly for drinking purposes. Similar plans have been conducted by the MoA and Green Plan to increase water harvesting from surface run-off in water efficient use through the promotion of drip irrigation. In addition, the recently established Lebanese Center for Water Management and Conservation is currently promoting urban/communal water harvesting and domestic efficient use.

Faced with mounting water-related challenges, Lebanon has invested in expanding existing water supply networks, providing wastewater collection and treatment systems, developing additional water resources, building the capacity of institutions to manage infrastructures, and improving service delivery. Overall progress however has been predictably slow.

Key emerging issues include options for augmenting water resources, and new approaches for water management including integrated water resource management (i.e. the elaboration of Irrigation or Water Act), water demand management, protection of water recharge zones and protection from flood plains. Some relevant Laws related to the water sector are listed in Table 73

Table 73 - List of relevant laws, decrees and decisions related to water sector

Type	Number	Title	Date issue	Remarks
Creation and organization of Water syndicates and their role				
Law	221	Organization of the water sector.	2000	Amended by Law 241, 2000 and law 377, 2001.
Decree	8122	Application of some clauses of Law 221.	2002	Fusion of water committees into regional water services.
Decree	65	Creation of a water syndicate for the water use of Nahr el Jawz River.	1943	
Decision	320	Conservation and use of public water .	1926	Amended by the decree 680, 1990. Includes clauses for the creation of water syndicates.
Creation and organization of water infrastructures				
Decision	3	Water policy for the creation of dams and hill lakes.	2003	10 year strategy; under Law 221, 2000.
Decree	13785	Creation of green Plan.	1963	Installation of hill lakes, water reservoirs, irrigation system on farm level.
Decree	20022	Creation of Qasmiyeh irrigation scheme.	1958	Irrigation scheme for farmers using water of Qassmiyeh (Litani) River.
Ottoman law		Rights for irrigation and use of distribution network and rivers and their maintenance.	1918	
Ottoman law		Irrigation law.	1913	
Water Use				
Law	3339	Property law	1930	
Ottoman law		Ottoman Journal for judicial provisions: Regulation of water use.	1876	

Source: Karam, 2012

7.1.2 Scope of work

In this project, technologies serving the overall target to increase water availability and optimize water efficient use are proposed and can be deployed at farm or exploitation level with minimal investments, and improve substantially farmers and crop resilience to climate change. The following technologies have been retained:

Increasing water availability: rain water harvesting from hill lakes or earth lakes, rainwater harvesting from ground surfaces or roads, and rainwater harvesting from greenhouse tops.

Optimizing efficient water use: efficient water use in irrigation systems, water users association and soilless culture.

Snow monitoring and the use of treated waste water are suggested technologies that would embark on both categories.

7.2 Possible adaptation technology options in the Water sector and their adaptation benefits

The proposed technologies in most cases are a combination of hard technologies (i.e. equipments), soft technologies (i.e. monitoring demand and supply then management) and organizational technologies (organization of users into associations).

7.2.1 Rainwater harvesting from hill lakes or earth lakes (RWHH)

Managing micro-catchments for water harvesting in earth lakes or hill lakes is a common technology for water harvesting used in the world. The technology consists of storing rainwater in excavated lakes where surface runoff is driven to increase storage capacity. Stored water can be allocated for both agriculture and domestic use; however a distribution system is required in order to transport water to the crops or settlements. In the case where the hill lake is collective, a water user association is needed to share maintenance costs and agree on distribution patterns. Suitable topography, geological conditions and the amount of rainfall are the key prerequisites for the construction of hill lakes. If the hill lake is excavated into a permeable soil, a layer of clay or impermeable membranes should be installed in order to retain the stored water. The mountainous topography of Lebanon increases the geographical extension where this technology can be deployed. Rainwater harvesting from hill lakes enables increasing water availability under current and future climate, to meet the increasing demand. Consequently this technology enables the reduction of vulnerability of crops and populations in mountainous areas. The use of surface runoff will also reduce the use of underground water, making water resources more available to the users in the lower parts of the watershed.

In Lebanon, this technology is witnessing some development. Since the initiation of the Green Plan in 1964, hundreds of hill lakes all over the country have been constructed with an excavated area of 60,000ha. In 2008, the Green Plan constructed several hill lakes (mostly in North Lebanon and Northern Bekaa), with a total capacity of 98,139 m^3 (Green Plan, 2009). However many barriers are hindering this practice to be widely used to optimize water availability in all areas in Lebanon.

7.2.2 Rainwater harvesting from ground or roads (RWHR)

Rainwater harvesting could be achieved from ground surface (roads) that constitutes the catchment area where the rainfall or water runoff is initially captured. Surface water flowing along the ground during rain is usually diverted toward a reservoir below the surface.

Rainwater harvesting represents an adaptation strategy to climate change for people living with high rainfall variability, both for domestic supply and to enhance crop, livestock and other forms of agriculture (UNEP RISOE Center, 2011a). This technology requires 1) designing new roads to be executed or rehabilitating existing roads in a manner enabling water drainage through canals to a lower point, 2) the construction of a pond for decantation and collecting sediments, and 3) a reservoir from earth or concrete material for storage. This technology is not applied so far in Lebanon and could be a potential for any area with a minimal slope allowing water runoff towards the collection point. A project has already been initiated in Bchaaleh in Batroun highlands, with a fund by the Environmental Fund for Lebanon (EFL). Stored water is an additional resource enabling to cover the increasing demand under future climate, for both domestic and agriculture uses.

7.2.3 Rainwater harvesting from greenhouse tops (RWHG)

Like any other roof top, greenhouses could be a potential ground to harvest rainwater. The collected water is stored in an underground concrete or plastic tank or even an earth reservoir. The technology is simple and quick to deploy. Water can be allocated for domestic use or for irrigation, especially when coupled with an efficient irrigation system. This technology although targeting a small proportion of land mainly on the coastal areas and mountains where precipitations are significant, it is important to increase water harvesting and reduce the pressure on pumping from the underground water which is prone to sea intrusion (Shaaban, 2009). Moreover, rain harvesting from greenhouse tops will increase water availability during the critical months of late summer and early autumn. Reducing the risk of salinity in both soil and water will increase the resilience of crops to prolonged drought and to some fungal outbreaks (Shaaban, 2009; Hanafi, 2008) and avoid increased crop vulnerability to climate change.

7.2.4 Efficient water use irrigation system (EWUIS)

Efficient water use irrigation systems are a combination of several hard technologies using different equipments (drip, micro-sprinkler) and soft technologies (models for water needs according to the relation between the soil, climate demand and crop characteristics). Efficient irrigation systems like drip-irrigation reduce water evaporation and percolation as the water is directly applied to the root zone of the plants. However, using an efficient irrigation system like drip along with monitoring water demand by the plants can allow reaching up to 90% efficiency (UNEP RISOE Center, 2011a). Supplying the plants with their water requirement on time will avoid water stress and provide higher yields when compared to crops under conventional irrigation methods. Moreover, water monitoring will optimize supplementary irrigation namely for cereals, legumes and forage crops (ICTSD, 2010). Hence, EWUIS increases the resilience to climate change and provides benefits for farmers in the form of minimized labor for irrigation, minimized cost for weed control as well as increasing yield (UNEP RISOE Center, 2011a). Revenues can increase by a minimum of 15% due to increased yield and reduced cost of production. Indirect benefits include the saved energy for pumping, plowing and the minimized chemical spraying. EWUIS is suitable for all crops grown in Lebanon, however, institutional and organizational arrangements for monitoring water demand and for scheduling water distribution into a network within an irrigation scheme are essential.

7.2.5 Water users' association (WUA)

A WUA is a unit of individuals that are formally and voluntarily associated to each other for the purposes of cooperatively sharing, managing and conserving a common water resource. The core activity of a WUA is to operate the waterworks under its responsibility and to monitor the allocation of water among its members. All farmers benefiting from a common water source can establish a WUA. It is a prerequisite to monitor irrigation networks and for irrigation systems requiring on-farm water supply on a daily basis (i.e. drip systems).

This organizational "technology" has been successfully applied in different countries, and is highly recommended to increase the resilience of water users to climate change (UNEP RISOE Center, 2011b). In Lebanon, the establishment of WUAs is absent since it requires several institutional arrangements (such as a Water Act or Irrigation Act). However several water committees and informal users' groups exist. Benefits of WUA are indirect, but enable the optimal use of irrigation systems, and hence optimal yields are obtained. The modernization of water distribution systems is a key prerequisite of WUA. Enabling monitoring water supply according to the climate demand can reduce crops vulnerability to climate variability by saving water by more than 40%, enabling further efficiecy in water use.

7.2.6 Soilless agriculture (SA)

This technology is cross-cutting between the agriculture and water sectors. However, since the major advantage of soilless agriculture is related to water efficient use and water quality, this technology is listed within the water sector. Soilless agriculture relies on the use of water culture using a liquid film technique or natural inert material substrate culture. Despite beeing characterised as intensive agriculture that increases the adaptation to climate through controlling the climate environment of the greenhouse, soilless agriculture resolves the problem of uncertainty of water and nutrient status of the soil. It enables protecting crops from water salinity, water shortage, soil-borne diseases (Hanafi, 2008), while offering good yields and quality of products. Soilless agriculture is feasible for crops grown greenhouses and it is still at its early stage in Lebanon due to the high technical requirements and high investment costs. Soilless agriculture can be harnessed by other technologies related to greenhouses like water harvesting from roof tops and Integrated Production and Protection.

7.2.7 Use of treated wastewater in irrigation (UTWWI)

The proposed technology presents a model or protocol for reusing treated wastewater in irrigation for recommended crops. The objective is to make efficient use of treated wastewater, ensure water for plants, without having any negative impact on human health or the environment. UTWWI will replace the rarified water resources and increase water availability for irrigation under current and future climate scenarios (UNEP RISOE CENTER, 2011; Choukrallah, 2011) and hence avoiding the pollution of aquifers. The components of UTWWI are a combination of crop selection, irrigation methods, and adoption of appropriate management practices (Steinel and Margane, 2011a). This soft technology consists of i) elaboration of regulations that permit the use of appropriately treated wastewater for irrigation of specific crops, while minimizing health risk, ii) monitoring effluent supply and its quality, and iii) training farmers on the preparation of an appropriate on-farm management strategy. To be able to implement UTWWI, wastewater treatment is a prerequisite. UTWWI does not require sophisticated expensive treatment plants, and can be functional with constructed wetlands (i.e. treatment through reed plantation) that are cost-effective and non energy intensive. In Lebanon, several treatment plants have been planned to serve major cities of which several are under construction. In parallel several municipalities and communities have made their own arrangements to improve wastewater collection and disposal. However, institutional and organizational challenges are numerous, such as the absence of laws specific to the use of treated wastewater, the absence of a financial mechanism to sustain the treatment plants, and the acceptance of the society including farmers to the UTWWI (Steinel and Margane, 2011b). The direct benefits of UTWWI are the reduced vulnerability of crops due to increased water supply and the reduction of water and soil pollution.

7.2.8 Early warning system for water supply management (river flow) through snowpack monitoring (EWS-SPM)

Lebanon depends mostly on its snow cover to feed river basins and the groundwater. Large variations in snow cover between years has direct impacts on water supply to rivers, especially that changes in flows can have adverse effects on multipurpose water resources supply (Shaaban, 2009). Methods for monitoring and predicting stream flow help increasing the readiness to climate uncertainty by predicting water supply and developing water safety plans (UNEP RISOE CENTER, 2011). This hard technology aims at providing an early warning system for water supply management, by developing a model that predicts stream flow variation based on snow cover in the river basin. Such models rely on snow cover spatial and temporal variations data derived from remote sensing. The system includes: 1) on-ground snow stations that record real time snow depth in different locations, 2) gauging stations on the river that records stream flow data and, 3) satellite images for snow cover monitoring. The Litani River Authority has the necessary institutional arrangement and expertise for undertaking such work. Beneficiaries range from water authorities to water users. Benefits from EWS-SPM are indirect, and related to the optimal use of available water resources for all sectors. Planning agriculture design according to the available water resources will minimize the risk of plant water stress and hence, preserve yields.

7.2.9 Criteria and process of technology prioritization

Process of technology prioritization

The technology prioritization process was elaborated based on the Multi-Criteria Analysis approach, where different technologies are ranked based on specific weighed selection criteria. The final weighed score is calculated according to the below formula:

$$\frac{\text{Tech.score-min.score}}{\text{Max.score-min.score}} \times \frac{\text{Weight of criterion}}{\text{Total weights}}$$

Technologies were identified and analyzed based on literature review, field experience and results of individual meetings conducted with different experts working in the field. Accordingly, factsheets were elaborated and disseminated to a wider spectrum of researchers and technicians from national and international institutions for review and commenting. These factsheets contained detailed information on technology characteristics, institutional and organization requirements, adequacy of use, capital and operational cost, advantages as well as barriers and challenges.

Based on this extensive dissemination process, an expert consultation meeting was held where a pool of experts validated the choice of technologies, the selection criteria and the proposed weights. A ranking was then conducted by attributing scores based on general consensus.

Selection criteria

Specific selected criteria allowed stakeholders to answer simple questions related to economical viability, environmental reliability and social acceptability of technologies and to compare between the technologies in order to prioritize the most appropriate for Lebanon.

The following criteria were retained for the prioritization exercise: capital and operational cost, extent of use, capacity to increase water supply , capacity to increase water efficient use, need for human resources and knowledge, need for infrastructure, social acceptance and negative environmental impact. Each criterion answers more than one question. For instance, the extent of use depends on the number of beneficiaries, the targeted agriculture-subsector, the covered regions, etc.

Absolute scale with misleading figures and numbers were avoided by ranking on relative basis over a top score of 5 -1 and weights of 1.5 were attributed to the criteria that were more significant in technology deployment.

The list of criteria with their scale and respective weight is presented in Table 74.

Results of the technology prioritization

After reviewing and fine tuning the criteria and their relative weights, a ranking was performed using weighed scores of MCA. The final results are reported in Table 75.

As appeared in Table 76, the top ranked technologies were: Rainwater harvesting from greenhouses, Rainwater harvesting from roads, and Water User Associations. Due to the importance of efficient water use, it has been agreed to tackle efficient water use as common base and overarching concept for the three selected technologies.

Table 74 - Brief description of the criteria of selection, their scale and respective weight

Criterion	Description	Scale	Weight
Capital and operational cost	This includes initial cost to establish the technology as well as the annual maintenance and operational costs. Some figures per surface or volume units are provided for some technologies. It highlights the easiness of access of farmers to the technology.	Very low (5) Low (4) Medium (3) High (2) Very High (1)	High (1.5)
Extent of use	It assesses the extent to which the technology is applicable within the different geographical contexts, agro-ecological zones, and the number of targeted beneficiaries.	Very low (1) Low (2) Medium (3) High (4) Very High (5)	High (1.5)
Capacity to increase water efficient use	The technology's ability on improving water efficient use. The higher the values the more water is used efficiently.	Very low (1) Low (2) Medium (3) High (4) Very High (5)	High (1.5)
Capacity to increase water supply	The technology's ability on improving water supply. The higher the values the better supply of water.	Very low (1) Low (2) Medium (3) High (4) Very High (5)	Standard (1)
Need for human resources and knowledge	The technology's human requirements and qualification. If the requirements in human resources and in training are high, the score is lowest.	Very low (5) Low (4) Medium (3) High (2) Very High (1)	Standard (1)
Need for infrastructure	It reflects the availability of the infrastructure needed to deploy the technology. If the infrastructure is absent, the score is lowest. If the infrastructure is simple, and available, the score is highest. It highlights the time requirement to establish and disseminate the technology.	Very low (1) Low (2) Medium (3) High (4) Very High (5)	Standard (1)
Social acceptance	It reflects the social acceptance at all levels: water users, farmers and decision-makers.	Very low (1) Low (2) Medium (3) High (4) Very High (5)	Standard (1)
Negative Environmental Impact	If there is a negative impact of the technology on the environment, the score is low.	Very low (1) Low (2) Medium (3) High (4) Very High (5)	Standard (1)

Table 75 – MCA exercise results for the water sector

Criteria	Weight	Rainwater harvesting from ground /roads		Rainwater harvesting from hill/ earth lakes		Rainwater harvesting from greenhouse tops		Efficient Water Use Irrigation System		Use of treated wastewater in irrigation		Soilless Agriculture		Water Users' Association		Early warning system for water supply management through snow pack monitoring	
		Score	Weighed score	Score	Weighed score	Score	Weighed score	Score	Weighed score	Score	Weighed score	Score	Weighed score	Score	Weighed score	Score	Weighed score
Capital and Operational Cost	1.5	2	0.05	1	0.00	3	0.11	2	0.05	2	0.05	1	0.00	4	0.06	2	0.05
Extent of use	1.5	5	0.06	3	0.00	3	0.00	4	0.08	3	0.00	3	0.00	5	0.16	3	0.00
Capacity to increase water efficient use	1.5	4	0.08	3	0.00	5	0.16	5	0.16	3	0.00	5	0.16	3	0.00	4	0.08
Capacity to increase water supply	1	4	0.08	5	0.11	3	0.05	1	0.00	4	0.08	1	0.00	1	0.00	2	0.03
Need for knowledge and human resources	1	4	0.08	2	0.03	5	0.11	2	0.03	3	0.05	1	0.00	2	0.03	1	0.00
Need for infrastructure	1	3	0.05	2	0.03	5	0.11	2	0.03	2	0.03	1	0.00	5	0.11	3	0.05
Social Acceptance	1	5	0.11	4	0.07	5	0.11	5	0.11	3	0.04	2	0.00	3	0.04	5	0.11
Negative environmental impact	1	1	0.00	4	0.11	1	0.00	2	0.04	2	0.04	2	0.04	1	0.00	1	0.00
Total		28	0.61	24	0.33	30	0.63	23	0.48	22	0.28	16	0.19	24	0.49	21	0.32

Table 76 - Multi-Criteria Analysis results for the technologies of the water sector.

Rank	Technology	MCA score
1	Rainwater harvesting from greenhouses	0.63
2	Rainwater harvesting form roads	0.61
3	Water users' association	0.49
4	Efficient water use irrigation systems	0.48
5	Rainwater harvesting from hill lakes	0.33
6	Early warning system for water supply management through snow pack monitoring	0.32
7	Use of treated wastewater in irrigation	0.28
8	Soilless agriculture	0.19

7.3 Barrier Analysis and Enabling Framework

7.3.1 Classification of technologies

The proposed technologies are divided to 4 categories: i) consumer goods, ii) public goods, iii) capital goods, and iv) non-market goods. Rainwater Harvesting from greenhouse tops is to be a technology that can be applied deployed at the exploitation level, whereas Rainwater Harvesting from Roads is a technology targeting collective users. The former embeds equipments for water drainage, storage and pumping to be purchased by the farmers from service providers. The latter technology requires more collective or public investments on capital goods like roads, drainage system, decantation lake and storage lake. Should harvested water be exclusively from public roads, and distributed for users by a public entity, it would be classified as a public good. In this case, roads are private to a group of farmers that will directly share the stored water among themselves therefore, the rainwater harvesting from roads has been classified as capital good. Water User Association, which is an organizational technology providing a service to user is considered as a non-market technology.

Fig. 64 - Technology classification according to type of goods for the water sector

Source: The author's own design

7.3.2 Methodology of identification of barriers and action plans

The barrier analysis of the proposed technologies was conducted based on literature review as well as group and individual consultations with key experts in the field, including the public institutions, research institutes, NGOs, service providers and direct beneficiaries (communities, farmers). The beneficiaries' feedback and participation was retrieved from direct meetings with pioneer farmers adopting one of the technologies, technicians of the Green Plan, the Litani River Authority and NGOs active in the sector. Questionnaires for beneficiaries involved in at least one of the technologies to analyze social acceptance and farmer's ownership were conducted along with this process.

A Cost Benefit Analysis (CBA) for the transfer and diffusion of the selected water technologies was also conducted. Since water pricing and monitoring are inexistent in Lebanon, the CBA was based on estimations and assumptions related to the potential revenues based on the crops related to the increased availability of water, or the incurred savings from using alternative water source. Water availability under a future climatic scenario with 20% reduction in water availability (MoE, UNDP, GEF, 2011) with or without adaptation is an additional pertinent method to show out the benefits of the technologies. A more in-depth CBA will be required to better estimate the real cost and benefit of adaptation of the water sector.

Finally, action plans specific to each technology were proposed to reach the targets of increasing water resources and optimizing water efficient use. These Technology Action Plans (TAP) were designed in a matrix that answers basic questions on the measures or activities to be conducted, their priority and their importance and responsibilities, The matrix included as well the time frame of these activities, the indicators for their monitoring and evaluation, estimated budget and finally the potential donors.

Note that many aspects are common to all technology action plans. In many cases, the same activities are to be conducted by the same actors for different beneficiaries under different technology action plans. Result-based indicators for monitoring and evaluation are proposed in most cases. Donors are common to all action plans as well. For this purpose, mainstreaming of efforts and coordination are highly required to achieve a maximum efficiency and effectiveness of the proposed action plans.

Fig. 65 - The different steps of the barrier analysis for transfer and diffusion of technologies of the water sector.

Source: The author's own design

7.4 Analysis of Technology: Rainwater Harvesting from Greenhouse tops (RWHG)

7.4.1 Description of technology

This technology is designed to collect rainwater from greenhouse tops, store it in earth concrete reservoirs, and use it for irrigating greenhouse crops. The technology is targeted for crops cultivated under greenhouses, and consequently has a defined limited market. RWHG increases the resilience of the crops as it ensures an autonomous reliable water resource of good quality, in periods of extended drought and increased salinity in ground and surface water. RWHG will sustain cropping in greenhouses, in areas where water availability and quality are becoming compromised by climate change in areas with significant precipitations (>600mm/year).

7.4.2. Identification of Barriers for Rainwater Harvesting from Greenhouse tops

The identified causes of the non diffusion of RWHG are diverse, with one killer barrier being the reduced cost-effectiveness of the technology when it is highly affected by limited rainfall or oppositely, the availability of surface water for irrigation at a much lower cost. Other key barriers include:

- Availability of surface water: in many irrigation schemes where water is available for free (mainly from surface water), farmers are not encouraged to invest RWHG (killer barrier).
- Limited rainfall: in areas where precipitations are below 600mm/year (killer barrier).
- Limited awareness: since RWHG is a new technology, both farmers and service providers are not necessarily aware of it.
- Absence of dissemination of the technology: since the few initiatives found are not yet transferred to farmers or promoted by any service provider.
- Limited quantity of harvested water: the farmer is not optimizing the use of limited quantity of water to make the system cost-effective through for example improper irrigation practices and cropping systems.
- Limited research and development: Plant water demand according to the climate variability especially for greenhouse crops and the offer illustrated by rainwater harvesting are not monitored.
- Limited spread of technology in market (service providers): as it is implemented individually by few farmers, service providers are not interested in such technologies.
- Limited available land for water storage: in small holdings in coastal areas where the available land is totally used for exploitation .
- Inappropriate land tenure system: as landowners do not rent land on a long term, farmers are less expected to invest in RWHG.
- High cost of land rental due to absence of land use zoning: farmers are driven to aim at maximum profit due to high cost of land, leaving less available surface on their exploitation for water storage. This is mainly caused to the improper land use zoning that does not valuate lands according to their end-use.

Linkages of barriers and their effects are shown in figure 66.

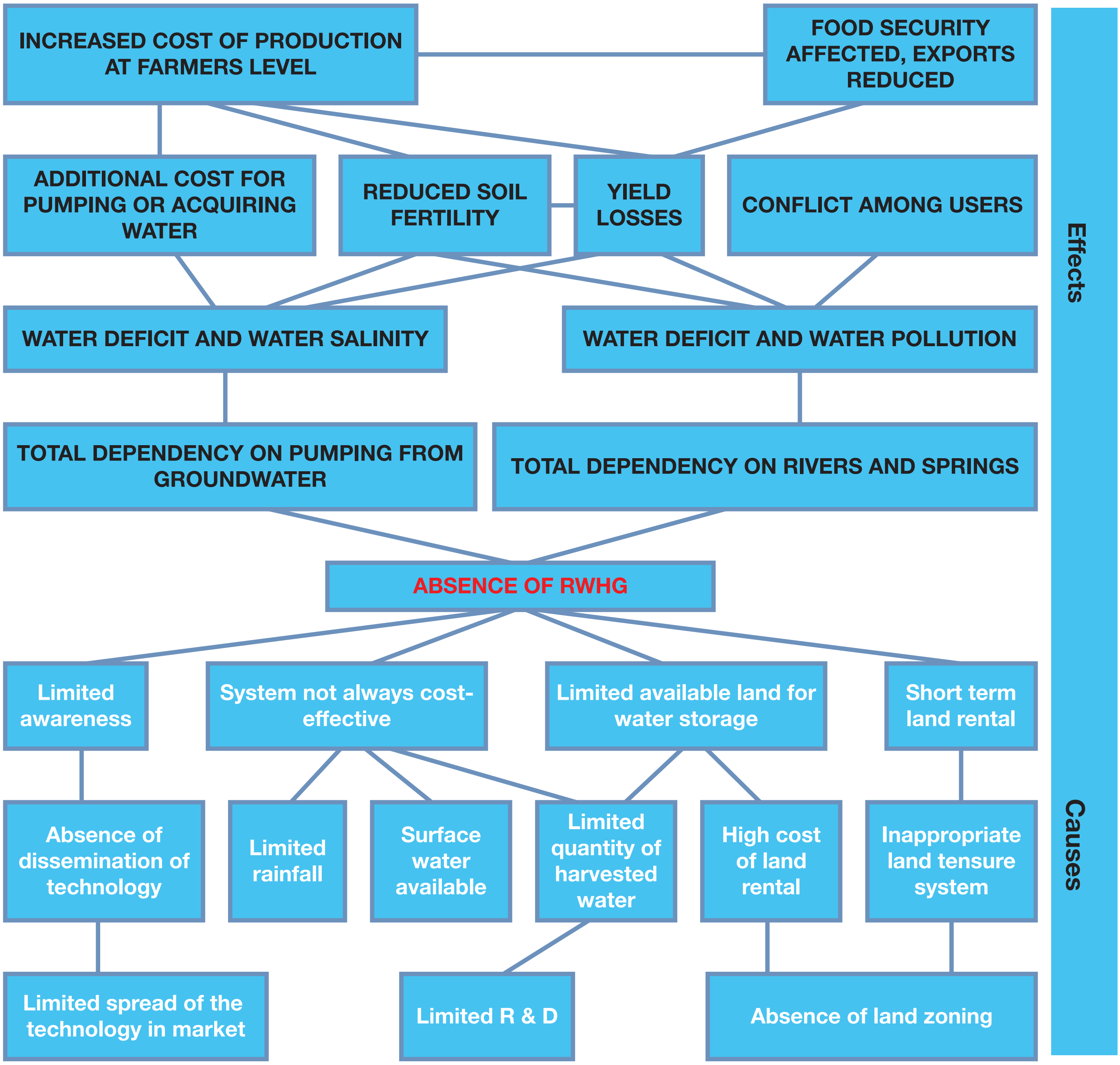

Fig. 66 - Problem tree for RWHG.

Source: Author's own design

7.4.3 Identification of measures for Rainwater Harvesting from Greenhouse tops

Measures to overcome barriers and to enhance the deployment of RWHG are to be conducted on two main axes: i) increase the awareness of farmers and ii) ensure a sustainable agriculture land management. Barriers related to short land rental constitute a more general and historical problem in Lebanon, while barriers related to system cost-effectiveness cannot be changed.

For the first axis, efforts on different levels should be implemented, including service providers' sensitization, and research and development programmes improvement. This will overcome the absence of the technology on the market and ensure scientifically proven information diffusion to farmers.

For the second axis, the initiation of a land use planning zoning to preserve agriculture land will enable overcoming barriers related to land tenure, land availability and short-term rental.

The key barriers and their respective solutions are mentioned in Table 77.

7.4.4 Cost Benefit Analysis for Rainwater Harvesting from Greenhouse tops

The estimated costs mentioned below are extracted from the AgriCAL project (Agrical, 2012) document and meetings with farmers (Sakr, 2012). Costs and assumptions are detailed as follow:

- Awareness raising - information transfer: USD 5,000.
- System Installation could be partially covered by Green Plan and be considered as public expenditure however these are site-specific and demand driven and cannot be accounted for at this stage.

Different scenarios are shown in Fig. 67 and Fig. 68:

- 100% pumping from ground water, in both high crop demand/low precipitation and low crop demand/high precipitation scenarios.
- 75% of Surface irrigation complemented by pumping in high crop demand/low precipitation scenario.
- 43% of Rainwater Harvesting from Greenhouse tops complemented either by surface water or pumping in high crop demand/low precipitation scenario.
- 100% of Rainwater Harvesting from Greenhouse tops in low crop demand/high precipitation scenario.

The deduced benefits are calculated by deducing only the cost of water from the revenue (USD 3,200/ year/greenhouse).

Table 77 – List of barriers and measures to overcome them for RWHG

Category	Barriers	Measures	Stakeholders
Information and awareness	- Limited awareness. - Absence of dissemination.	Awareness campaign.	MoA, Green Plan, farmers, media
Institutional and organizational capacity	-Limited Research and development. - System ineffectiveness. - Limited quantity of harvested water.	Conducting research and development programmes on RWH on farm level, on different storage variances for: i) better cost effectiveness, ii) optimizing stored water use according to climate demand and iii) selecting crops according to storage capacity.	LARI Academic institutions
Market failure	Limited spread of Technology in market.	Integrating RWHG system within greenhouse infrastructures deployed by the service providers.	Service providers
Policy, legal and regulatory	Short term land rental due to inappropriate land tenure system; - Limited available land. - High cost of land rental. - Absence of land use zoning.	Initiating land use zoning process, namely to protect the remaining agriculture areas on the coastal zone, where most greenhouses are located.	MoPWT (DGUP), CDR, Municipalities

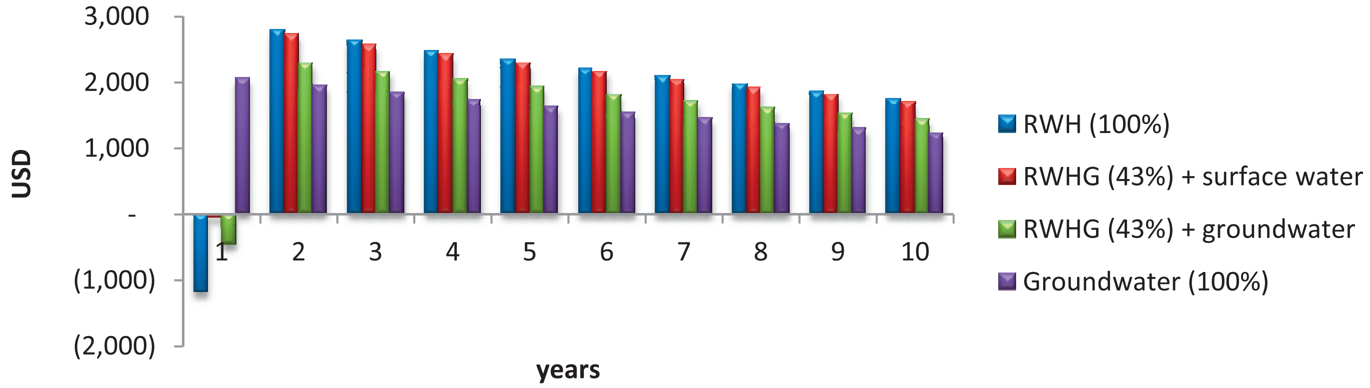

Fig. 67 - Discounted benefits over a period of 10 years for different water source scenarios

Source: Author's own design

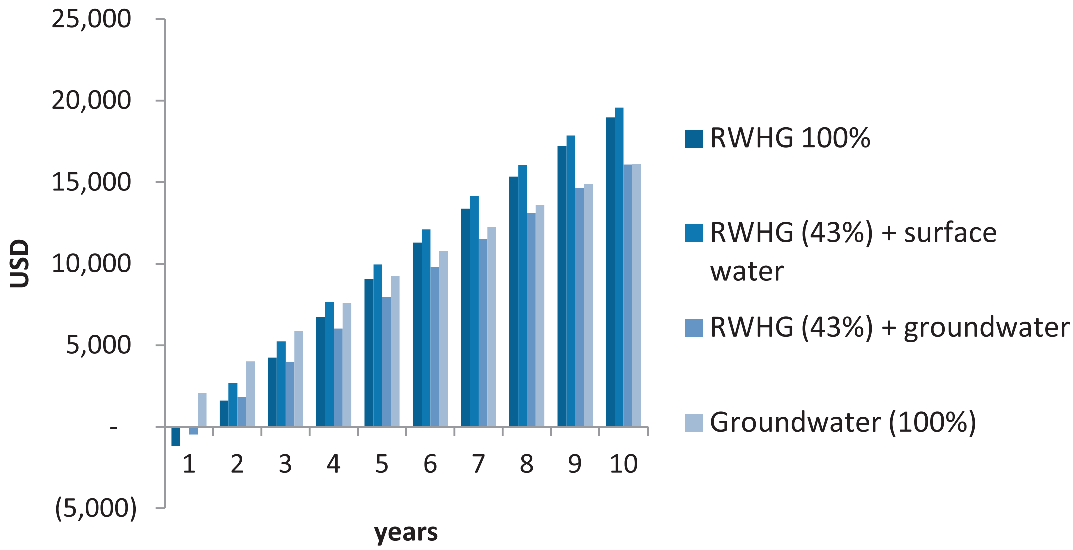

Fig. 68 - Cumulated discounted benefits over a period of 10 years from different water source scenarios

Source: Author's own design

Under all scenarios, RWHG is cost efficient to farmers, except if the farmer has a sustainable source of surface water of a standard quality all year round. Even if RWHG does not cover all the water demand, 43% of the water demand will keep the system cost-effective.

Beside the reduced costs from pumping, GHG emission is significantly diminished and the risk of water pollution and soil degradation is minimized if compared to other water sources. In addition, the farmer is more autonomous in terms of water supply and relies less on other fluctuating resources, which increases his resilience and reduces conflict risks among users. The farmer will preserve his water resources under future climate, which enables him to keep producing, and consequently sustain his revenue and food security.

Costs and benefits of RWHG are drawn in the figure below. From what is mentioned above, RWHG is feasible whenever it ensures a minimum of 50% of plant water requirements. RWHG is not cost-effective in areas where surface water is available for free.

7.4.5 Technology action plan for Rainwater Harvesting from Greenhouses

Target for technology transfer and diffusion

The target of the action plan is to be able to collect rainwater form 25,000 greenhouses (standard single span), between 2015 and 2025 considering that 50% of the total cost is subsidized.

The technology action plan for the diffusion of the Rainwater Harvesting from Greenhouses technology is presented in Table 78.

Assumptions for Rainwater Harvesting from Greenhouse tops

- An annual average rainfall of 600mm are necessary to cover from RWHG, water demand for the crops inside a greenhouse.
- A storage unit can be used for irrigation before being totally filled, which supposes that a storage unit could be filled twice a year.
- The annual demand of a standard greenhouse of 400m^2 is between 360 and 550m^3 depending on the crop type and microclimatic conditions.
- The collected water from a standard greenhouse is 240m^3 for an area with average precipitations of 600mm/year, up to 400m^3 in areas having 1,000mm/year of rainfall.
- The storage unit of a greenhouse should have a minimal capacity of 125m^3 (half of the annual water demand) in exploitations with limited land available.
- Cost of storage unit is USD 16/m^3 in earth reservoirs. The economy of scale is not accounted.
- Cost of drainage system (USD 30/m) or USD 1,200/greenhouse. This can be reduced by half in "Chappelle" system. To add USD 180/greenhouse for service providers' technical assistance.
- Current maximal cost of land rental (value of area dedicated for earth reservoir): USD 1/m^2/year. The economy of scale is not accounted.
- Pumping cost is USD 1.833/m^3 at 500m altitude, on a deep water Table.
- In this exercise we consider that the price is the same even next to sea level where water Table is shallow, in order to value the poor quality of water (salinity).
- Surface water annual fees in a common irrigation scheme are USD 100/year. We assume that this water is rarely available all year round due to several reasons (water shortage, leakage problems, water pollution, etc.).
- A greenhouse produces 4 tonnes of crops, sold at USD 800/tonnes, generating a revenue of USD 3,200/ha/year.

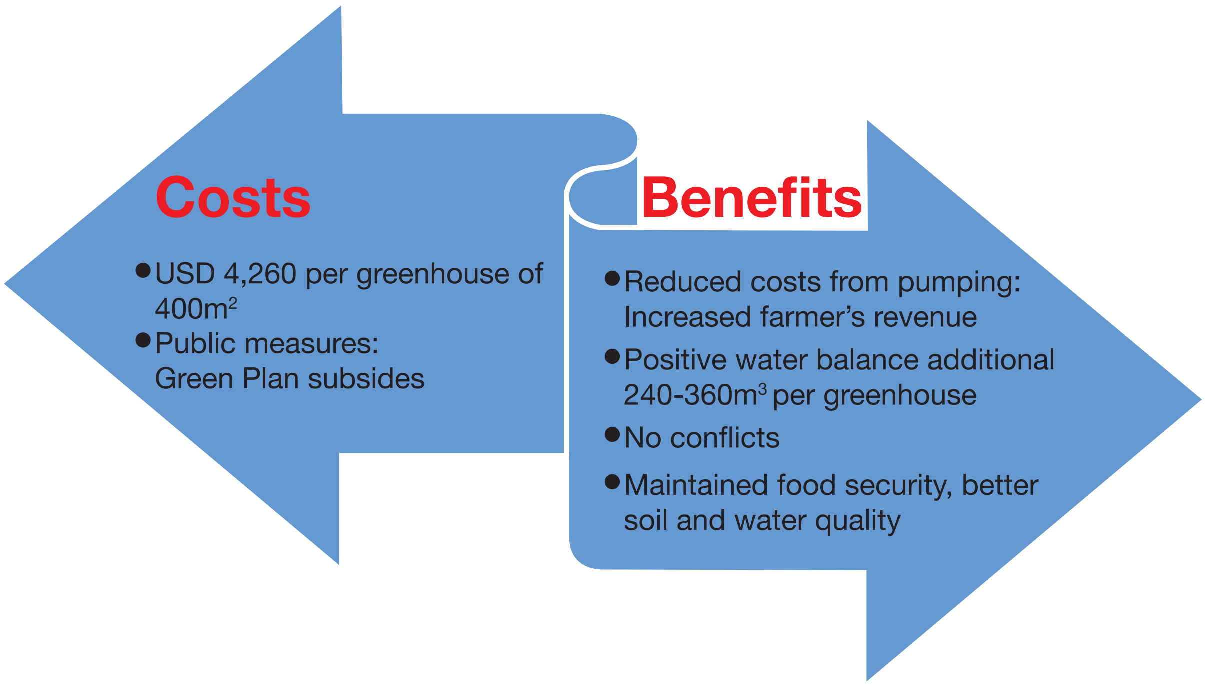

Fig. 69 - Cost and Benefits of RWHG

Source: Author's own design

Table 78 - Technology Action plan for Rainwater Harvesting from Greenhouses

Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring and Evaluation indicators	Estimated cost (USD)	Donors
Organizing awareness campaign through seminars, field visits and TV programmes	1	To disseminate the information and promote RWHG to farmers.	National experts, MoA extension service, media, Green plan	Service providers technicians, farmers	Medium term	Number of farmers demands at Green Plan for installing RWHG system.	5,000 for 3 seminars, 3 field visits and a TV program.	World Bank Adaptation Fund GEF IFAD FAO Islamic Bank EU USAID Kuwaiti Fund Italian, Spanish Cooperation.
Conducting experiments on farm level, on different storage variances	2	To increase information about the optimal use of RWHG for better resilience to climate, better water efficiency and optimal cost effectiveness.	Research centers and academic institutions	Farmers	Medium term	Number of experiments conducted and number of publications; Increase in the number of greenhouses adopting RWHG according to the crop; calculation of water efficiency for different crops in greenhouses adopting RWHG.	15,000 to conduct research at farm level: a one-year full study for 3 type of crops in two climatic zones (two researchers plus inter students).	
Integrating drainage system in the design of greenhouse	2	To avoid market failure and reduce the cost of the infrastructure.	Service providers	Farmers	Short term	Number of greenhouses produced with drainage system by service providers.	0	
Initiating land use zoning process	1	To protect the remaining agriculture areas on the coastal zone, where most greenhouses are located.	DGUP	Farmers, municipalities	Long term	Number of municipalities having land use zoning agriculture surface preserved on coastal areas.	0	
Increasing Green Plan budget for implementing water reservoirs for RWHG	2	To avoid budget constraints at farmers level to implement RWHG.	Government, Green Plan	Green Plan, farmers	Medium term	Funds allocated for water reservoirs for RWHG; number and their capacity of achieved reservoirs.	2,000,000 annually covering 50% of the cost of reservoirs with a capacity of 500,000 m^3.	

7.5 Analysis of Technology: Rainwater Harvesting from Roads (RWHR)

7.5.1 Description of technology

Rainwater harvesting from all type of roads, in agriculture area, enables collecting water from surface runoff on the roads, and the upstream. Water is carried through the drainage system to a decantation earth lake then stored in another lake. Water is further pumped and distributed to the farmers/fields surrounding the road. Targeted roads are both asphalted or agriculture roads, which consequently involves a larger number of stakeholders. These include different public institutions, including the Ministry of Public Works (with its main directorates for public works and urban planning), the Ministry of Agriculture, the Ministry of Interior and Municipalities, the Ministry of Finance, the CDR and the Green Plan. Landowners of contingent lots to the road as well as farmers are also concerned.

This technology is usually being promoted to increase the resilience of the local agriculture communities to climate change. The harvested water could be allocated for either agriculture or domestic use, as well as for recharging the aquifers. In this chapter, water is only considered for agriculture use. This technology has a potential to increase crop adaptation to climate change by ensuring additional water resource for irrigation, in areas with significant precipitations or surface run-off.

7.5.2 Identification of Barriers for Rainwater Harvesting from Roads

Several barriers hinder the deployment of RWHR, however they all have a major root cause related to the absence of institutional and financial arrangements to ensure the necessary budget, to inform the local authorities about the importance of RWHR, improve public works quality, undertake adequate urban planning and road design and ensure the necessary land for water storage. The list of key barriers identified for RWHR is as follow:

- Limited awareness: farmers and technicians are not aware of the potential benefits of RWHR.
- Inappropriate road design: roads are not designed to enable water catchment through drainage system.
- Additional cost for infrastructure: collecting, converging and storing water requires additional cost.
- Drainage not accounted in public works: most roads have no drainage system.
- Topography constraints: many roads are designed and constructed in areas where water harvesting is limited due to the topography of the terrain.
- High cost of land acquisition: acquiring land for water storage in urban and peri-urban areas is almost impossible due to the high cost of land.
- Presence of roads in private lands: most agriculture roads or urban roads are totally private which requires the permitting of the owners to undertake the necessary works.
- Limited information on drainage impacts at authorities' level: most municipalities are not aware of the cost of floods and transport deficiency due to the absence of rainwater drainage system.
- Restricted professional Contractors: most contractors for minor scale public works are not backed up by professional engineers to follow works onsite.
- Inappropriate urban planning or land use management: most roads do not have water catchment or enough space to implement RWHR.
- Scarcity of funds: funds for adapting road design to RWHR are not allocated.
- Insufficiency in financial and institutional arrangements: RWHR is not accounted in the tender dossiers and budget allocated for road construction.

Linkages between barriers are illustrated in the figure below:

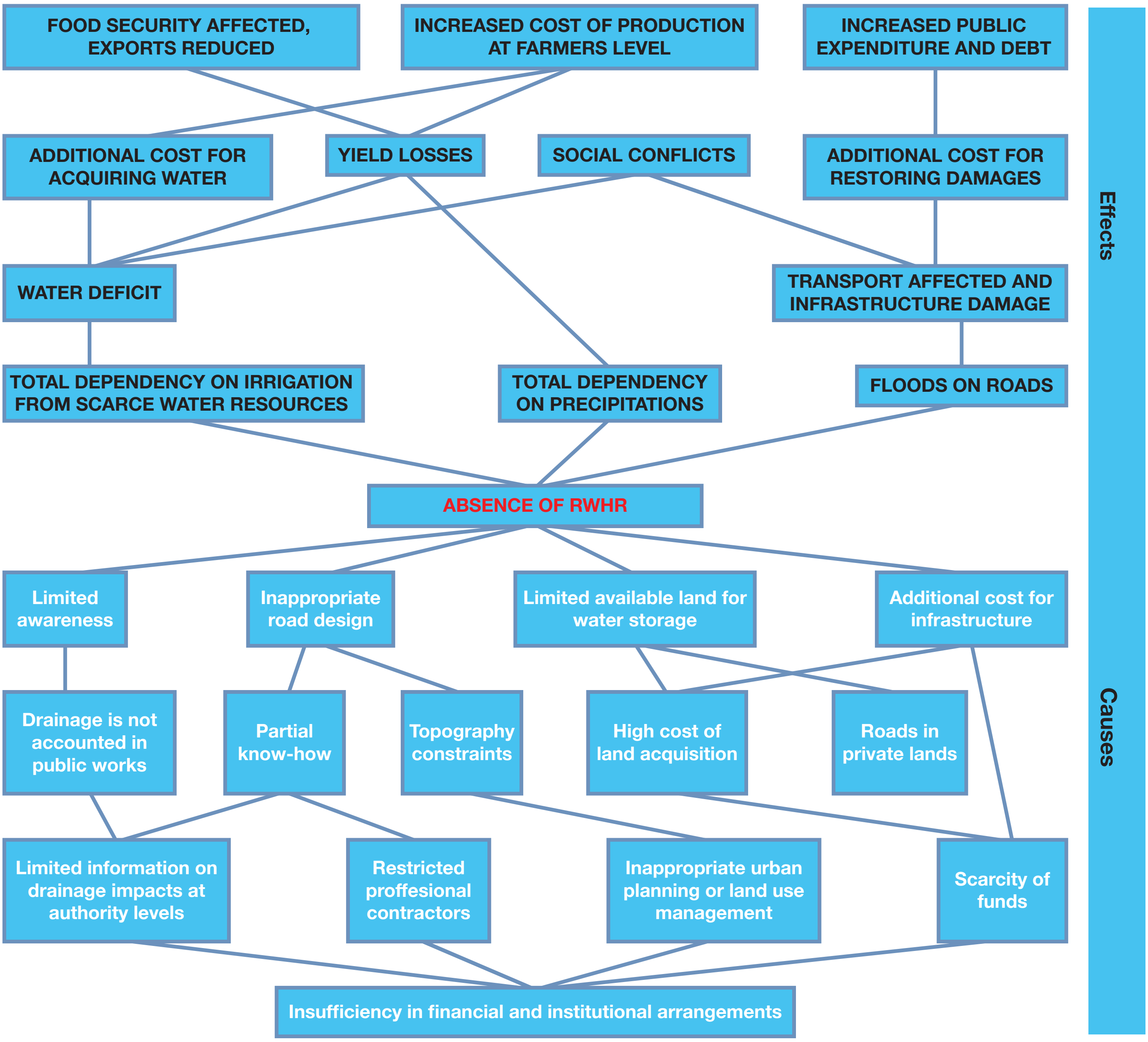

Fig. 70 - Problem tree of RWHR.

Source: Author's own design

7.5.3 Identification of measures for Rainwater Harvesting from Roads

A first initiative for rainwater harvesting from roads is currently being undertaken by EFL with the municipality of Bchaaleh in North Lebanon to install a drainage system and decantation and storage units in the area and to sell water to the community at a competitive price. This initiative has served in this analysis for the collection of concrete information on barriers and cost analysis.

On a communal scale, barriers are minimal when rainwater is harvested from municipal and public roads, the topography usually enables optimizing water harvesting and installing the system, and land is available for digging and establishing the decantation and storage units. Water distribution, system maintenance and economical sustainability are usually covered by the municipality.

If the selected road is private, and shared with many owners, barriers to overcome are related mostly to land availability and the willingness of the owners and users to participate. Funds are lacking and difficult to access. Therefore, institutional arrangements for the entities responsible on the execution of such works (i.e. MoPWT, CDR, Green

Plan) enabling designing roads for RWHR and allocating the necessary funds is a major step to overcome barriers to transfer and diffusion. An example of creating an enabling environment is the Green Plan which creates agriculture roads on a demand-driven basis. This approach overcomes barriers related to land availability and land use, as well as conflicts among land owners.

The list of barriers and their respective measures are listed in Table 79.

7.5.4 Cost benefit analysis for Rainwater Harvesting from Roads

The expected public expenditure mentioned below is extracted from the AgriCAL project document (Agrical, 2012) and based on bilateral meetings with Green Plan technicians and EFL (EFL, 2012; Greenplan, 2012):

- Institutional arrangements: USD 5,000.
- Implementing regulations for road design and norms: USD 10,000.
- Installation of financial mechanism: USD 5,000.

Based on these assumptions, RWHR is viable within a period of 14 years as illustrated in Table 80. Benefits are expressed in terms of horticulture crops sold in the additional irrigated area from RWHR. An increase in higher surface run-off or higher precipitation will increase the cost-effectiveness of RWHR.

Table 79 – List of barriers and measures to overcome them for RWHR

Category	Barriers	Measures	Stakeholders
Human skills	Partial know-how; Restricted professional contractors.	Training of technicians of concerned actors; Enhancement of a sound control of works.	Green Plan, MoPWT, Municipalities
Information and awareness	Limited awareness; Limited information on drainage impacts at authorities' level.	Awareness campaign at Municipalities level about RWHR, and land use and urban planning.	Municipalities, DGUP
Institutional and organizational capacity	Drainage is not accounted in public works.	Road designs elaborated by concerned Ministries, Green Plan and Municipalities taking drainage system into account.	Green Plan, MoPWT, MoIM
Technical	Topographic constraints.	Elaborating proper urban planning and road designs.	Municipalities, DGUP, MoPWT
Economic and financial	Additional cost for infrastructure; High cost of land acquisition (private land); Scarcity of funds.	Budget allocated for Green Plan, MoPWT and Municipalities to implement RWHR.	Municipalities, Green Plan, CDR, MoIM, MoF, MoPWT
Policy, legal and regulatory	Inappropriate road design; Limited available land for water storage Inappropriate urban planning or land use management; Insufficient financial and institutional arrangements.	Conduct the necessary arrangements for budget allocation and the elaboration of regulations and norms for roads and RWHR; Implement a process of land use planning in concerned areas.	MoF, MoIM, Green Plan, DGUP, MoPWT

Assumptions for RWHR

- Road slope > 5%
- Road length: 1,000m
- Road width: 6m
- Rainfall: 0.8m/year
- Additional water coming from upstream >50%
- Losses in infiltration : 20%
- Losses in evaporation during storage: 15%
- Water available for irrigation: 4,900m^3
- The expected costs per road are:
  - Road design for RWH (drainage system): USD 1,025/m
  - Decantation unit including sieves, filters and pumtps: USD 2,500
  - Digging earth for storage: USD 8/m^3
  - Vehicle for water distribution: USD 40,000
  - Annual maintenance of system: USD 250
  - Annual cost for water distribution: USD 150
- The stored amount will produce 20t of agriculture products, with an average value of USD 800/t

Table 80 - Cost benefit analysis for RWHR over a period of 14 years for a 1km road serving

	Revenues without RWHR	Revenues under RWHR	Additional revenue under RWHR	Additional costs from RWHR	Net benefits from RWHR	Discounted net adaptation benefits (6%)
	A	B	C=B-A	D	E=C-D	F=E/(1+0.06)^{yr}
Year	USD/ha	USD/ha	USD/ha	USD/ha	USD/ha	USD/ha
1	0	16,000	16,000	-137,480	-121,480	- 114,604
2	0	16,000	16,000	400	15,600	13,884
3	0	16,000	16,000	400	15,600	13,098
4	0	16,000	16,000	400	15,600	12,357
5	0	16,000	16,000	400	15,600	11,657
6	0	16,000	16,000	400	15,600	10,997
7	0	16,000	16,000	400	15,600	10,375
8	0	16,000	16,000	400	15,600	9,788
9	0	16,000	16,000	400	15,600	9,234
10	0	16,000	16,000	400	15,600	8,711
11	0	16,000	16,000	400	15,600	8,218
12	0	16,000	16,000	400	15,600	7,753
13	0	16,000	16,000	400	15,600	7,314
14	0	16,000	16,000	400	15,600	6,900
Benefits					81,320	
NPV						15,681

7.5.5 Technology Action Plan for Rainwater Harvesting from Roads

Target for technology transfer and diffusion

Since the establishment of agriculture roads and water harvesting equipments are demand driven under the Green Plan's policy, the target for the below action plan (Table 81) is to achieve RWHR over 50km of roads between 2015 and 2025. Beneficiaries will be farmers having their exploitations along these roads. The estimated cost is USD 70,000 per 1Km of roads, or 3.5 million USD to achieve a target of 50km over a 10-year period.

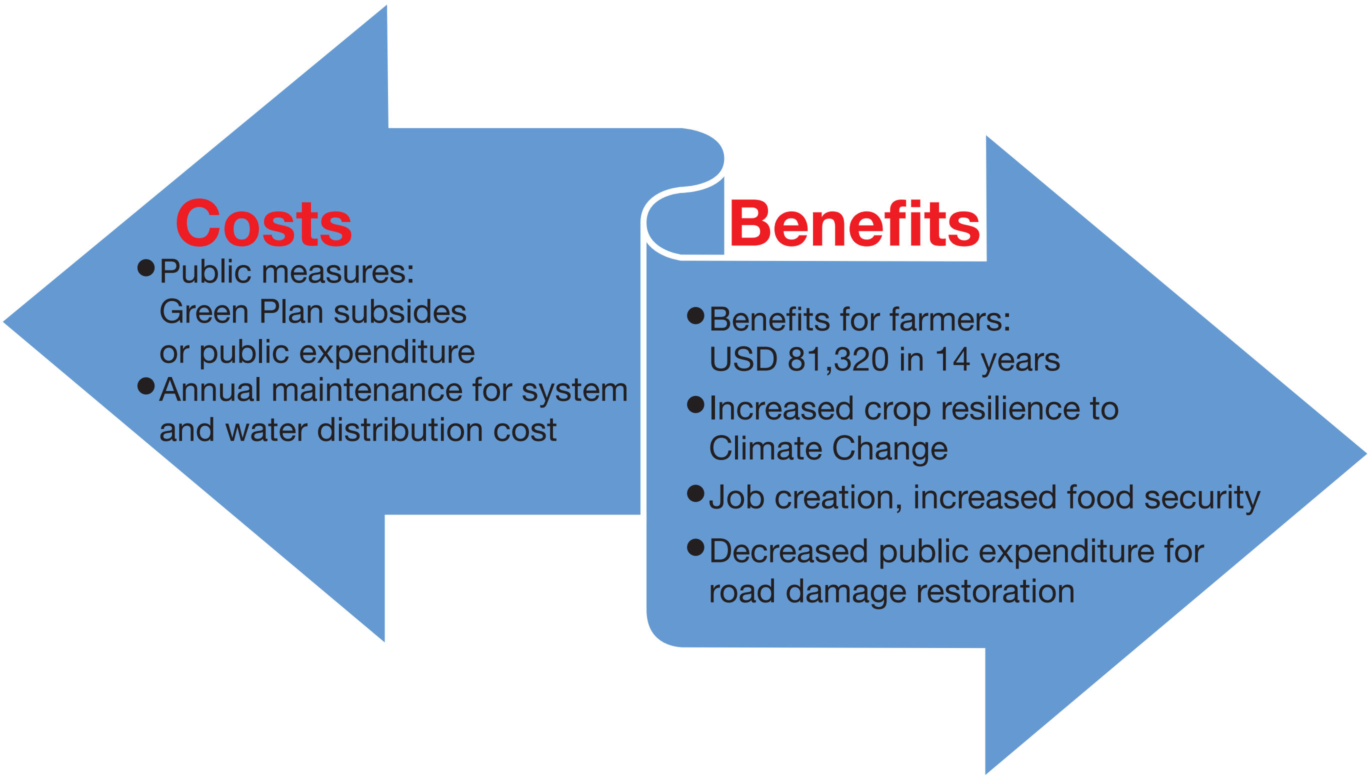

Fig. 71 - Cost and benefits of transfer and diffusion of RWHR

Source: Author's own design

Table 81 - Technology Action plan for Rainwater Harvesting from Roads

Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)	Donors
Training of technicians at the order of engineers	1	To be able to adapt road design for RWHR.	National experts	Green Plan; CDR; MoPWT; DGUP; Orders of engineers	Short term	Number of trained technicians able to create new road designs.	2,000 to train 10 technicians	World Bank Adaptation Fund GEF IFAD FAO Islamic Bank EU USAID Kuwaiti Fund Italian, Spanish Cooperation
Elaboration of adapted tender documents control construction works	3	To be able to control public works according to set standards and design.	CDR, MoPWT, Green Plan, Municipalities	Public, farmers, municipalities, Government	Medium term	Number of roads according to preset design.	0	
Awareness raising through Seminars, bi-lateral meetings, TV program	1	To better understand the impact of rainwater and flood risk, drainage, and the importance of RWHR and to avoid market failure and enhance RWHR from existing and planned roads.	Trained technicians, media	CDR; Municipalities; MoPWT; DGUP; public work contractors	Long term	Number of demands for roads with infrastructure for RWH and drainage in municipalities, and demands for urban planning and zoning.	3,000 for 3 seminars and a TV program	

Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)	Donors
Elaborating terms of references with technical specifications for new road designs.	2	To set standards for road design, in order to enable RWHR and reduce floods in urban areas.	CDR; MoPWT; Green Plan and Municipalities	Public, farmers, municipalities, Government	Medium term	Tender dossier and technical specifications elaborated.	0	
Conducting arrangements for budget allocation and creation of a financial mechanism	2	To ensure the extra funds for achieving the required infrastructure and land acquisition for water storage and to maintain the system.	Government, MoF, MoIM, CDR; national financial expert	MoPWT, Municipalities, Green Plan	Long term	Budget allocation for RWHR within the annual budget of the beneficiaries.	5,000 for the charges of the financial expert	
Re-considering urban planning and land zoning upon request of municipalities	3	To overcome the limited availability of land for water storage and ensure the sustainability of agriculture land benefiting from RWHR.	DGUP	Municipalities, farmers	Long term	Number of municipalities having land use zoning and urban plans.	0	

7.6 Analysis of Technology: Water Users Association (WUA)

7.6.1 Brief description of the technology

A Water User Association is an organization for water management made up of a group of small and large-scale water users, such as irrigators, who pool their financial, technical, material, and human resources for operation and maintenance of a local water system, such as a river or water basin. The association plays a key role in integrated approaches to water management that seek to establish a decentralized, participatory, multi-sectorial and multi-disciplinary governance structure.

The objectives of a WUA commonly include: i) Conservation of water catchments, ii) Sustainable water resource management, iii) Increase availability of water resources and, iv) Increase the usage of the water for economic and social improvements. Its core activity is to operate the waterworks under its responsibility and to monitor the allocation of water among its members. WUA is hence different from the traditional "water committee" that used to manage spontaneously without any institutional or scientific support water distribution in common water sources in villages, and that was prohibited recently by law.

7.6.2 Identification of Barriers for Water Users Association

The key barriers, as illustrated in the problem tree illustrated in Fig. 72, are as follow:

- Difficulties in managing a common water resource: Farmers individualism and the difficult distribution of roles, costs and water amount among users are the main barriers which is behind the failure of the resolved local water committees in some watersheds in Lebanon.
- Limited social acceptance for water pricing: legal pricing is difficult to adopt due to religious tradition imposing water as a free resource for all. The current symbolic water usage fees are not enough for water monitoring, covering the fees of maintenance of the distribution system and monitoring of water flow amongst users.
- Insufficiency in water laws: such as "Water Act" setting the basis of modern WUA, knowing that Law 221 merged all local water committees under regional committees. One law in 1943 enabled the creation of a "water syndicate" however this law became obsolete with time.
- Limited awareness at social (water users) and decision maker's level: the social perception is incrusted into the old "water committees" and stakeholders are not aware of WUA existence.
- Inherited sharing rights: the "water turn" and share is based on inherited number of hours per week or month, which does not enable irrigation on a daily basis or based on climatic demand.
- Scarce human skills to manage WUA: where the required skilled human resources are limited
- Unsuitable university curricula: the lack of knowledgeable engineers capable of running a WUA is due to the absence of appropriate university curricula for water management
- Absence of institutional support: No clearly defined institutional body organizes WUAs and supervises their work.
- Limited institutional and financial arrangements: for funding irrigation distribution schemes and for implementing a university curriculum on WUA, as well as making the necessary law amendments enabling the creation of WUA.
- Limited enabling structure for water monitoring: water distribution system, pressurized with counters is essential for water flow and distribution monitoring.
- Deficit funds: to establish water distribution networks and monitoring system.
- Low revenues: farmers with their modest income are not able to fund the installation of water distribution networks or to cover upgrade and maintain the existing network.

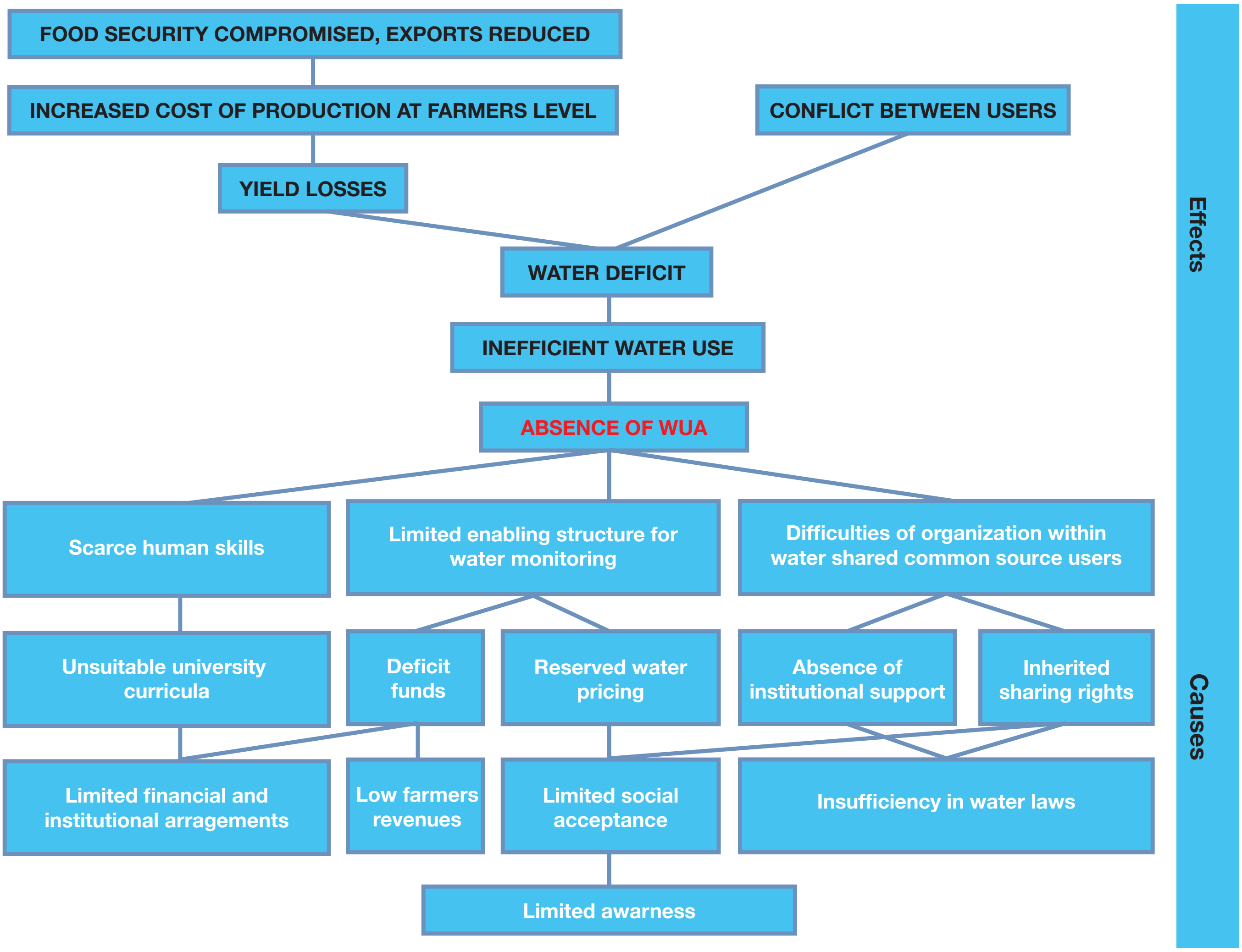

Fig. 72 – Problem tree of WUA

Source: Author's own design

7.6.3 Identification of measures for Water Users Associations

As Water User Association has several barriers, the measures to overcome these barriers should be performed through a mainstreaming process to boost the transfer and diffusion of WUA.

These measures include activities on the social and behavior aspects of the local communities, in regard to enhancing communal thinking, understand the impact of climate change and the positive aspects of WUA, improve social acceptance towards water pricing and institutional and organizational arrangements related to inherited share rights in collective water springs. For this purpose, Media, LRA, MoEW, MoA and NGOs are all involved and should synchronize their activities for better efficiency.

A particular attention should be given to capacity building of technicians and human skills, starting from an adequate curriculum at university level to specialize engineers in water and WUA management.

Finally, all efforts should be backed up by a legislative framework capable of initiating an institutional support for WUA, a water law and the necessary institutional and financial arrangements for WUA creation and establishment of the infrastructure for water distribution.

These barriers and the measures to overcome them are illustrated in Table 82.

Table 82 – List of barriers and measures to overcome them for WUA

Category	Barriers	Measures	Stakeholders
Human skills	Scarce human skills to run WUA.	Introducing the WUA management skills and concept within the curricula of agriculture/natural resources management faculties.	Academic institutions
Information and awareness	Limited awareness at social (water users) and decision maker's level.	Awareness campaign about the importance of WUA in relation to water management as an alternative to water committees.	Media, MoEW, LRA, MoA, Municipalities
Social, cultural and behavioral	Limited social acceptance for water pricing or to change inherited sharing rights, absence of communal thinking; lack of trust among users.	Awareness raising at social level, to show the importance of WUA, and the positive impact of changes related to water pricing and inherited sharing rights.	Media, water share owners and users
Institutional and organizational capacity	Lack of organization among users sharing a common water resource.	- Promoting communication among actors. - Capacity building/lobbying at all levels to boost arrangements enabling the installation of WUA, and enabling good governance for water resources.	Media, MoEW, LRA, MoA, Municipalities, farmers (water users)
Policy, legal and regulatory	Insufficiency in water laws; Absence of institutional support; Unsuitable university curricula.	Reviewing actual laws, do the necessary amendments, and elaborate the legislative framework for WUA. - Assigning a legal body to enable institutional support. - Introducing WUA concept in university curricula.	MoJ, MoEW, LRA
Economic and financial	- Reserved water pricing. - Limited financial arrangements for infrastructure and university curricula. - Low revenues of users. - Deficit funds.	Elaborating a cost-effective financial mean that could be an alternative to water pricing for implementing the necessary water distribution infrastructure.	MoF, MoEW, LRA

Assumptions for WUA

- Target area to reach in irrigation schemes under WUA: 5000ha
- There is no change in the cost of production assuming that the contribution fees of the farmer are covered by the spared cost of labor for irrigation, weed control…
- Farmers will use efficient irrigation systems on farm, that they will install on their own
- Estimated yield improvement: 4.5t/ha for irrigated horticulture crops and fruit orchards
- Estimated crop price: USD 800/t
- Water used for surface irrigation without WUA: 8,000m^3/ha, while under WUA, there are at least 2,000m^3/ha of saved water.
- Water sources are expected to be 10% less by 2040 and plant needs higher by 5%
- Plant water demand (6,000m^3/ha) is estimated to increase by 5% by 2040

7.6.4 Cost benefit analysis for Water Users Association

Meeting with relevant stakeholders (CDR, 2012; MoA, 2012; and LRA, 2012) enabled the estimation the costs of these measures as follow:

- Awareness at community level: USD 50,000.
- Lobbying, information diffusion at decision makers' level: USD 20,000.
- Review of laws, law amendments and elaboration of "water act": USD 50,000.
- Introducing the WUA and water management concept within university curricula: USD 10,000.
- Elaborating a study for alternative funding mechanism: USD 10,000.

Establishing the water distribution infrastructure (outside farm gate): USD 180/ha for a target area of 5,000ha of irrigated schemes: USD 900,000

Hence the total cost for deploying WUA is USD 1,040,000.

Following the assumptions mentioned above, water availability under the current conditions and by 2040, with or without WUA is expressed in Table 83.

The benefits will be:

- Reduced water losses from 50% to less than 10% with water savings and additional resources available even by 2040 (currently 1 million m^3 and 450,000 m^3 by 2040).
- Improved yields by 15% from water monitoring according to climate demand.
- Enabled use of efficient irrigation system (drip): water efficient use up to 90% on farm level, labor reduced, less energy and labor for weed control, etc. (This will not be accounted in CBA, as we assume the farmer will invest in drip system, and get the benefits of it, independently from the measures).
- Increased revenues by USD 4,000,000/year for 5,000ha with WUA.

Table 83 – Water balance in m^3 with or without WUA under current and future scenario

		Available water (m^3)	Water used for irrigation (m^3)	Plant need (m^3)	Water losses (m^3)	Water balance (m^3)
2012	Without WUA	40,000,000	40,000,000	30,000,000	-10,000,000	0
	With WUA	40,000,000	30,000,000	30,000,000	0	10,000,000
2040	Without WUA	36,000,000	36,000,000	31,500,000	-4,500,000	0
	With WUA	36,000,000	31,500,000	31,500,000	0	4,500,000

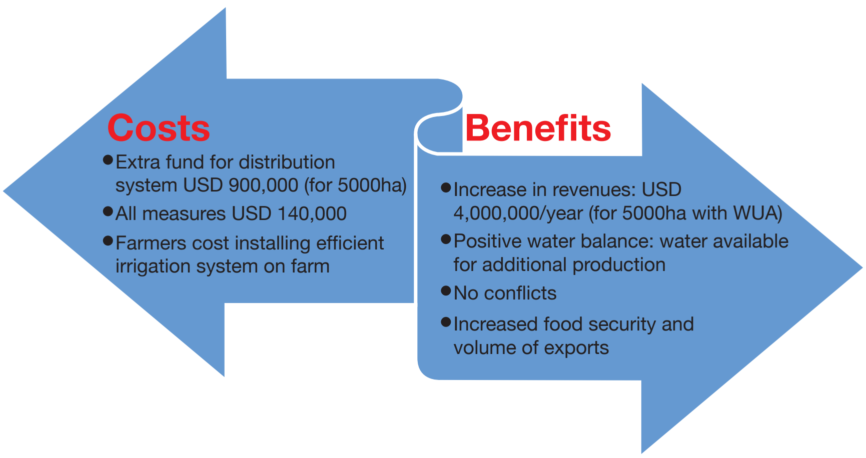

Fig. 73 – Costs and benefits of WUA

Source: Author's own design

7.6.5 Technology Action Plan for Water Users' Association

Target for technology transfer and diffusion

The overall target is to apply the concept of WUA in irrigation schemes totaling 5,000ha between 2015 and 2025. The estimated budget for the deployment of WUA and its diffusion is USD 1.04 million, out of which USD 900,000 are for water distribution and monitoring infrastructure. The technology Action plan for water users association is presented in Table 84.

7.7 Linkages of identified barriers

The lack of awareness at different levels of the ladder of responsibilities is the most common barrier for the three technologies, along with the abscence of land use planning and zoning and the high cost of land, as land rental for a long term period is difficult under the current land tenure system. Budgetary requirements for the necessary infrastructure for water storage or distribution are also a common aspect between RWHR and WUA. This offers the opportunity of tackling barriers like water pricing and water laws deficiency. The major actors concerned in overcoming these barriers are: the Ministry of Energy and Water, the Ministry of Agriculture, the Ministry of Justice, the Ministry of Public Works and Transport (namely the Directorate of Urban Planning), the Ministry of Finance, the CDR, the Green Plan and the Litani River Authority.

7.8 Enabling Framework for overcoming the barriers in the water sector

The prioritized water technologies have different aspects. RWHR which is a public good requires the ownership of the relevant responsible implementing bodies. In the scope of this report, RWHR is addressed with the Green Plan. This institution which implements agriculture roads based on farmers' demand is fully supportive to adopt the technology, and ensure partial funding for RWHG (for water storage units). Nevertheless, Green Plan capacity to absorb additional projects is limited due to its limited capacity to conduct large projects. Internationally assisted projects as well as the capacity building of the institution are necessary.

RWHG which has a simple market chain reduced to the farmers and service providers could be enhanced by the promotion of the technology as a whole package with the installation of greenhouse and irrigation infrastructures.

WUA is an organizational technology involving different public institutions including MoEP, LRA, CDR and MoA that are acting at different levels (water collection and distribution, water monitoring and water use). A principle milestone is related to the definitions of roles and responsibilities of all actors, through appropriate legislative framework, enabling the creation of WUAs. Further, a participatory top-down approach to ensure social acceptance is a must in order to resolve difficulties related to users organization, water pricing and inherited water sharing rights.

Table 84 - The technology Action plan for Water users Associations

Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)	Donors
Introducing the WUA concept within university curricula after approval by Ministry of Education	2	To ensure qualified technicians in WUA and related fields.	International expert MoEducation	Agriculture and natural resources management faculties (LU, AUB, USJ, USEK); students	Long term	Number of students attending courses related to WUA, water management and related fields	10,000 for the charges of the expert	World Bank Adaptation Fund GEF IFAD FAO Islamic Bank EU USAID Kuwaiti Fund Italian, Spanish Cooperation
Awareness campaign through the organization of workshops and TV programmes	1	To increase awareness and information about WUA as an alternative to water committees; to show the importance of WUA and the positive impact of changes related to water pricing and inherited sharing rights and gain social acceptance.	National and international experts, LRA, FAO, NGOs	MoEW, MoJ, MoA, CDR, MoIM, municipalities, farmers (water share owners and users)	Medium to long term	Number of meetings and attendance of concerned parties to workshops; Number of demands for the creation of WUA by water users	50,000 for the charges of experts, 3 workshops for technicians and decision makers, 10 seminars for water users	
Capacity building of farmers and and lobbying at all levels	3	To establish a coordination mechanism leading to the installation of WUA and familiarize all stakeholders with team work and communication.	National and international experts, LRA, FAO, UNDP	MoEW, MoJ, MoA, CDR, MoIM, municipalities, farmers (water share owners and users)	Short to medium term	Number of meetings and attendance of concerned parties; Project law proposal enabling the creation of WUA; Number of effective WUA	20,000 for the charges of experts, 3 workshops and 5 bilateral meetings	

Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)	Donors
Proposing a law for WUA and lobbying for adoption by council of ministers	2	To enable institutional support.	National and international experts MoJ, MoEW, MoA, LRA Parliament	Farmers (water share owners and users)	Medium to long term	Law amendments enabling the creation of WUA: Executive decrees and terms of references the responsible organism for institutional support; regulation of shares of common water sources	50,000 for the charges of the experts and the cost of workshops	
Preparation of feasibility study and financial mechanism for WUA	3	To find an alternative to water pricing for implementing (and maintain) the necessary water distribution infrastructure.	National and international experts, LRA, FAO, UNDP, MoF	Created WUA (water users), MoEW, CDR	Long term	Feasibility study report; budget allocated for the creation of water distribution infrastructure; annual financial report of WUAs	10,000 for the charges of the experts	
Establishing the water distribution infrastructure	2	To enable water distribution, monitoring and water efficient use (outside farm gate).	MoF, CDR, MoEW, LRA	Created WUA (water users)	Long term	Length and capacity of created water distribution infrastructure; area covered under effective WUA	900,000 for a target area of 5,000 ha	