The Agriculture Sector

6.1 Sector overview

The geographical situation of Lebanon and its topography offers the possibility of diversifying agriculture production. Five agro-climatic zones characterize the country: On the coastal strip, tropical crops, citrus and horticulture crops are grown. On the lower altitudes, olive, grape and other Mediterranean crops are predominating. Temperate fruit orchards cover the middle altitudes, while field crops, grapes and fruit orchards are biggest in central and western Bekaa. Northern Bekaa with large marginal lands has few irrigated crops and rainfed cereals or fruit trees. The total cultivated area is 277,169ha out of which 58,600 ha of olive trees, 77,100ha of other fruit trees, 69,600ha of cereals and 41,700ha of vegetable crops (MoA, 2007). Half of the agriculture surface is irrigated and only 2% of it is protected under greenhouses and tunnels. Irrigated crops are mainly vegetables and fruit trees, whereas rainfed cropping characterizes mostly olive tree, tobacco, cereals and legumes. The major agriculture areas of the country are located in the Bekaa (38% of the arable land) and North Lebanon (28%). Lebanese exports accounted to some USD 140 million in 2007 and mostly comprise fruit and vegetable crops. However, Lebanon relies on food imports to satisfy the local demand. Imported fresh food products reached USD 583 million for the same year (MoA, 2007). Therefore, the food security balance is chronically negative in the country, and the agriculture sector only contributes 5.5% of the GDP (Presidency of the Council of Ministers, 2006).

The Second National Communication report to the UNFCCC (MoE/UNDP/GEF, 2011) for Lebanon highlighted the crops that are of a national economical and social importance and vulnerable to climate change. These include potato, tomato, apple, cherry, grapevine, banana and wheat. The impact of climate change on agriculture production and quality has been extensively studied under diverse scenarios for the mentioned crops. The report shows that negative impact is likely to occur in the near future leading to an accelerated trend of food insecurity. The vulnerability of these crops was evaluated and it was found very fluctuating under the different scenarios and between the different regions. Some of the crops will not meet their chilling requirement which will negatively affect their yields (potato, fruit trees), while others will be affected by increasing heat and drought waves (cherry, tomato, wheat, grape). The decrease in precipitations and the available water for irrigation will have a direct impact on irrigated agriculture areas and crops (banana, apple, potato, tomato). Moreover, increased temperature and humidity will augment pest outbreaks in some crops (olive, potato, tomato and apple). National adaptation measures have been proposed either to directly face up to climate change impacts or to increase the resilience of the farmers and the crops to such variability. Agriculture is confronted to produce more marketable products under unpredictable climate conditions. Adaptation to climate change is crucial not only to support the livelihood of rural populations and to sustain the viability of the agriculture sector, but also to maintain a tolerable level of food security.

The Agriculture Strategy the Ministry of Agriculture for the period 2010-2014 stressed out the problem of “desertification and land degradation, due to climate change”. The strategy cites the “limited of national legislative framework for the agriculture sector in Lebanon”, and puts among its priority axis the elaboration of necessary laws, decrees and decisions. The Agriculture Strategy has a target of promoting sustainable agriculture under its different agriculture systems.

6.1.1 Scope of work

The objective of this project is to propose technologies for adaptation to climate change for vulnerable crops (potato, tomato, apple, cherry, banana, olive, grape and wheat) and production systems (i.e. open field or protected crops, irrigated or rainfed crops). These crops are major exportable products, with a high national production value, and are considered as essential components of food security. The deployment of these technologies will bring a positive impact on agriculture in general, and enhance the sustainability of the system by improving agriculture practices, reducing chemical inputs, sustaining natural resources, reducing cost of production and preserving or increasing farmers’ income. In other words, the suggested technologies should enable to: i) increase yields and preserve food security, ii) sustain production under different climatic scenarios, iii) make the production systems more efficient, and iv) reduce GHG emissions from agriculture production system (ICTSD, 2010).

6.2 Possible adaptation technology options in the Agriculture sector and their adaptation benefits

Among the list of globally available technologies related to the adaptation of the agriculture sector to climate change, a number of technologies have been selected to cover all the agriculture sub-sectors, except animal husbandry. Since small ruminants vulnerability to climate change relies on natural rangelands ecosystems, an ecosystem-based management approach would be preferred over other adaptation technology.

The proposed technologies in most cases are a combination of hard technologies (i.e. equipments, seedlings) and soft technologies (i.e. software, communication, management), as presented below.

6.2.1 Conservation Agriculture (CA)

Conservation agriculture is one of the most sited technologies that harness adaptation to mitigation measures (FAO, 2007; CGIAR, 2010). Its principle is minimal tillage with conservation of crop residues to conserve both water and organic matter. Avoiding plowing not only saves energy, but mostly reduces carbon dioxide emissions from the soil. Studies have shown that conservation agriculture involves minimal machinery for land preparation and is suitable from most crops. It doesn't necessarily improve yield under all agro-climatic zones, however, its benefits are mostly significant in arid and semi-arid zones (i.e. northern Bekaa), which are in fact the most vulnerable. Crops grown under conservation agriculture have shown to be more resilient to drought conditions, leading to minimal inter-annual yield variation. The direct benefit for farmers includes the increase in income due to savings in the cost of production, which varies between USD 350/ha to USD 650/ha according to the crop type, when compared to conventional agriculture (ACSAD/GIZ, 2010).

6.2.2 Risk Coping Production Systems (RCPS)

The Risk Coping Production Systems technology is a set of different field practices involving landscape management and diversification of production: terracing, windbreak plantation, intercropping, agro-forestry, crop rotation and crop and livestock association production system (FAO, 2007). Many of these features rely traditional knowledge, and increase crop and farmer's resilience through minimizing climate adverse impacts on the crops. Terraces enhance water and soil conservation on mountain slopes while windbreaks protect the crops from dry winds in the coastal and inland plains (WOCAT, 2007). Some of these features are adapted or better fit to field crops (i.e. crop rotation, crop and livestock association) and require large exploitation areas in order to be cost-effective. The diversification of the production system minimizes possible damages related to pest outbreaks, market congestion and climate adverse. Yield and income are not directly affected, but their stability is better guaranteed. The adaptation benefit will be indirectly related to the reduction of inputs (fertilizers, water, pesticides and herbicides) and to the reduction of damages related to climate extremes (heavy rain, drought). Crop rotation of wheat/vetch over a period of 2 years for cereals for example, has shown an increase of income reaching USD 200/ha if compared to conventional monoculture of wheat (ACSAD/GIZ, 2010).

6.2.3 Selection of Adapted Varieties and Rootstocks (SAVR)

Plant breeding and biotechnology are the two pillars for producing plant varieties that help the sector cope with climate change (CGIAR, 2010; FAO, 2007). Adapted varieties could be tolerant or resistant to different climate/soil aspects such as drought, salinity, low chilling requirement, snow, frost, cold, heat and short or long vegetative season. Even if Genetically Modified Organisms and Property Rights are major barriers towards the development and deployment of these technologies, Lebanon relies on the import of conventionally selected varieties and rootstocks. Several non-patented varieties are also multiplied locally and disseminated to farmers. However, the selection of the varieties for plantation is mostly market oriented, rather than based on adaptation to climate. The plantation of suitable selected varieties and rootstocks could have a positive result on yields (20% at least) with early bearing of fruits in fruit trees (2-4 years gain) and consequently a better income for farmers, when compared to conventional fruit orchards with old varieties grafted on non-selected rootstocks.

6.2.4 Integrated Pest Management (IPM)

Integrated Pest Management or Ecological Pest Management (MoE/UNDP/GEF, 2011; FAO, 2007) is a concept that relies mainly on timely field observations rather than timely based spraying. Consequently, farmers tend to adapt their operations according to the occurrence of pest outbreaks. Since outbreaks are uncertain and related to climate variability, then resilience of farmers to climate change is increased. IPM helps reducing pesticide use, and consequently greenhouse gas emissions. In addition, the cost of production is diminished and the impact on human health and the environment is reduced. If yield improvement is not always obtained, improved quality of production is more certain. An increase of income is expected due to a decrease of the cost of production (15-30% according to the crop and area) and a higher added value of the final product.

6.2.5 Integrated Production and Protection for greenhouses (IPP)

An Integrated Production and Protection system for greenhouses is also a technology that has started to be promoted to modernize the greenhouses (FAO, 2004). Even if this technology targets a minor agriculture sub-sector, it is important to keep production under greenhouses sustainable. Off season production is not only of a higher added value, but contributes also to food security, especially that greenhouses are considered the most cost-effective agriculture systems around urban areas. IPP combines hard technologies like adapted greenhouse structure, insect proof net, thermal plastic film and fertilization system, with soft technologies or practice, like integrated pest management, and the selection of adapted varieties and rootstocks. Most studies report an improvement in both yield and production quality under IPP when compared to conventional production under traditional greenhouses (Hanafi, 2008).

6.2.6 Early Warning System - Information and Communication Technologies (EWS-ICT)

Amongst the most recognized technologies for adaptation to climate change is Early Warning System, which relies mostly on weather stations, satellite and aerial images for weather forecast (MoE/UNDP/GEF, 2011; UNFCCC, 2006). This hardware is topped up with a set of software technologies which are essential to implement risk analysis of different features related to climate (i.e. frost, snowfall, flood, moisture, cold and heat waves, wind, drought and pest outbreaks). The effectiveness of the system is centered on the dissemination of the warning to vulnerable target groups. EWS cannot be effective without embedding developed Information and Communication Technologies. These technologies work mainly on increasing the readiness of different beneficiary groups to different uncertainties and can also be used as tools for other technologies like IPM and Index Insurance, or technologies related to water monitoring (Ospina and Heeks, 2011).

6.2.7 Index Insurance (II)

Index insurance is a new soft technology that is gaining popularity worlwide under the adaptation measures worldwide. However, the technology can only be use once weather stations equipped with the necessary ICT are established and the institutional and organizational requirements are arranged. Index insurance is based on one climatic index that has the highest negative impact on agriculture revenues in a defined area, or for a defined crop. These could be frost, drought, hot wind, hail, flood, snow, and heat or cold waves. Index insurance relies on weather station data, and avoids field assessment. However, no indexing has been set yet. Financial mechanisms for funding and administrative issues related to indemnity distribution to affected farmers are to be determined to ensure effectiveness and viability of the system. When properly deployed, Index Insurance would be an opportunity for investment, and also a tool to increase the resilience of farmers to climate change (MoE/UNDP/GEF, 2011). The SNC mentions that climate variability will lead to an increase by 20% in fruit set failure in cherry for example leading to a reduction of farmers' income compared to current climate. Index insurance is meant to cover the damages for farmers and enable them to sustain their livelihood.

6.2.8 Criteria and process of technology prioritization

Process of technology prioritization

The technology prioritization process was elaborated following the UNDP handbook guidelines (2010) and based on the Multi-Criteria Analysis approach. Technologies were identified and analyzed based on literature review, field experience and results of individual meetings conducted with different experts working in the field and knowledgeable of specific technologies. 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, expert consultation meetings were held where a pool of experts validated the MCA criteria and relative weights. Accordingly a scoring exercise was conducted resulting in technologies ranking based on the following equation:

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

Selection Criteria

An identified set of criteria allowed the comparison between these technologies based on the three pillars of sustainable development: economical viability, environmental reliability and social acceptability or readiness. Technologies should be cost-effective, environmentally sustainable and socially acceptable (UNFCCC, 2006).

The selection criteria were identified as follows: capital and operational cost, importance of economical impact, improvement of resilience to climate, technology capability and suitability for the country, human and information requirement and social suitability for Lebanon. Each criterion answers more than one question. For example, the importance of economical impact embeds not only the generated income at farm level, but also the contribution to the GDP at national level. The later is related to the number of beneficiaries or targeted area as well as the degree of impact of the technology on the different crops. These criteria include as well the increase in yields, efficiency of the production system, preservation of food security (economical impact), the capability of the technology to sustain production under different climatic scenarios and its capacity to reduce GHG emissions from agriculture production systems (criteria related to environmental reliability).

For the prioritization exercise, absolute scale with misleading figures and numbers were avoided and ranking on relative basis over a top score of 5 has been used based on the MCA approach.

Weights have been attributed to each criterion, as they do not have the same importance or impact, and since choices are not influenced in an equal way by each criterion. For example, the capital and operational cost define the easy access to the technology and its economical viability, which are crucial requirements for the decision making process and which are more significant than human or information requirement. The criteria related to financial issues are the driving force in the selection, and consequently are double weighted. Oppositely, criteria related to human and social aspects are relatively less important in the selection, since these factors are subject to change and improvement when the financial resources are found, and consequently these criteria were not weighted. Consequently, economical viability criteria were higher weighed, followed by those related to environmental reliability and finally the criteria associated to social readiness. The criteria description, their scale and weight are described below in Table 60.

Table 59 - Suggested criteria of selection for the agriculture sector

Economic Viability	Capital and Operational cost.
	Importance of economical impact.
Environmental reliability	Improvement of resilience to climate.
	Technology capability and suitability.
Social Readiness	Human and information requirement.
	Social suitability for Lebanon.

Table 60 - Brief description of the criteria of selection with the respective scales and weights.

Criterion	Description	Scale	Weight
Capital and operational cost	The 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)	Highest (2)
Importance of economical impact	It integrates the following indicators: • Increase of income/profit at farm level. • Number of beneficiaries/covered area. • Economical importance of targeted crops. • It highlights the equity among regions and importance to food security and national policy.	Very low (1) Low (2) Medium (3) High (4) Very High (5)	Highest (2)
Improvement of resilience to climate	The technology's ability on improving crop resilience under current and future climate scenarios. If several types of impact due to different climate adverse (drought, frost, chilling requirement, insect outbreak, etc.) are minimized, the degree of improvement is higher.	Very low (1) Low (2) Medium (3) High (4) Very High (5)	High (1.5)
Technology capability and suitability	It assesses how much the technology is widely applicable within the different bioclimatic zones. If it is applicable for different crops, or cropping systems, and suitable for different geographical contexts, it is higher scored. It highlights the degree of viability of the technology.	Very low (1) Low (2) Medium (3) High (4) Very High (5)	High (1.5)
Social suitability for Lebanon (readiness)	Social acceptance at all levels: farmers and social suitability, organizational requirements and institutional arrangements at decision-makers level.	Very low (1) Low (2) Medium (3) High (4) Very High (5)	Standard (1)
Human and information requirement (readiness)	Human requirements and their qualification, coupled with the capacity building and technology/information transfer needed to deploy the technology. It highlights the time requirement to establish and disseminate the technology.	Very low (5) Low (4) Medium (3) High (2) Very High (1)	Standard (1)

Results of the technology prioritization

Table 61 presents the final scores that were attributed to the proposed technologies of the agriculture sector. The main points raised during the discussion were related to the complementarily of the technologies, the extent of geographical coverage, the applicability and use by farmers and the importance of capital and operational costs in the decision making process.

As a result, the MCA exercise enabled the selection of priority technologies for Lebanon in an objective way and based on consensus. The top-ranked technologies as shown in Table 62 were: 1) Selection of Adapted Varieties and Rootstocks, 2) Conservation Agriculture and 3) Risk Coping Production Systems over more costly and less applicable technologies. Although most of the participants showed interest in the EWS-ICT and II, it was unanimously agreed that under the current circumstances, there cannot be considered priority technologies. The urgent need to establish a solidarity fund or another mechanism to increase the human resources, training and capacity building for EWS_ICT and IPP was highlighted by all experts.

Table 61 - Results of MCA exercise for the agriculture sector

Criteria	Weight	Conservation Agriculture		Risk Coping Production Systems		Integrated Pest Management		Selection of adapted varieties / rootstocks		Integrated Production and Protection for greenhouses		Early Warning System - Information and Communication Technologies		Index Insurance	
		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	2	5	0.222	3	0.111	4	0.167	3	0.111	1	0.000	2	0.056	2	0.056
Importance of Economical impact	2	4	0.167	3	0.111	5	0.222	5	0.222	1	0.000	5	0.222	3	0.111
Improvement of resilience to climate	1.5	4	0.125	4	0.125	3	0.083	4	0.125	5	0.167	5	0.167	4	0.125
Technology capability and suitability	1.5	4	0.125	5	0.167	4	0.125	5	0.167	5	0.167	3	0.083	3	0.083
Social suitability for Lebanon (readiness)	1	3	0.074	4	0.111	3	0.074	4	0.111	2	0.037	4	0.111	2	0.037
Human and information requirement (readiness)	1	5	0.111	4	0.083	2	0.028	5	0.111	3	0.056	3	0.056	3	0.056
Total		25	0.824	23	0.708	21	0.699	26	0.847	17	0.426	22	0.694	17	0.468

Table 62: Multi-Criteria Analysis results for the technologies of the agriculture sector.

Rank	Technology	MCA score
1	Selection of Adapted Varieties and Rootstocks.	0.847
2	Conservation Agriculture.	0.824
3	Risk Coping Production Systems.	0.708
4	Integrated Pest Management.	0.699
5	Early Warning Systems/Information and Communication Technologies.	0.694
6	Index Insurance.	0.468
7	Integrated Production and Protection (greenhouses).	0.426

6.3 Barrier Analysis and Enabling Framework

6.3.1 Preliminary targets for technology transfer and diffusion for agriculture

The three prioritized technologies for the agriculture sector as identified by stakeholders are: i) Selection of Adapted Varieties and Rootstocks (SAVR), ii) Conservation Agriculture (CA) and iii) Risk-Coping Production Systems (RCPS).

RCPS includes several features as presented in Fig. 49. However, in this report, only adapting plantation systems (density of plantation, orientation, distances between rows and plants, etc.) and adapted training systems and pruning in fruit orchards and vineyards

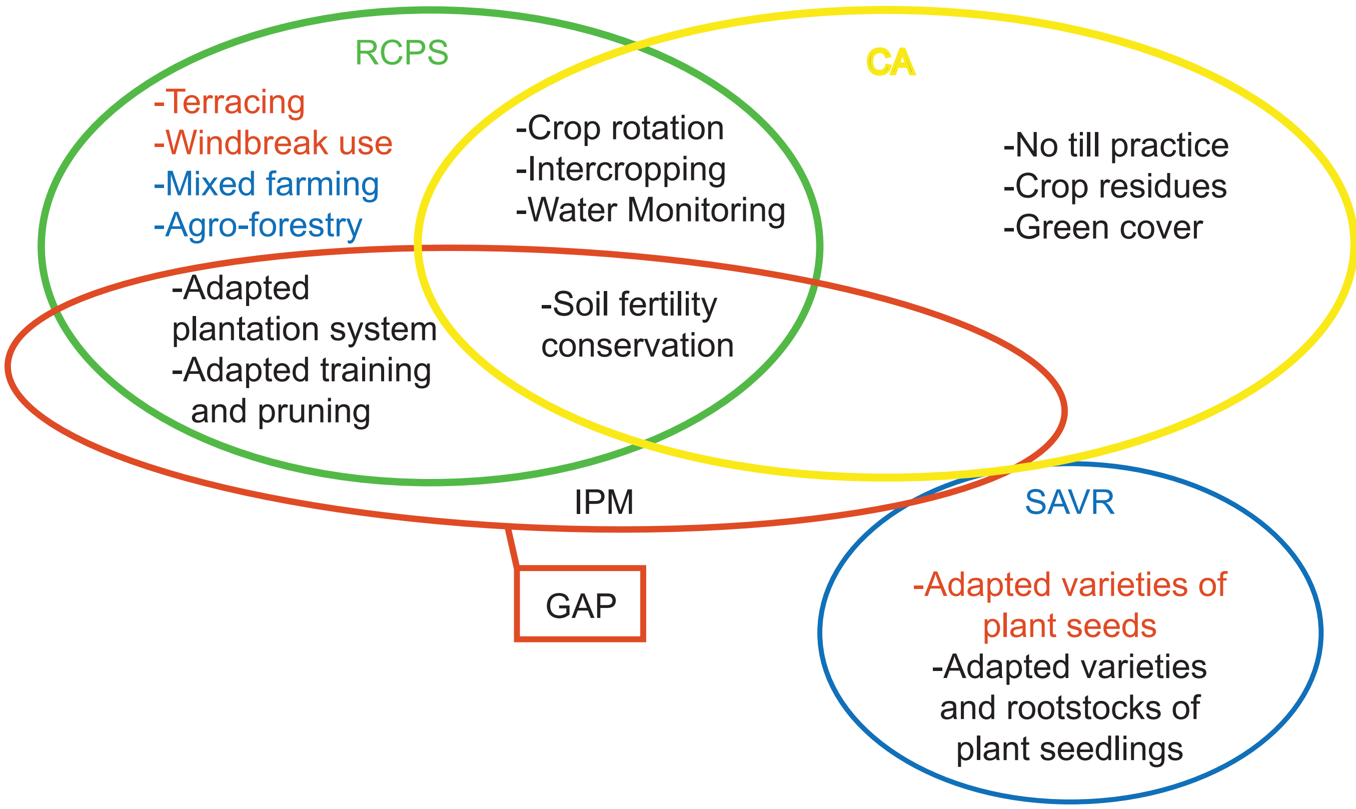

Fig. 49 - Prioritized technologies inter-linkage

Source: Author's own design

will be tackled since crop rotation, intercropping and green cover maintenance are already covered under CA.

Adapting plantation systems and adapted training systems and pruning in addition to many other practices applied at farm level, could be included in what is known as "Good Agriculture Practices" (GAP), currently promoted through MoA's policy. Good Agricultural Practices are "practices that address environmental, economic and social sustainability for on-farm processes, and result in safe and quality food and non-food agricultural products" (FAO COAG, 2003). Fig. 49 indicates the common areas where each of the technologies cross over with GAP cross. However, Integrated Pest Management (IPM), which is generally recognized as one of the main adaptation tools to climate change and which was ranked 4th in technology prioritization, is a core component of GAP. Therefore, the barrier analysis for the RCPS will include analysis for IPM and will be classified as Good Agricultural Practices, embedding adapted plantation system, adapted training and pruning and IPM as shown in the red circle in Fig. 49. This allows avoiding duplication with the two other technologies.

6.3.2 Classification of technologies

Technologies are divided into: i) consumer goods, ii) capital goods, and iii) non-market goods, as shown in Fig. 50.

The Selection of Adapted Varieties and Rootstocks is a typical consumer good, with a wide market and a large number of stakeholders. On the other hand, Conservation Agriculture is a non-market good, with an objective oriented mostly to change farmer's behavior and practices within the exploitation. As for Risk-Coping Production Systems, depending on the nature of the measures, it can be a consumer good where minimal material is required from the market (i.e. selective pesticides, insect-proof nets, mulch, etc.), a capital good when investments are required in goods enabling the production of the end-market product (i.e. terraces, trellis), or non-market goods such as in Good Agriculture Practices, where field operations are adapted to cope with climate change.

CONSUMER GOODS	CAPITAL GOODS	OTHER NON-MARKET GOODS
• Selection of Adapted Varieties and Rootstocks. • Risk-Coping Production Systems.	• Risk-Coping Production Systems.	• Conservation Agriculture. • Risk-Coping Production.

Fig. 50 -Technology classification according to type of goods for agriculture sector

Source: The author's own design

6.3.3 Methodology of identification of barriers and action plans

The barrier analysis for the agriculture sector mainly relied on literature review and individual consultations with experts in the field, followed by a consultation meeting with representatives from public institutions, experts and technicians from research institutes, NGOs, service providers and farmers.

Following a Logical Problem Analysis (LPA), problem trees were drawn for each technology, showing inter-linkages between causes (key barriers) and effects and validated by the stakeholders. Accordingly, a list of specific measures were collectively proposed to overcome the selected barriers.

Identified measures have been developed in action plans and a Cost Benefit Analysis (CBA) was conducted for each technology. Assumptions and figures were validated by the concerned stakeholders and experts in the field. The Net Present Value (NPV) was estimated as follow:

$$NPV = \frac{(\text{Benefits} - \text{Costs})}{(1 + \%\text{ of annual interest})^n}$$

A fixed discount rate (loan interest rate) of 6% was used based on the average of the lending rate of Kafalat program.

A more in-depth CBA will be required at later stages to better estimate the real cost and benefits of adaptation of the agriculture sector.

Finally, action plans specific to each technology were proposed to reach the targets of increasing resilience of the agriculture sector to climate change. These Technology Action Plans (TAP) are designed in a matrix that answers basic questions on the measures or activities to be conducted, their priority, their importance and responsible entities. The matrix includes as well the time frame of these activities, the indicators for their monitoring and evaluation, estimated budget to conduct them 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.

The process of barrier analysis and overcoming them is resumed in Fig. 51.

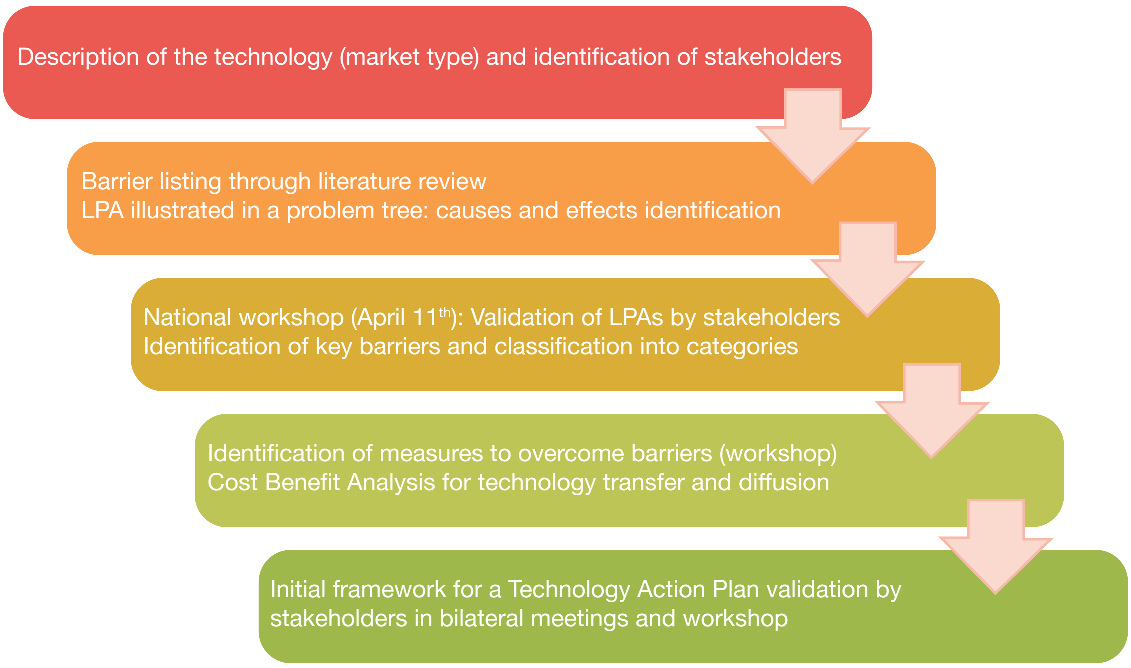

Fig. 51 - Process of Barrier Analysis and Technology Transfer and Diffusion

Source: The author's own design

6.4 Analysis of Technology: Conservation Agriculture (CA)

6.4.1 General description of Conservation Agriculture

Conservation agriculture is a "technology" based on changing agriculture practices within the exploitation by conserving soil and water through no-till and the use of agriculture residues in addition to rotating crop and green cover plantation to preserve soil fertility and break down weeds and pests lifecycle. It is a non-market good, as it doesn't involve investments in capital or market goods. Existing seeder equipments for annual and grain crops can be adapted for seeding.

Conservation agriculture is slowly moving from a trial stage towards a diffusion stage since no regulations exist to enhance the deployment of this technology in Lebanon. The government, through the Bureau of Cereals has been historically subsidizing wheat production, to sustain the cultivation of this "strategic" crop. A similar approach has been adopted for tobacco plantations (through annual governmental decisions) and sugar beet. However, this has proven not to be sustainable and cost-effective and the subsidies for the sugar beet were cut off. A more "practice-oriented" approach is required to promote the diffusion of CA, especially amongst cereals and legume growers, although no decisions are taken towards this issue at governmental level. An initiative from GIZ Lebanon and the MoA aimed at elaborating an initial frame for the transfer and diffusion of CA in Lebanon. In addition ACSAD/GIZ have been promoting this type of agriculture for the last four years and efforts with research institutes including AUB and LARI have aimed at promoting CA in northern Bekaa and Akkar.

6.4.2 Identification of Barriers for Conservation Agriculture

Conservation Agriculture covers around 1500ha all over the country. However, several key barriers hinder the proper diffusion of CA including:

- Limited information and the inherited behavior affecting farmer's perception of no-till. Farmers have been tilling their lands for centuries, and it would be difficult to change this attitude, especially that their information about benefits of CA is still precarious.
- Few skilled extension technicians: Technicians are not necessarily aware of the concept of CA and the agricultural extension services established by MoA are not providing farmers with the adequate amount and quality of relevant information.
- Limited demonstration plots: Farmers are difficult to convince unless they visualize the advantages of CA, and rare demonstration plots have been established as case studies to generate concrete results.
- Re-use of agriculture residues: Cereal growers rent their land for grazing after harvesting their crops to maximize their profit, which leaves the soil without crop residues to be used under CA.
- Inappropriate Land Tenure system: since CA embeds crop rotations and requires few years to show significant results, a yearly-basis rental period is not appropriate.
- Insufficient revenues: This is very typical for rainfed agriculture, especially for cereal growers who tend to rent their land post harvest for grazing, which makes CA perceived as a risky practice.
- Low yields in rainfed agriculture (especially cereal and legume growers): subsidies are only paid for wheat production, and are not based on the type of agriculture production system.
- Limited research and development programmes: There is limited R&D initiatives namely in areas where CA could be deployed (olive groves, cereal and legume plantation in semi-arid zones, fruit orchards).
- Budget constraints: no budget is allocated for research and development or to subsidize CA.
- Deficiency in institutional and financial arrangements: No decrees and laws for resource mobilization for subsidies or R&D are existent or to change subsidy policy from crop-oriented to practice oriented.

Fig. 52 illustrates the problem tree with causes and effects of the rejection of CA.

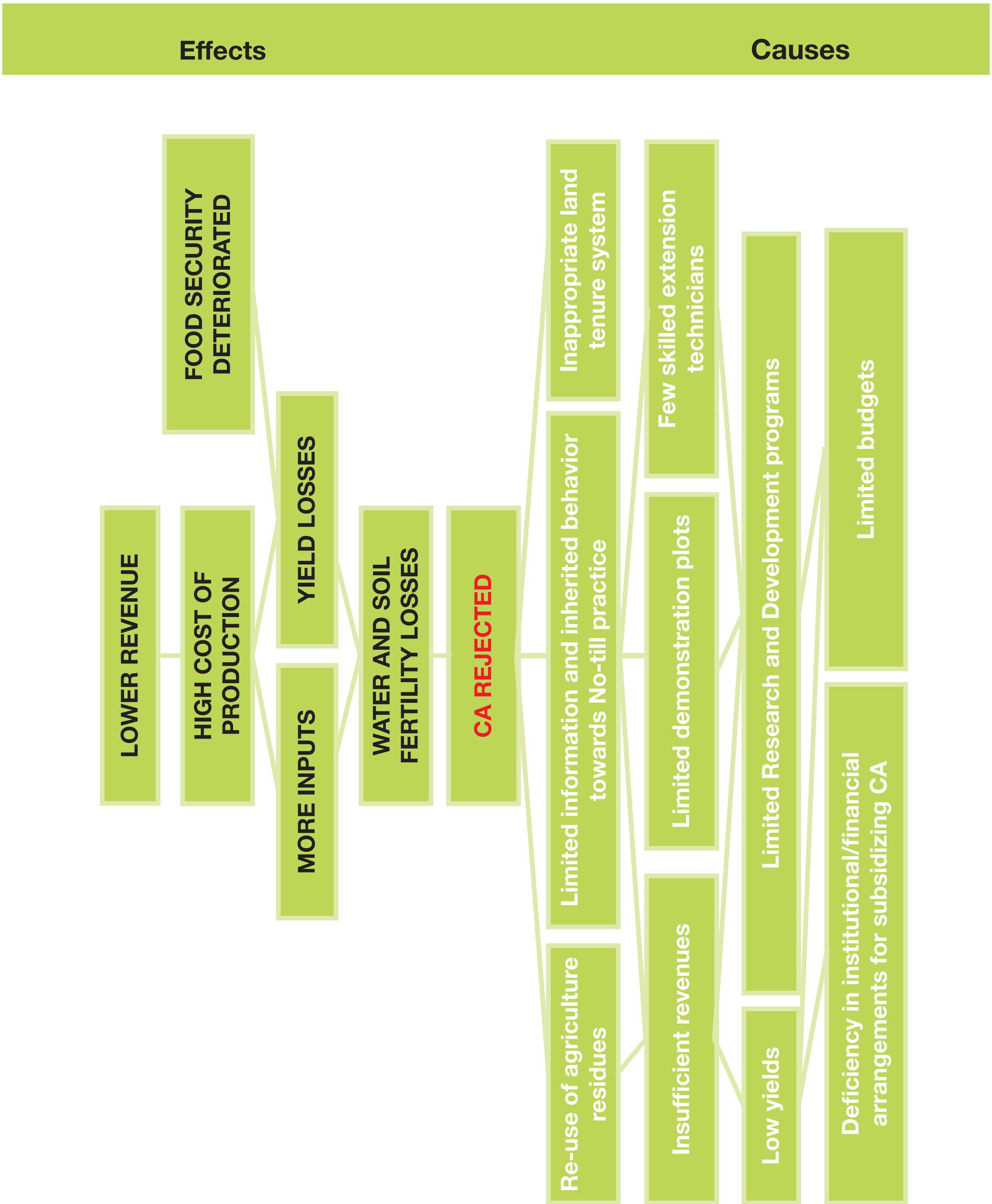

Fig. 52 - Problem tree for Conservation Agriculture.

Source: Author's own design

6.4.3 Identification of measures for Conservation Agriculture

The causes of non-adoption of Conservation Agriculture and their respective measures are presented in Table 63.

Table 63 - List of barriers for CA and respective measures to overcome them

Category	Barriers	Measures	Stakeholders
Human skills	Lack of skilled extension service.	Training of trainers for extension service and NGO technicians.	MoA, NGOs
Institutional and organizational capacity	Lack of research and development programmes.	Increasing research and development programmes on CA into different research stations of the country (LARI) and on farm level, on different crops under diverse climatic and soil conditions.	LARI, AUB
Policy, legal and regulatory	- Inappropriate Land tenure system: need long term renting (killing barrier). - Deficiency in institutional arrangements for subsidies.	Changing crop-oriented subsidies (i.e. to wheat and tobacco) to practice-oriented subsidies.	MoEc, MoF, Parliament
Information and awareness	- Limited information at farmers and decision maker's level. - Limited number of demonstration plots.	Organizing awareness campaign and field visits to demonstration plots.	MoA, LARI, NGOs, farmers
Economic and financial	- Budget restrictions for R&D. - Absence of appropriate subsidies. - Cereal growers' low income. - Export of agricultural residues.	Allocating the necessary budget for research and development and for subsidies.	MoF, MoA, LARI, AUB
Social, cultural and behavioral	Inherited behavior affecting farmer's perception of no-till and the export of agriculture residues.	- Arranging field visits to demonstration plots -Conducting seminars for farmers to show the comparative advantage of no-till.	MoA, LARI, NGOs, farmers

6.4.4 Cost benefit analysis for CA

Conservation Agriculture requires mostly research and development programmes all over the bioclimatic zones of the country, in order to transfer and diffuse scientific proven practices for farmers growing different crops under diverse conditions. Institutional and financial arrangements are required as well to allocate subsidies whenever needed.

Costs related to CA are estimated as follow, and validated by stakeholders and literature on potato and olive productions for integrated production protocols (MoA, CNRS, CIHEAM, IC, 2008):

- Research and development: USD 240,000 (4 years).
- Institutional/financial arrangements: USD 10,000.
- Training of trainers: USD 5,000.
- Training for farmers: USD 15,000.
- Subsidies: USD 50/ha for cereals and legumes.

The projected annual budget for subsidies is shown Fig. 53. The total cost for the deployment of all measures, including subsidies will be hence USD 3.47 million. If the actual subsidizes for wheat production are reallocated for cereals under conservation agriculture, no additional budget requirements are needed.

Assumptions for CA

- The added value of agriculture residues in conventional agriculture (cereals) is:
  - Counterbalanced by the saved water and fertilizers used wherever deficit irrigation is applied (5,000ha).
  - Covered by subsidies in rainfed areas (10,000ha)
- Total area under CA (scope):
  - Baseline 1,500ha of cereals (wheat, barley, corn) and legumes (vetch, alfalfa, lentils, chickpea) with 30% annual increment, due to the presence of incentives.
  - Baseline 500ha of olive trees and other rain feed fruit trees (almond, cherry) with annual increment of 25%.
  - Baseline 100ha of irrigated fruit trees (apple, apricot, cherry, peach, plum, etc.) with annual increment of 20%.
- Yield in CA is stable if not increased in a 10 year period, for all crops in general. Oppositely in conventional agriculture annual variability is high. In this report we assume that:
  - Yields are similar for both conventional agriculture and CA for irrigated fruit trees.
  - Yield annually decreases by 1% for cereals under conventional agriculture.
  - Yield is constant for olive starting the 3th year after conversion to CA, while under conventional growth, biennial fluctuation in yields reaches 50%.
  - The price of the seeder (grain crops) is counterbalanced by the price of machinery normally used in conventional agriculture.
  - In CA the use of herbicides for weed control is high in the first 3 years, with an additional cost to maintain a green cover. The cost of these operations is about USD 100/ha the first year, USD 40/ha the second and the third year. Oppositely, no-till enables savings of USD 350/ha (machinery, energy and labor cost for plowing) for cereals, legumes and irrigated fruit trees, and USD 650/ha for olive tree (2 plowings/year).
  - Additional costs on the farmers are directly deducted from the savings in cost of production.

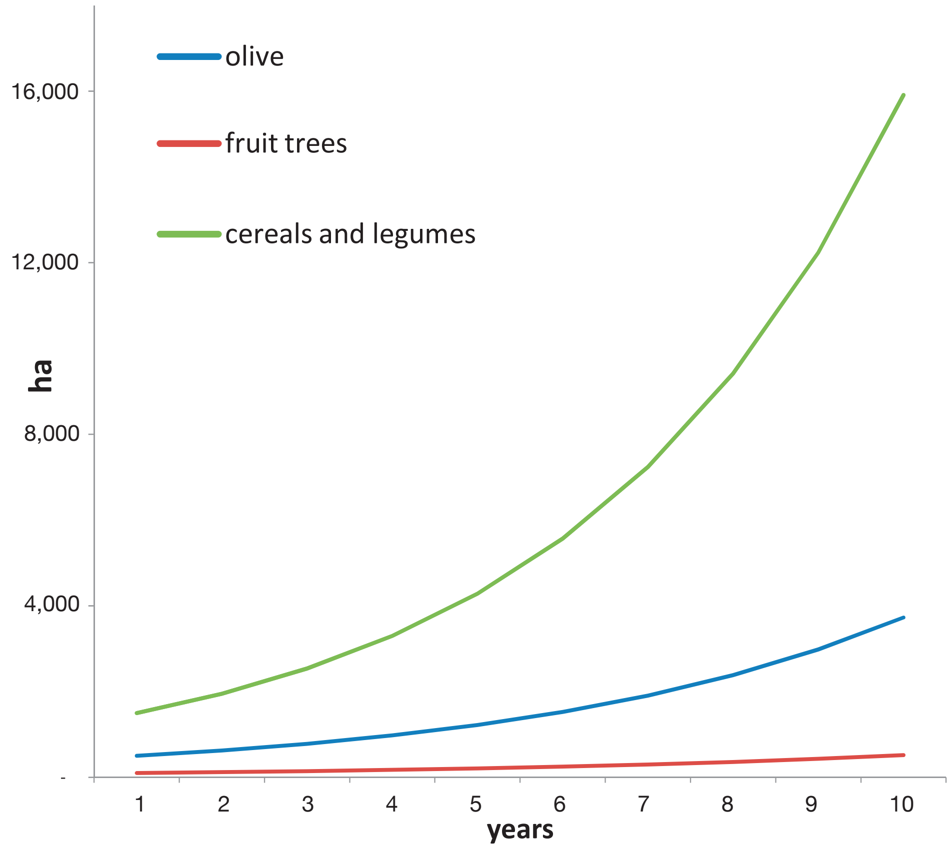

Fig. 53 - The projected expansion of areas under CA for a 10-year period

Source: Author's own design

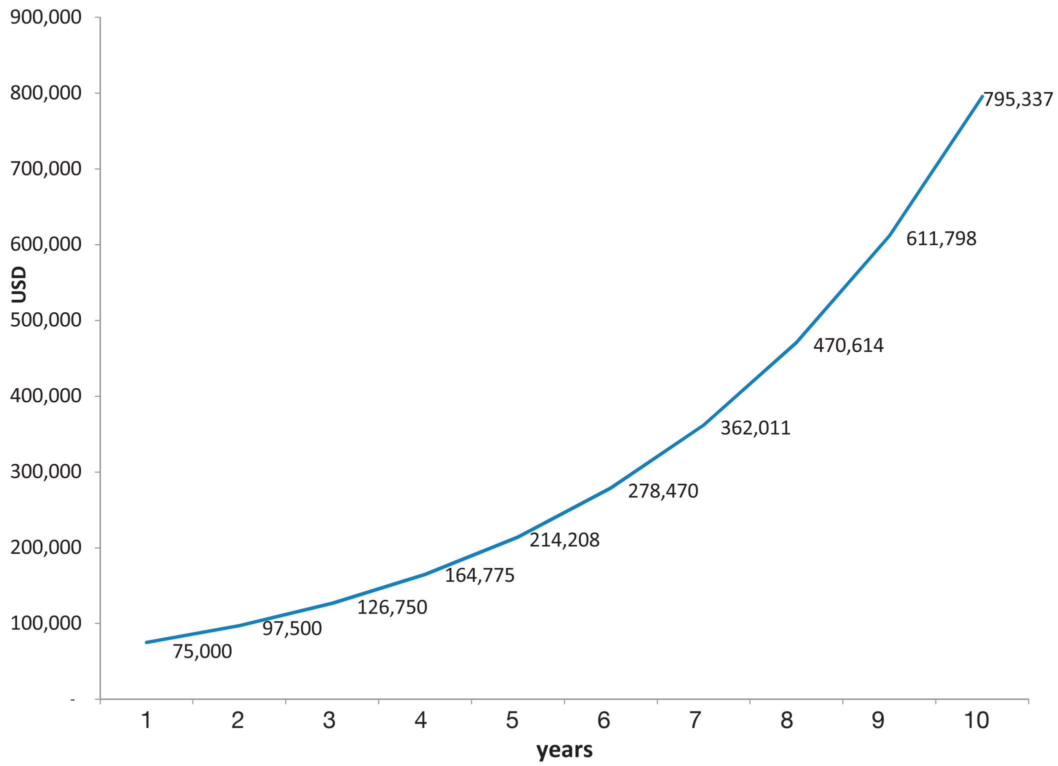

Fig. 54 -The estimated annual subsidies in USD for cereals and legumes according to their annual surface increase

Source: Author's own design

The expected benefits at farm level after a 10-year period will be mainly from reduced cost caused by minimizing land preparation cost (energy, labor) and consequently increased farmers' revenues by:

- USD 760/ha/year for cereals/legumes.

- USD 490/ha/first year, then USD 620/ha starting 2nd year for rainfed trees.

- USD 250/ha/first year then USD 310/ha starting 2nd year as reduced cost from no-till for irrigated fruit trees.

Figure 55 illustrates different NPV according to crop type in Conservation agriculture. Benefits at farmer's level with or without the deployment of CA are shown for olive tree in Table 64. Olive tree was taken as an example for analysis since its values as considered in the mid-range as shown in Fig. 56.

In conclusion, adopting and diffusing conservation agriculture for cereals, olive and fruit trees on up to 16,000ha in 10 years will enable: i) achieving a total Net Present Value over a 10 year period estimated at USD 36.9 million (Annex VI), ii) improving soil and water conservation through minimal soil disturbance and maintaining a green cover or agriculture residues on the soil surface, iii) reducing CO_2 emissions through minimal soil disturbance and iv) preserving food security, since yields are stable (availability of food), with lower inter-annual variation.

The mobilized resources to realize these benefits are less than USD 3.5 million. Therefore, and since the benefits exceed by far the cost of the technology, the transfer and diffusion of CA is a favorable and encouraged practice in Lebanon.

Table 64 – Cost Benefit Analysis (in USD): an example for olive production at farmer's scale (1ha).

	Revenues under conventional agricultural practices	Revenues under CA	Additional revenue under CA	Additional costs from applying CA	Net benefits from applying CA	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	380	1,000	620	0	620	585
2	340	800	460	0	460	409
3	380	1,000	620	0	620	521
4	340	1,000	660	0	660	523
5	380	1,000	620	0	620	463
6	340	1,000	660	0	660	465
7	380	1,000	620	0	620	412
8	340	1,000	660	0	660	414
9	380	1,000	620	0	620	367
10	340	1,000	660	0	660	369
NPV						4,528

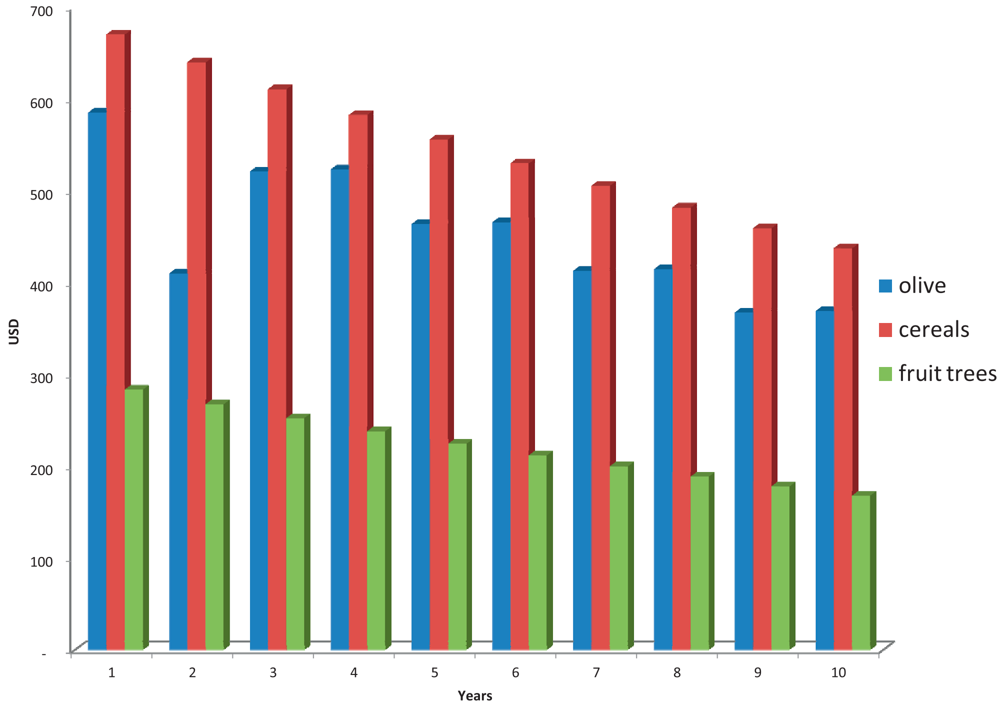

Fig. 55 - Comparison of annual NPV per ha over a 10-year period for 3 types of crops under CA at farmer's level

Source: Author's own design

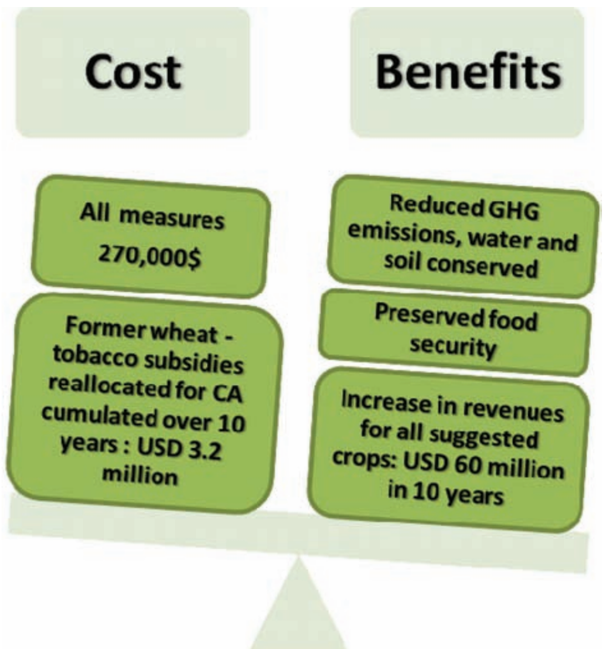

Fig. 56 - Costs and benefits of Conservation Agriculture over a 10-year period

Source: Author's own design

6.4.5 Technology Action Plan for Conservation Agriculture

Target for technology transfer and diffusion

The target for the action plan proposed is a large scale and long term project between 2015 and 2025 aiming at shifting more than 4,000ha of fruit trees and 15,000ha of cereals and legumes to Conservation Agriculture. The required budget is 3.47 million USD.

The Technology Action plan for the deployment and diffusion of conservation agriculture is presented in Table 65.

Table 65 - Technology Action plan for Conservation Agriculture

Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring and Evaluation indicators	Estimated cost (USD)	Donors
Conducting training sessions and filed work	1	To increase the experience of technicians in CA	National and international experts (ICARDA, ACSAD, LARI, GIZ, etc.)	MoA, NGOs	Short term	Number of training sessions, Percent active technicians in disseminating CA	5, 000 For 50 technicians	World Bank Adaptation Fund GEF IFAD FAO Islamic Bank EU USAID Kuwaiti Fund Italian, Spanish Cooperation
Conducting experimental studies in fields of research institutes and on farm level	1	To better understand the effect of CA on different crops under different agro-climatic conditions	LAR, Academic institutions	MoA, NGOs, farmers	Medium term	Publications of research results Number of experiment plots % of budget dedicated to R&D	240,000 for experiments in 6 LARI stations and 20 on-farm plot covering 10 crops	
Conducting field days and visits to demonstration plots, seminars and TV programme	1	To change farmers behavior concerning no-till and show the comparative advantages of CA	MoA, LARI, NGOs	farmers	Medium term	Number of farmers converted to CA, surface producing in CA	9,000 for 450 farmers participating in seminars and field days; 6,000 for TV program	
Lobbying to get ministerial proposal to shift from crop-oriented to practice-oriented	2	To avoid additional public debt, and promote CA	National consultant-MOET, MoF, MoA, Parliament	farmers	Long term	Parliament and government decisions and law amendment	10,000 For National consultant study	
Allocating the necessary budget for subsidies	2	To give incentives to farmers to keep their crop residues in field and enhance R&D	MoF, MoET, MoA	farmers	Long term	Amount of subsidies per annum given to cereal-legume growers	3,200,000 for subsidies as estimated in assumptions	

6.5 Analysis of Technology: Selection of Adapted Varieties and Rootstocks (SAVR)

6.5.1 General description of SAVR

This technology embeds the replacement of actual seeds and seedlings produced locally or imported, by appropriate adapted varieties and rootstocks to future climate.

SAVR is a consumer good involving public and private sectors as well as different actors within the market chain, mainly seed and seedling importers, which are usually agriculture companies. Most of the import is demand driven, where farmers make their requests. Imported plant material is in many cases patented, and royalties legitimate to plant breeders as Intellectual Property Right (IPR), are added to the price which makes the SAVR of a higher cost. In the case of many horticultural crops, seeds are germinated and grafted locally then sold to farmers such as fruit tree and grapevine seedlings, however in most cases, the plant material origin, property right and quality are not guaranteed since plants are not inspected or certified by a third party.

Regulations for seed and seedlings import are minimal. A prior permit of import is currently being required, however registration of varieties is not yet done. Certificates of origin and phytosanitary certificate are required by both MoA and Custom Service, yet plant material authenticity, traceability and property right are not guaranteed. Lebanon which is not a member of the International Union for the Protection of New Varieties of Plants (UPOV) is trying to overcome this obstacle through bilateral agreements with foreign nurseries in order to import and pay the necessary royalties, hence enable SAVR multiplication locally. Standards and norms of multiplied plant material are limited to the seedlings delivered by “Machatel Loubnan” nurseries association which authenticity and sanitary inspection are guaranteed through a certification programme conducted by LARI-MoA. Yet a limited number of seedlings of varieties of pome stone and citrus fruits are produced.

The Ministry of Agriculture is trying to develop a seed/seedling policy to monitor and control this market. In collaboration with LARI, it has initiated the multiplication and certification of some non-patented varieties in accredited nurseries. However sanitation, conservation and multiplication of local SAVR are still far from being reached in the short term. Further diffusion of plants by local nurseries without paying the mentioned royalties will not be a solution on the long run; exports of products resulting from patented varieties to countries under UPOV is restricted. Making the necessary institutional arrangements for IPR will not only stimulate foreign trade, but also create the necessary enabling environment for the development of biotechnologies and SAVR in Lebanon.

Table 66 presents the legislation related to seed and seedlings varieties.

Table 66 - List of laws, decrees and decisions related to seed and seedlings

Type	Number	Title	Date issue	Remarks
Control in Import				
Law	778	Plant Quarantine	28/11/2006	
Decision	781/1	Conditions to import seeds other than potato seed	26/8/2011	Import permit/Quality control
Decision	783/1	Conditions to import propagating plants for fruit trees	26/8/2011	Import permit/Quality control
Decision	782/1	Conditions to import banana plants	26/8/2011	Import permit/Quality control
Decision	780/1	Conditions to import strawberry plants	26/8/2011	Import permit/Quality control
Decision	1/1038	Amendment of the decision 781	23/11/2011	Some exceptions
Decision	877/1	Conditions to import potato seeds for the season 2011-2012	26/9/2011	Quality control, yearly issued
Decision	900/1	Conditions to import potato seeds for trial	11/10/2011	
Decision	1/496	Sampling for inspection	21/9/2010	Including Seeds and seedlings
Organizing the Seedlings sector				
Decision	41/1	Establishment of a committee at MoA to organize the private nurseries	27/1/2010	Participants from public and private sector
Decision	526/1	Registration and control of private nurseries	4/6/2011	Compulsory Registration and control of private nurseries
Certification Programme for Seedlings				
Decision	493/1	Establishment of a scientific certification committee at MoA	20/9/2010	Its mission: To promote and supervise the certification program
Decision	528/1	Voluntary Certification of seedlings of Fruit trees produced in private nurseries	4/6/2011	Implementation of the seedlings certification
Decision	457/1	Establishment of the Certification Committee for seedlings of Fruit trees produced in private nurseries	19/5/2012	Its mission to implement the decisions 526 and 528
Decision	876/1	Amendment of the first article of the decision 751	26/9/2011	Add a member to the certification committee

Type	Number	Title	Date issue	Remarks
Production of Seeds and Seedlings				
Law	240	Patent	7/8/2000	Including PVP
Decision	346/1	Production of Potato seeds	23/10/1973	Not actually implemented
Ratification of related agreements				
Law	360	Ratification of CBD	1/8/1999	MoE focal point
Law	31	Ratification of Cartagena Protocol	16/10/2008	Only draft law prepared at MoE
Law		Ratification of the ITPGRFA	4/6/2004	LARI focal point Draft law prepared

Source: Siblini, 2012

6.5.2 Identification of Barriers for SAVR

The use of adapted varieties and rootstocks requires not only investments, equipments but also changes in behavior and practices of the different market components, from the producer to the consumer level. Key barriers for the transfer and diffusion of SAVR are listed below:

- Difficulties in changing food and agriculture habits to the new adapted varieties: the society in Lebanon and the export market is used to some old varieties of fruits and vegetables (i.e. Spunta potato, Red Delicious Apple, Pink Tomato, etc.) and changing their consumption habits is a main challenge for the market expansion.
- Market failure: growers are reluctant to use SAVR as they have difficulties in marketing new products.
- Limited know-how and information about SAVR: farmers and nurserymen are not aware of the yield and quality benefits of SAVR, and lack experience in field operations of new varieties.
- High cost of imported patented plant material: additional royalties and shipment fees are added to cost.
- Limited availability of healthy/certified plant material (for non-patented varieties and rootstocks): the existing plant material is often carrying viruses or diseases since it is not multiplied from healthy mother plants.
- Limited qualified nurseries: few nurseries are collaborating with MoA and LARI for the certification programme due to lack of infrastructure.
- Import restrictions on some patented varieties: some providers do not allow the import of specific varieties to Lebanon, since the country is not a member of UPOV.
- Export difficulties: since products do not meet international standards and pirated patented varieties cannot be exported to countries under UPOV, Lebanese growers are facing difficulties in exporting products.
- Lack of financial facilities (subsidies, access to long term credits) for SAVR: fruit trees need a long period to start producing, and agriculture credits adapted to such conditions are lacking.
- Limited research and development programmes: the implementation of SAVR requires a long research program, where SAVR can be tested and conserved before dissemination.
- Scarcity in human skills in research and academic institutes: the number of technicians specialized in the field is very limited.
- Deficit in necessary infrastructure: to multiply and sanitize SAVR, and study the performance of SAVR under different site conditions, and use them as demonstration plots for farmers. Local varieties need to be conserved in special sites, sanitized and further multiplied by nurseries and monitored for certification.

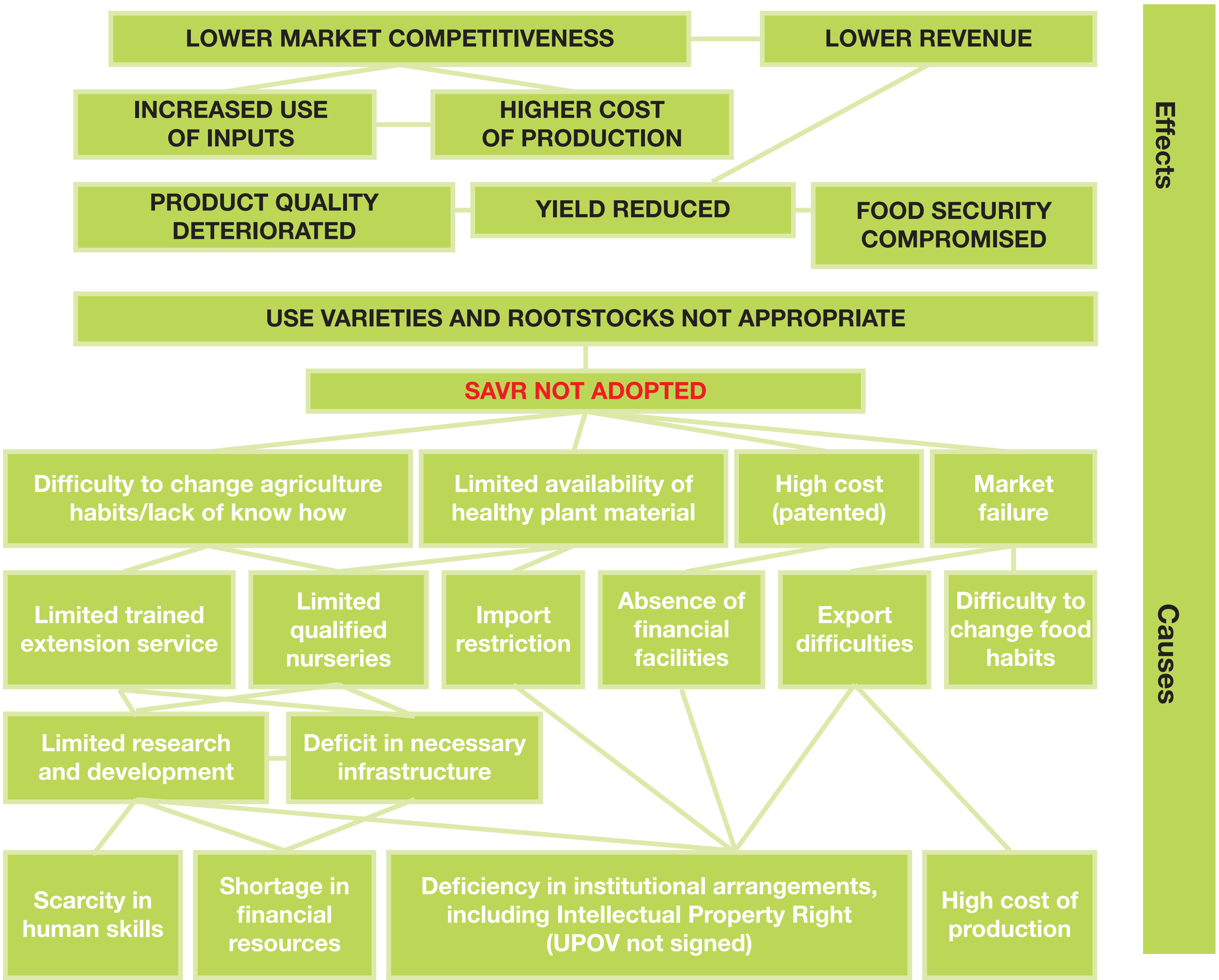

Fig. 57 - Problem tree of Selection of Adapted Varieties and Rootstocks

Source: Author's own design

- Shortage in financial resources: essentially in R&D, capacity building, awareness campaign and for allocating subsidies.
- Deficiency in institutional arrangements: for crediting system, subsidies and Intellectual Property Right in Lebanon.
- High cost of production: this is due to low yields and excessive use of inputs leading to a diminished competitiveness of Lebanese products especially for the export markets (not directly linked to SAVR).

The root problem of the selection and use of adapted varieties and rootstocks is the absence of institutional arrangements for protecting Intellectual Property Right since Lebanon is not a member country of the International Union for the Protection of New Varieties of Plants. This has a direct effect on the limited research and development and the deficiency of biotechnologies in the country, as the royalties for breeders are not guaranteed. The most affected varieties and rootstocks are fruit trees and grapevine which require a larger time span for plant breeding with higher investments.

Other main causes hindering the use of adapted varieties and rootstocks are the difficulties in changing food habits in Lebanon and exporting destination countries and the high cost of production. All are barriers directly causing market failure of SAVR and consequently the abstinence from using them. This is the case of many crops, including potato, apple, and some horticulture crops like watermelon. As for cereals and legumes, LARI has already created multiplication plots to supply farmers with new adapted varieties selected by ICARDA of wheat, barley, chick-pea, lentils and fava bean.

Figure 57 illustrates the key barriers, and their complex inter-linkage due to the wide market chain of SAVR. Nevertheless, the effects of non-adoption of SAVR are similar to any other technology in the agricultural sector, with direct impact on food security and farmer’s revenue, as yields are reduced.

6.5.3 Identification of Measures for SAVR

The barriers of adoption of SAVR are, with the respective measures to overcome them are presented in Table 67.

Table 67 - List of barriers for SAVR and respective measures to overcome them

Category	Barriers	Measures	Stakeholders
Human skills	- Scarcity of human skills in research and academic institutes. - Limited trained extension service.	Training of trainers for extension service, LARI staff, private sector and NGO technicians.	MoA, LARI, service providers, NGOs
Information and awareness	Lack of know-how and information about SAVR.	- Capacity building of Extension service through training and demonstration plots at farmers, nurserymen and seed importers level. - Awareness campaign about the importance of SAVR.	MoA, nurserymen, NGOs, seed importers, farmers
Social, cultural and behavioral	Difficulties in changing food and agriculture habits.	Marketing campaign, tasting, awareness about SAVR products.	Media, public
Market failure	- Market failure for SAVR products, difficulty to export SAVR. - Import restrictions. - Limited availability of healthy/certified plant material (for non-patented varieties and rootstocks).	- Marketing campaign. - Adhesion to UPOV. - Respect of Intellectual Property Right. - Product traceability establishment. - Promotion of the multiplication of local certified plant material.	Media, MoA, MoET
Institutional and organizational capacity	Limited research and development programmes.	Increasing R&D programmes on SAVR into different research stations (LARI) and on farm level, on different varieties and rootstocks under diverse climatic and soil conditions, accounting market potential.	MoA, LARI, AUB, key farmers
Technical	- Limited qualified nurseries; - Limited availability of healthy/certified plant material (for non-patented varieties and rootstocks). - Deficit in necessary infrastructure for plant conservation, sanitization and demonstration plots.	- Establishing the necessary infrastructure within research institutes to enable conservation, sanitization and multiplication of certified plant material. - Creating demonstration plots for extension purpose.	MoA, LARI, AUB
Policy, legal and regulatory	Deficiency in institutional arrangements for crediting system, subsidies and Intellectual Property Right in Lebanon.	- Undertaking the necessary decisions and laws allowing subsidies for SAVR. - Conducting a participatory process to reach the respect of Intellectual Property Right. - Ratifying international agreements to resolve import restrictions on patented plant material.	MoEc, MoF, MoA, parliament
Economic and financial	- High cost of imported patented plant material; - Absence of crediting system, subsidies for farmers and funds for R&D.	Allocating the necessary budget for research and development as well as for the necessary funds for demonstration plots and extension and infrastructure for plant material multiplication and certification.	MoA, MoF, LARI, AUB, donors

6.5.4 Cost benefit analysis for SAVR

The Cost Benefit Analysis focuses on: i) crops vulnerable to climate change, ii) crops where SAVR is recommended as a measure to increase resilience, iii) crops of a high importance in terms of economy and food security. These include tomato (in greenhouses and open field), potato and fruit trees.

After bilateral meetings with representatives from major stakeholders (MoA department of Horticulture, service providers, and the nurseries association: Machatel Loubnan) , costs related to public investments are estimated as follow:

- Infrastructure for multiplication, conservation, demonstration: USD 2,000,000.
- R&D (including sanitization and certification): USD 2,000,000.
- Training of trainers: USD 100,000.
- Marketing studies, campaigns to promote SAVR, tasting, etc.: USD 100,000.
- Awareness campaign on intellectual property right: USD 20,000.
- Product traceability system establishment: USD 50,000.
- Respect of IPR - adherence to UPOV process: USD 20,000.
- Institutional and financial arrangements to subsidize SAVR- financial mechanism to sustain R&D: USD 25,000.
- Subsidies covering price difference between conventional plant material and SAVR: around USD 23 million in 10 years, for fruit trees, potato and tomato. This figure could reach more than USD 25 million if all horticulture crops are accounted. Free distribution of seedlings as currently applied by MOA, will be hence replaced by a more efficient mechanism, that guarantees plant material quality, its traceability and its diffusion to the concerned beneficiaries.

Hence, the total cost for deploying SAVR will not exceed USD 30 million. It should be noted that costs of SAVR at farmer's level are minimal and do not exceed 4% of the total cost of production of horticulture crops in general. The main expense will have to be borne by the government to create the enabling environment for the diffusion of this practice.

Assumptions about market demand for SAVR

- Fruit trees seedlings demand from SAVR is accounted as follow:
  - Locally produced: 250,000 seedling/baseline year, with an increment rate of 50,000 seedlings/year
  - Imported: 250,000 seedling/baseline year, with a decreasing rate of 25,000 seedlings/year to reach a constant value of 150,000 seedlings/year
- Adapted potato seeds demand is accounted as follow:
  - Imported: 100t/baseline year, with annual increment of 100t to reach a constant rate of 600t/year.
- Tomato seedlings demand for greenhouses is accounted as follow:
  - A baseline production of 600,000 seedlings/year with an annual increase of 20% the first year, then 25% the 3 following years, as Methyl-Bromide will be totally banned from the market. Further, the increment rate will decrease to 20%, then 10% to reach a constant production.
- Tomato seeds demand for field cultivation will be assumed to remain start at 1 million seeds, with an annual increase of 1 million seeds/ year to reach a threshold of 9 million seeds/ year.

Assumptions for yields and sale prices for SAVR

- Yields without SAVR are expected to decrease by 1% as an annual trend for all crops as a result of impact of climate change. As for fruit trees, the trend is 5% as tree productivity decreases due to ageing.
- Tomato conventional production yields 30 tonnes in open field and 100 tonnes in greenhouses, while the use of SAVR enables producing 40 tonnes in open field and 150 tonnes in greenhouses. Sale prices for SAVR are the same open field, and USD 70/tonnes higher for greenhouse production.
- Potato adapted varieties have the same yield of the current ones. Sale prices for adapted varieties are USD 50/ tonnes higher (USD 450/tonnes instead of USD 400/tonnes)
- Fruit trees production is averaging 20 tonnes/ha, however the use of SAVR will gradually increase from null to reach 30 tonnes/ha, the 9th year after plantation. Sale prices for fruits resulting fro SAVR are USD 300/ tonnes higher (USD 1,000/tonnes instead of USD 700/tonnes).

In this scenario, after 10 years, 1,485ha of tomato under greenhouses will be produced with SAVR, and 3,600ha in field, 1,500ha of potato will be converted to adapted varieties in vulnerable areas, and 7,525ha of fruit trees will be using SAVR, as illustrated in Fig. 58

Consequently, with this rate of annual increment of SAVR, the cost of subsidies covering the difference between the cost of conventional varieties and rootstocks and SAVR will be as follow:

- The budget mobilized for subsidies during a period of 10 years, according to the rates mentioned above will be around USD 23 million according to figure 59.
- The NPV per ha over a period of 10 years according to the mentioned assumptions for fruit trees, potato, tomato in greenhouses and in open field are mentioned in figure 60.

Locally produced fruit tree seedlings	Imported patented fruit tree seedlings	Locally produced horticulture crops seedlings	Imported horticulture crops seeds (i.e. tomato)	Potato seeds
USD 1.5/seedling	USD 6/seedling	USD 0.25/seedling	USD 5/100 seeds bag	USD 50/ tonnes of seeds

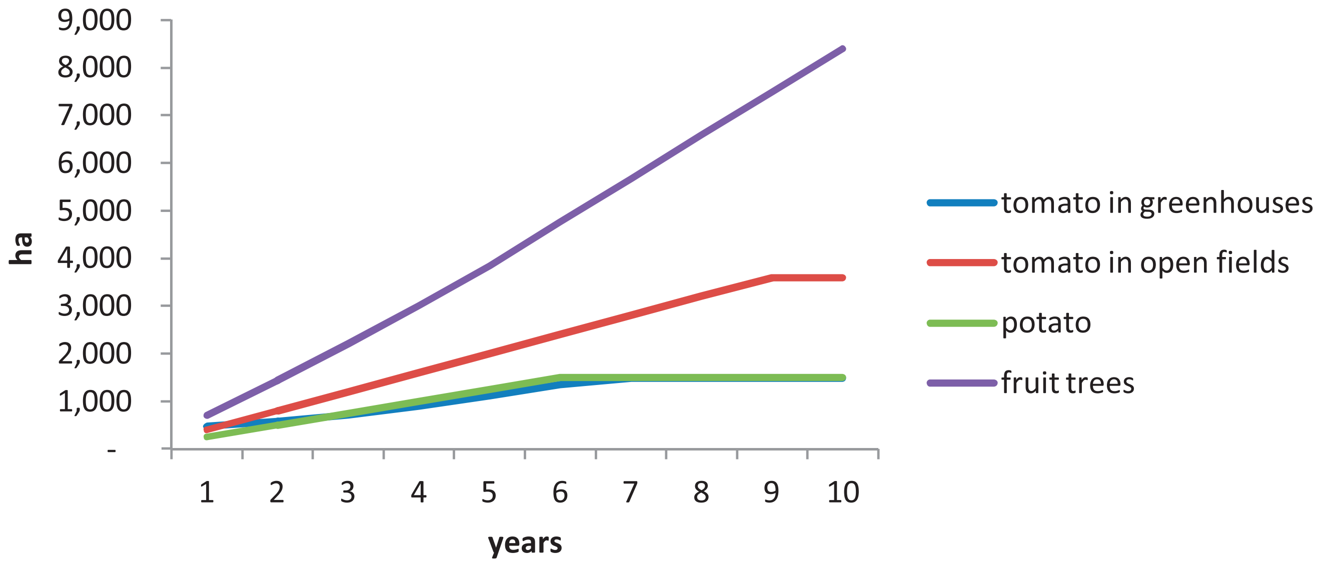

Fig. 58 - Evolution of cultivated areas with SAVR over 10 years

Source: Author's own design

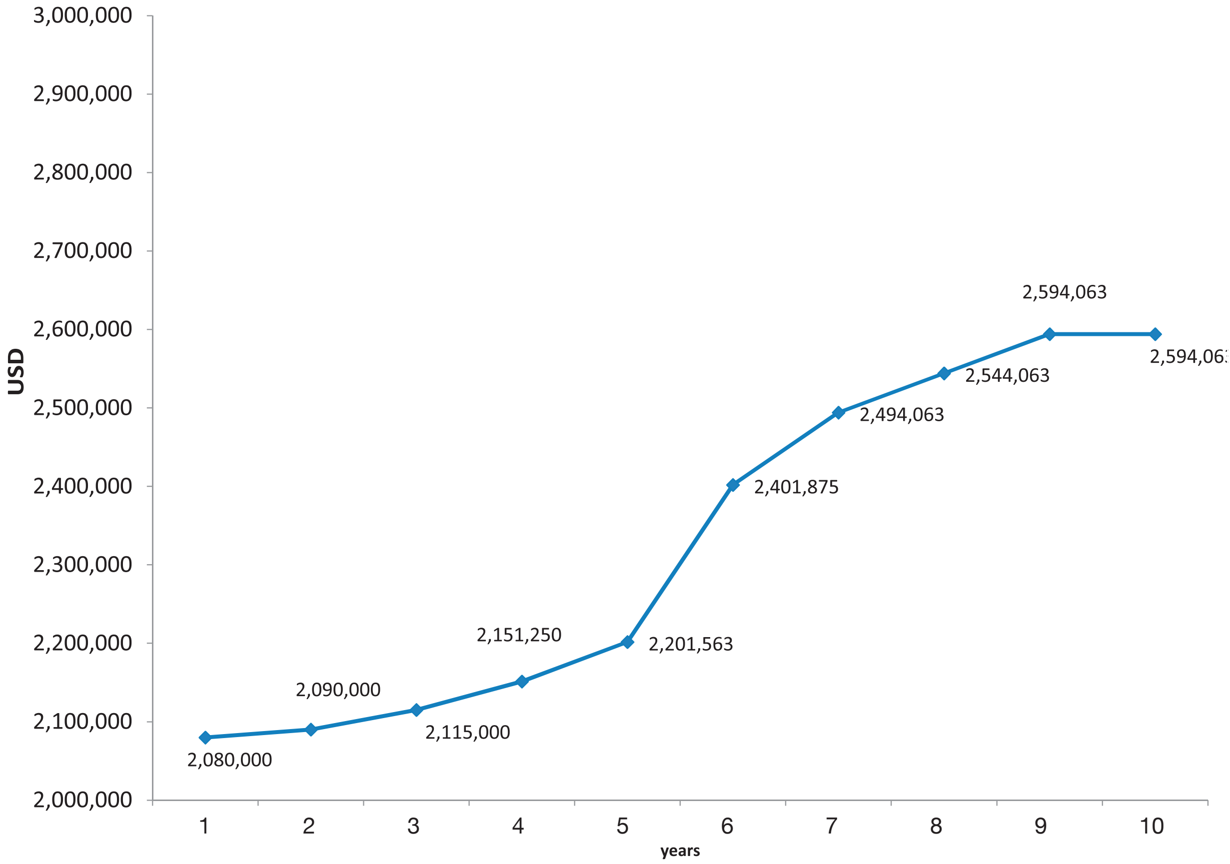

Fig. 59 - The evolution of the estimated annual budget allocated for subsidies for the diffusion of SAVR

Source: Author's own design

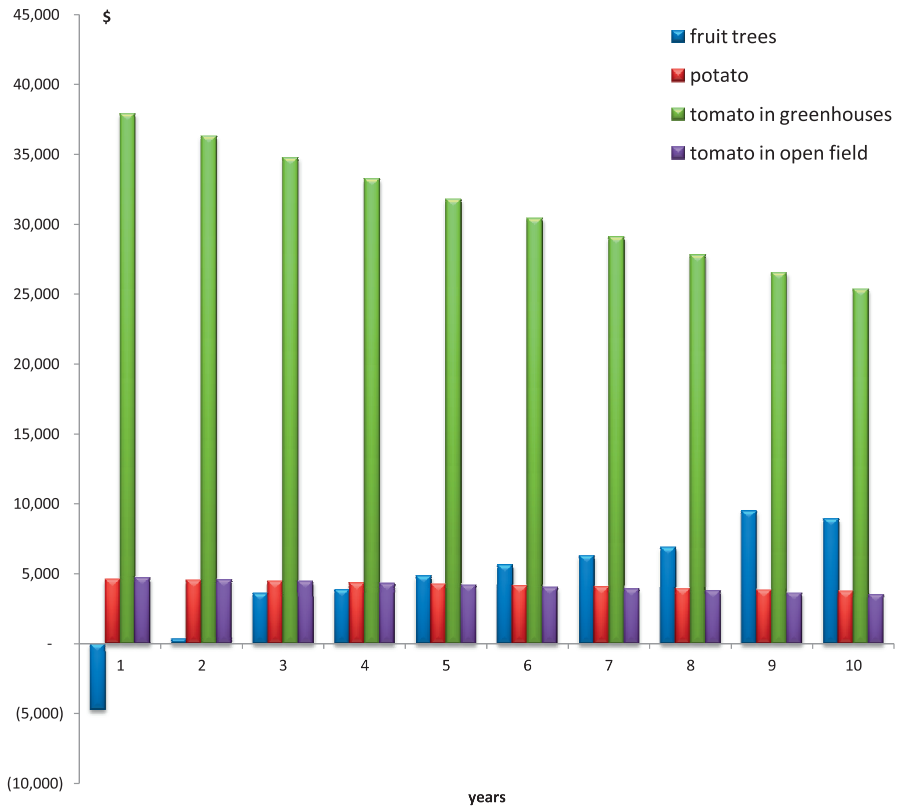

Fig. 60 - NPV over a 10 years period for 1ha of fruit trees, potato, tomato in greenhouses or open field.

Benefits at farmer's level have been studied for fruit trees, which has the longest period for investment return using imported SAVR as shown in the Table 68.

Following the rate of expansion of the use of SAVR mentioned in Fig. 59, with the assumed subsidy rates per type of crop, and benefits estimates per type of crop over a 10 years period, the total NPV would reach more than USD 892 million with a total cost for diffusion not exceeding USD 30 million. Yield will be sustained, while about 10% losses will be expected under conventional agriculture. Food security will be preserved. Products will be more marketable, and more likely to be exported. Nurseries and seed importers will benefit from the technology deployment. Pesticide, chemical and water use will be reduced when compared to conventional varieties and rootstocks, with a positive impact on the environment, and on the quality of the product. Therefore and since the benefits of using SAVR exceeds the cost of adopting the technology, it is cost-efficient to transfer and diffuse the SAVR technology in Lebanon.

Table 68 – Cost Benefit Analysis (in USD) of SAVR per 1ha of fruit orchard for the first 10 years after plantation

	Revenues under conventional agricultural practices .	Revenues under SAVR.	Additional revenue under SAVR.	Additional costs from using SAVR.	Net benefits from using SAVR.	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	0	0	5,000	-5,000	-4,717
2	140	500	360	0	360	320
3	700	5,000	4,300	0	4,300	3,610
4	2,100	7,000	4,900	0	4,900	3,881
5	3,500	10,000	6,500	0	6,500	4,857
6	7,000	15,000	8,000	0	8,000	5,640
7	10,500	20,000	9,500	0	9,500	6,318
8	14,000	25,000	11,000	0	11,000	6,902
9	14,000	30,000	16,000	0	16,000	9,470
10	14,000	30,000	16,000	0	16,000	8,934
NPV						45,216

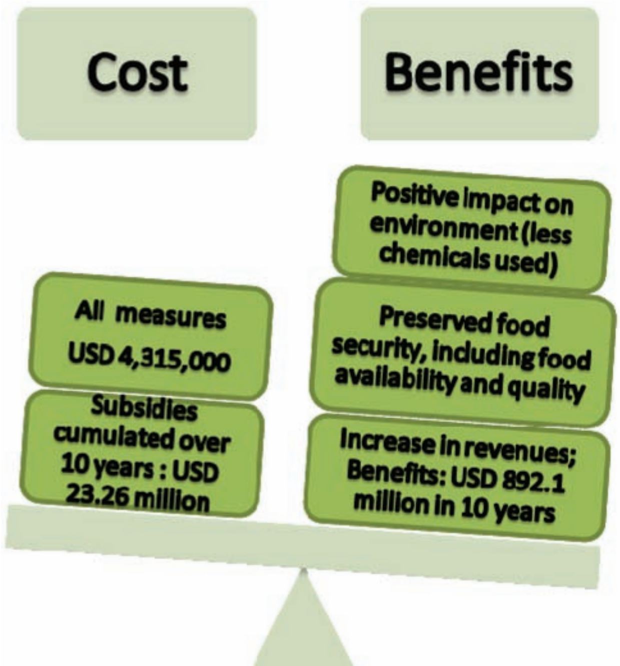

Fig. 61 - Cost and benefits of SAVR diffusion and transfer

Source: Author's own design

6.5.5 Technology Action Plan for Selection of Adapted Varieties and Rootstocks

Target for technology transfer and diffusion

The transfer and diffusion of this technology is a very long term project and of a large scale. The target of this action plan is to achieve the adoption of SAVR on 15,000ha of various horticulture crops, in a period of 10 years, at a cost of around USD 4.3 million. Including subsidies in the cost calculation could increase the budget to USD 23 million. In order to achieve this target in the near future, a technology action plan is hereby proposed.

In the light of the seed policy and certification of plant material efforts that are implemented by MoA, the project suggests measures leading to overcome barriers related to the respect of Intellectual Property Right, the import and export of patented plant material and their products. The installation of the necessary infrastructure enabling all the activities enhancing the transfer and diffusion of SAVR is coupled with research and development programmes, marketing campaign to promote SAVR products, extension and capacity building. Social acceptance and changing farmer's behavior could be corrected through incentives or subsidies covering the difference in price between common plant material and seeds and SAVR. Hence stakeholders list is very wide ranging from decision makers, to researchers, extension technicians, nurserymen, seed and plant material importers, exporters, farmers and consumers. The action plan for SAVR is presented in Table 69.

Table 69 - Technology Action plan for the Selection of Adapted Varieties and Rootstocks

Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring and Evaluation indicators	Estimated cost (USD)	Donors
Conducting training of trainers through seminars, training workshops, field visits	1	Improving human skills for the diffusion of SAVR, and for the installation of a national register of varieties.	International and national experts.	MoA extension service, LARI staff, private sector and NGO technicians, media staff	Short term	number of training sessions, percent active technicians in disseminating SAVR.	75,000 to train 100 technicians and researcher on biotechnology techniques, multiplication, sanitation, certification, plant disease monitoring, distinguish-uniformity-stability (DUS) and value of commerce and use (VCU), etc.	World Bank Adaptation Fund GEF IFAD FAO Islamic Bank EU USAID Kuwaiti Fund Italian, Spanish Cooperation.
Conducting training of farmers through field visits to demonstration plots	2	Improving farmers' behavior and perception to SAVR.	MoA extension service, NGOs.	Nurserymen; Seed importers; farmers	Medium to long term	Changes in varieties and rootstocks produced or imported and in plantations.	25,000 to train 1000 key farmers, 20 seed importer, 50 nurserymen.	
Promoting New varieties through tasting in agriculture fairs and awareness campaigns	3	Reducing market failure risk, enhancing exports and stimulating local market demand.	Media.	Farmers; public	Long term	Changes in demand on SAVR in major supermarkets Changes of export quantities of SAVR.	100,000 for participation in 5 national and regional agriculture fairs, tasting, TV and other media publicity.	
Acquiring the necessary land and procurement of material within research institutes	1	Enabling conservation, sanitization and multiplication of certified plant material. Creating demonstration plots and mother plant plots.	MoA with international assistance.	LARI, research institute	Medium term	Number of mother plots established Number of certified seedlings produced per variety and rootstock per nursery.	2,000,000 for mother plots for 50 varieties and rootstocks,, equipments for multiplication, sanitation and certification in 4 stations.	

Conducting experimental studies in research stations and farmer exploitation nationwide	2	Understanding the performance of different varieties and rootstocks under diverse climatic and soil conditions, accounting market potential.	Research centers (LARI) and academic institutions.	MoA extension service, nurseries, seed importers, key farmers	Long term	Number of publications on SAVR Performance of SAVR in terms of yield compared to traditional plant material in different regions % of budget dedicated to R&D.	2,000,000 for 10 years of multiplication trials in different regions, and sanitization and certification at nursery level to produce the amount of seeds and seedlings as estimated in the assumptions.	
Providing subsidies for SAVR, enforcing Intellectual Property Right	1	To increase the import of patented SAVR for all crops and their multiplication in Lebanon. To create within the national seed policy the enabling environment for the diffusion of SAVR.	MoET, MoF, MoA, parliament assisted by international and national experts.	seed importers, nurseries, exporters, farmers, research institutes	Medium term	laws, decrees or decisions elaborated in relation to intellectual property right national seed policy amendments.	50,000 for experts assisting MoET and MoA, 3 workshops, law amendments, and creation of a legislative framework for SAVR.	
Allocating the necessary budget for subsidies	3	To give incentives to farmers to use SAVR.	MoF, MoET, MoA.	Farmers	Long term	Amount of subsidies per annum.	25,000,000 in 10 years as estimated in assumptions.	
Creating a seed law and a national registrar for traceability of produced or imported plant material	2	to achieve the seed law and guarantee plant material quality control and authenticity and enable Intellectual property right respect.	MoET, MoA assisted by international and national experts.	seed importers, nurseries, research institutes	Medium to long term	seed law created and number of SAVR registered in a national register system.	50,000 for experts and establishment of the system.	
Signing International agreements to resolve import restrictions on patented plant material. Or adhesion to UPOV-respect of Intellectual Property Right	2	To overcome future expected restrictions on imports and exports of patented products and enhance biotechnology in Lebanon, through ensuring funds from royalties generated by the release of new varieties.	Media, MoA, MoET assisted by international and national experts.	seed importers, nurseries, exporters, farmers, research institutes	Long term	Law on adherence to UPOV value of exports number of local varieties registered in the national or international registers for new patented varieties.	20,000 for expert charges and 3 national workshops, at decision makers level to reach a consensus about adhesion to UPOV.	

6.6 Analysis of Technology: Risk-Coping Production system - Good Agriculture Practices (GAP)

6.6.1 General description of GAP

Good Agriculture Practices (GAP) is a risk–coping production system which includes field operations related to plantation scheme management, fertilization management, pest management and harvesting.

In this section, GAP for grapevine is taken as an example for the Cost Benefit Analysis as it embeds several additional adaptation practices requiring investments in plantation scheme (adapting trellis and pergola systems) and in field operations (pruning vines, leaves and grapes, etc.).

Regulations for Good Agriculture Practices (GAP) are inexistent, with a first shy initiative of implementing a farmers "Terms of Reference" on grapevine to ensure better control on the quality of the product, and reduce pesticide residues. LIBNOR has implemented a series of non-mandatory norms and standards for the end product of several crops. MoA has set regulations for the import, packaging, and trade of pesticides (Decree 13528, 1998; Decision 392/1, 2003) and material related to plant protection (Decision 29/1, 1962 and its amendments starting 2003) and fertilizers (Decree 15659, 1970). These include a list of prohibited molecules, and regulations for import, bottling and labeling. Instructions on the safe use of pesticides are shown on the product label.

6.6.2 Identification of Barriers for GAP

The list of barriers for GAP transfer and diffusion for the different agriculture market chains is as follow:

- Difficulty to change farmer's behavior: This is most valid for pruning methods and pest management.
- Limited information: farmers are not aware of the concept and benefits of GAP.
- Inappropriate land tenure system: By law, the use of agricultural lands is limited to a short renting period, namely for annual crops which hinder the adoption of GAP as farmers tend to intensify the use of land with the minimal investment possible.
- Deficiency in necessary equipments: some traps, pheromones, pesticide molecules, equipments, etc. are not abundantly found on the local market.
- Scarcity in budget: farmers do not have enough budgets to invest in new plantation schemes in vineyards and orchards.
- Absence of quality control: inspection on farms to control the use of chemical inputs is absent.
- Limited extension service: the human resources to diffuse GAP concept are lacking.
- Inefficient dissemination: although the information is available, the tools for communicating GAP to farmers are not always adapted to the local context (many are unable to read booklets, or unable to attend the demonstration plots or training sessions).
- Limited R&D programmes: GAP tools and recommendations are not studied for most crops yet.
- Import difficulties: import of traps, pheromones, natural predators and other non-chemical products are facing administrative constraints and service providers are not encouraged to import these items which reduce their sales of pesticides.
- Inappropriate crediting system: access to agriculture credits in Lebanon is very limited.
- Weak institutional/financial arrangements: to facilitate import of non-chemical products, enhance agriculture crediting systems and to mobilize resources for technology transfer and diffusion.

The complex inter-linkage between these barriers is mentioned in Fig. 62

6.6.3 Identification of Measures for GAP

Good Agriculture Practices have numerous barriers to overcome, including limited human resources, financial resources and institutional and financial arrangements. The identified measures to overcome the barriers are listed in Table 70.

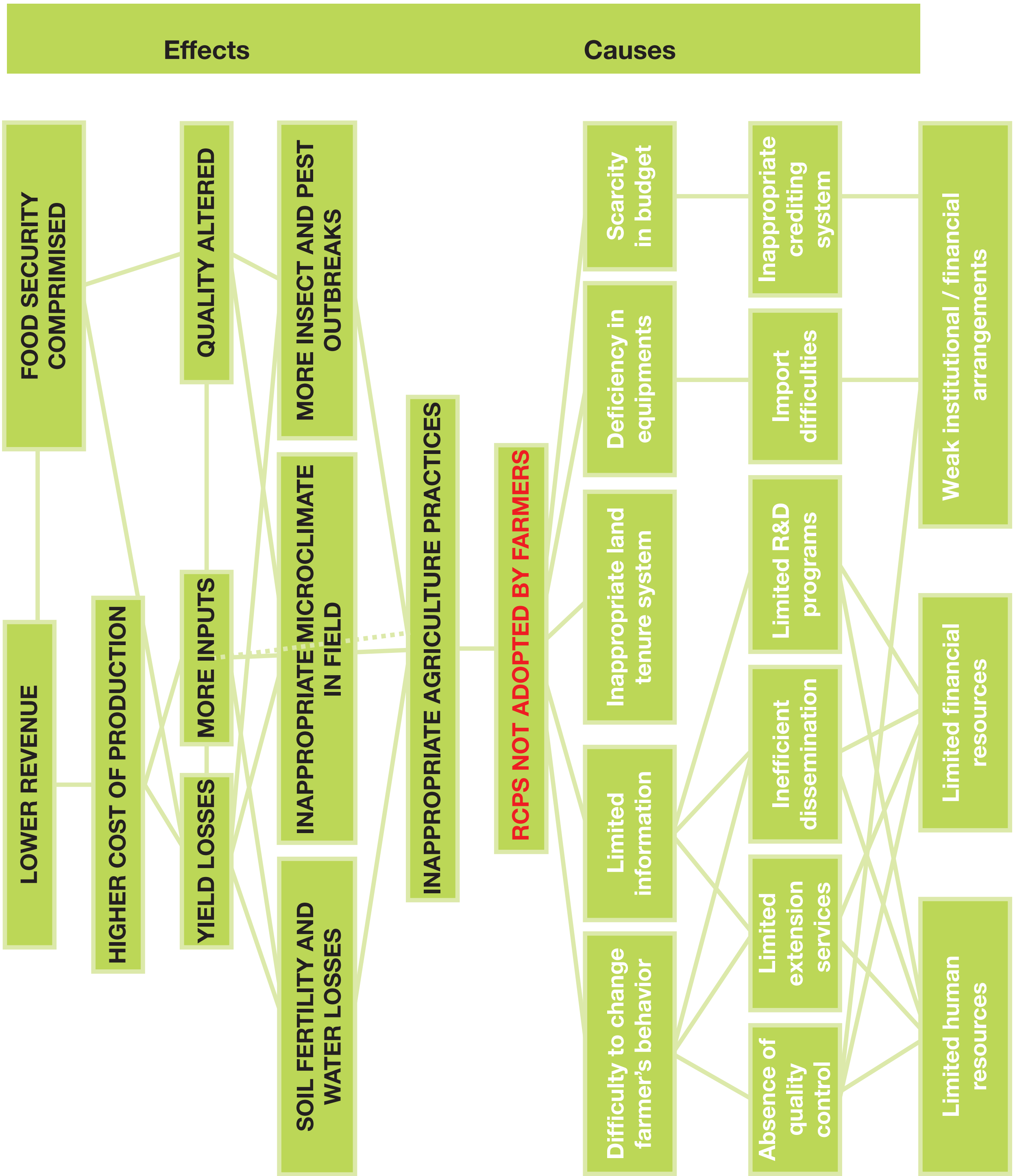

Fig. 62 - Problem tree of Risk-Coping Production System: Good Agriculture Practices

Source: Author's own design

Table 70 - List of barriers for GAP and respective measures to overcome them

Category	Barriers	Measures	Stakeholders
Human skills	Limited human resources for implementing extension and research.	Recruitment of competent technicians, researchers.	MoA, LARI, Civil Servant Council
Institutional and organizational capacity	- Limited extension service capacity - Inefficient dissemination Limited R&D programmes on GAP for most crops.	- Increasing field research and development programmes on GAP on main crops in different agro-climatic zones; - Planning and implementing an information dissemination strategy to farmers and relevant stakeholders. - Training of trainers.	MoA, LARI, NGOs
Policy, legal and regulatory	- Inadequate land tenure system. - Import difficulties for equipments. - absence of quality control and institutional and financial arrangements to guarantee the quality of GAP products. - Inappropriate crediting system from banks.	- Providing incentives for the import of equipments and material, - Elaborating norms of production (specifications). - Providing legislative arrangements for the recruitment of skilled technicians, - Establishing of quality control system and facilitating the agriculture crediting system.	MoA, Custom Service, MoF, Banking sector
Information and awareness	Narrow information on GAP at farmers level.	Organizing awareness campaigns and field visits to demonstration plots, seminars, and trainings .	MoA, NGOs
Economic and financial	Scarcity of funds for R&D and for recruitment.	Allocating the necessary governmental budget for R&D and information dissemination.	MoF, MoA, LARI
Social, cultural and behavioral	Inherited behavior affecting farmer's agriculture practices and acceptance for GAP.	Organizing field visits to demonstration plots and conducting seminars for farmers to learn and train them about the advantages GAP.	MoA
Technical	Deficiency in suitable equipments.	Facilitating equipment import by service providers.	Service Providers, Custom Service, MoA

6.6.4 Cost benefit analysis for GAP

The estimated public expenditure to overcome barriers related to GAP makes a total of USD 325,000, detailed as follow (Agrical, 2012; MoA, FAO, IC, 2011):

- Research and development: USD 250,000.
- Training of trainers: USD 20,000.
- Information dissemination strategy: USD 5,000.
- Awareness campaign (media, field visits, etc.): USD 50,000.

If the recruitment of additional technicians in public institutions is not foreseen on the short term, the mainstreaming of NGOs efforts for training their existing technicians onto GAP could be a solution for information diffusion. These efforts should be backed up by audio-visual packages to be diffused by media.

Since Good Agriculture Practices are diverse and different from one crop to another, in this particular exercise table grapevine is selected for the cost-benefit analysis exercise. This crop is not only vulnerable to climate change, but is also of national importance. The additional cost and benefits for shifting to GAP at table grapevine grower's level is estimated as follow:

- Adapting plantation scheme infrastructure (first year): USD 3,000/ha.
- Adapting training and pruning methods (first 3 years): USD 50/ha.
- Soil fertility management: USD 400/ha saved annually.
- Integrated Pest management: USD 250/ha (starting the 4th year) saved
- Insect-proof nets(4th year): USD 5,000/ha.
- Additional labor (grape pruning, hormone application and so, starting the 4th year): USD 200/ha.

In the case of table grapevine growers, after a 10-year period, 2,000ha will have adopted GAP. The total cost spent by the grapevine growers is expected to reach USD 8.66 million for the mentioned area and period. Costs and benefits at farmer's level are illustrated in Table 71.

Costs and benefits of the transfer and diffusion of GAP, with an emphasis on Table grape production are illustrated in Fig. 63.

Assumptions for table grapevine under GAP

- Baseline area under GAP: 200ha
- Annual increment rate: 200ha
- The expenses of farmers will not be subject to subsidies.
- Yield in GAP is higher than in conventional agriculture: 30t/ha instead of 20t/ha
- Yield is subject to an annual decrease of 1% in for grapevine under conventional agriculture, while it remains stable under GAP.
- Since Baseline year, Table grapes under conventional have 10% less marketable production.
- Grapes under GAP have a better quality; we consider that there 50% higher price for products under GAP: USD 0.75/kg for grapevine under GAP instead of USD 0.5/kg for conventional production.

Table 71 –Cost Benefit Analysis (in USD) of 1ha of vineyard under GAP for a 10-year period

	Revenue under conventional agriculture without adaptation	Total revenues under GAP	Additional revenue under GAP	Additional costs from applying GAP	Net benefits from applying GAP	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	9,000	22,500	10,850	2,650	8,200	7,885
2	8,910	22,500	13,940	-350	14,290	13,740
3	8,821	22,500	14,029	-350	14,379	13,826
4	8,733	22,500	9,217	4,550	4,667	4488
5	8,645	22,500	14,305	-450	14,755	14,187
6	8,559	22,500	14,391	-450	14,841	14,270
7	8,473	22,500	14,477	-450	14,927	14,353
8	8,389	22,500	14,561	-450	15,011	14,434
9	8,305	22,500	14,645	-450	15,095	14,515
10	8,222	22,500	14,728	-450	15,178	14,595
NPV						126,292

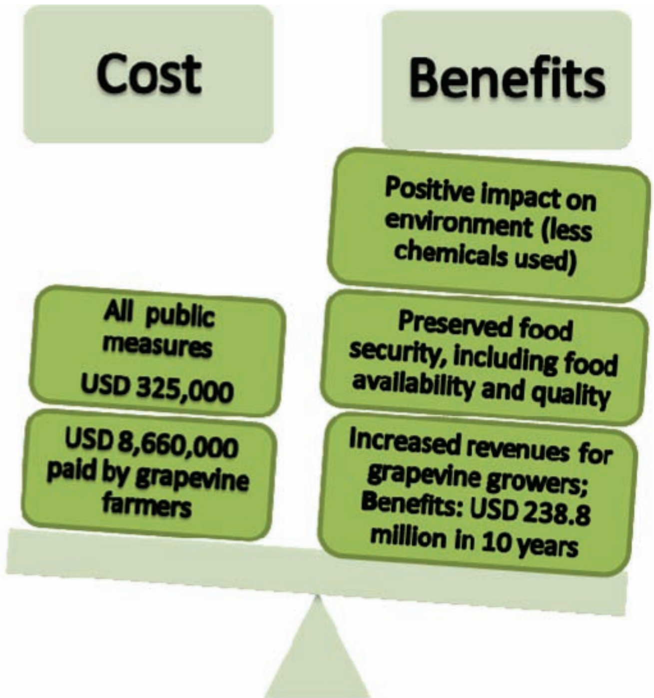

Fig. 63 - CBA for the transfer and diffusion of GAP for table grapevine.

Source: The author's own design

Benefits related to the transfer and diffusion of GAP include: i) less inputs in terms of chemicals, with a positive impact on the environment (water and soil) and food quality, ii) food security preserved due to food availability (yield stability), increase in revenues (access to food) and preserved food quality and, iii) benefits exceeding USD 238 million in 10 years following the assumptions related to yield, surface applying GAP and NPV per 1ha in a 10-year period, as mentioned in Figure 63.

Costs from public expenditure are USD 325,000 while the expenses paid by table grapevine growers are USD 8.66 million, making a total of USD 9 million approximately. Based on a revenue of USD 238.8 million for 10 years, and compared to the costs incurred for the deployment of the GAP, results show that the adoption of good agricultural practices are cost-efficient and feasible in Lebanon.

6.6.5 Technology Action Plan for a Risk Coping Production System: Good Agriculture Practices

Target for technology transfer and diffusion

If GAP is to be applied at a national scale, and for different crops, a nationwide awareness and training campaign is to be initiated, especially that Good Agricultural Practices can be easily coupled to other technologies or practices for optimal efficiency and adaptation at farmer's level. The appropriate technology action plan is presented Table 72.

Table 72 - Technology Action plan for Good Agriculture Practices

Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring and Evaluation Indicators	Estimated cost	Donors
Initiating civil servants recruitment procedure	2	To overcome the lack of human resources for R&D.	Civil Servant Council	MoA, LARI	Short term	Number of recruited personnel.	0	World Bank Adaptation Fund GEF IFAD FAO Islamic Bank EU USAID Kuwaiti Fund Italian, Spanish Cooperation
Conducting experiments in different research stations and on farm in all agro-climatic zones	1	To better understand the response of crops to different RCPS, including GAP and adapt practices according to crops and agro-climatic zones.	LARI, NGOs	MoA, NGOs, farmers	Medium to long term	Number of experiments conducted Number of publications related to GAP.	250,000 for experiments in at least 5 stations, and at 50 farmers on 8 major crops.	
Elaborating communication tools	2	To ensure an efficient diffusion to farmers of information, including research results.	MoA assisted with external experts	MoA, Custom Service, MoF, Banking sector	Short term	Strategy report.	5,000 fees for the expert.	
Conducting annual seminars to show research results, field visits	1	To increase the skills of technicians.	MoA, NGOs external experts	MoA, NGOs staff	Medium term	Number of technicians Guidelines on gap for different crops.	20,000 to train 50 technicians by experts.	
Providing import facilities for equipments and material	2	To facilitate the deployment of GAP and overcome constraints related to material import, quality control and lack of agriculture credits.	MoA, Custom Service, MOF, Banking sector	Service providers, exporters, consumers and farmers	Medium to long term	Number of decisions and decrees taken; % of custom rates; Elaborated standards for GAP; % of loans for agriculture investments.	0	
Elaboration of standards of production Allowing agriculture crediting system								
Conducting field visits to demonstration plots, seminars, training	3	To sensitize the farmers about GAP and change their behavior in agriculture practices.	MoA	Farmers	Medium term	Cost of production Yield variation Quality control reports.	20,000 cost of 3 seminars and field visits per farmer, for a target of 1000 farmers.	

6.7 Linkages of identified barriers

The three selected technologies are characterized by common barriers that are interlinked. These focus mainly on the absence or deficiency of specific institutional or financial arrangements and to awareness and information dissemination as well as research and development. For instance, financial resources are needed not only to conduct research programmes on topics related to the three technologies, but also for ensuring subsidies, which require governmental decisions to shift subsidizing mechanism from crop oriented (for wheat and tobacco) to practice oriented (for the use of SAVR or adopting CA, etc.). Meanwhile indirect subsidies or services provided by some institutions (i.e. distribution of seedlings to farmers; extension activities) should be embedded in the process of transfer and diffusion of SAVR, CA and GAP.

Although these might be of different nature, the major actors involved are public institutions, namely: i) the Ministry of Agriculture, ii) the Ministry of Finance and iii) the Ministry of Economy and Trade. Other public institutions, such as i) the Ministry of Environment, ii) the Green Plan, iii) the Lebanese Agriculture Research Institute, iv) the General Directorate of Customs, v) the General Directorate of Urban Planning, and vi) The Council for Development and Reconstruction could also be involved. A holistic approach for overcoming these barriers could be overseen with the mentioned stakeholders. Other important actors are private or international research institutions active in Lebanon (AUB, USJ, LU, USEK, CNRS, ICARDA, and ACSAD) or active NGOs in the diffusion of technologies (Arc-en-Ciel, Frem Foundation, Hariri Foundation, Moawad Foundation, Safadi Foundation, YMCA, etc.).

Mainstreaming of measures for overcoming these common barriers is hence required. Such effort would optimize the efficiency of transfer and diffusion of the technologies.

6.8 Enabling Framework for overcoming the barriers in agriculture

The use of a Selection Adapted Varieties and Rootstocks, Conservation Agriculture and Good Agriculture Practices concern mostly farmers' behavior and their readiness to change their agriculture production system and field operations. Therefore, the enabling framework is limited to the capacity of public institutions to transfer these technologies on the grass root level. Few arrangements to facilitate the requirement of necessary equipments are to be done (like seed drillers for some crops under CA or plant material under SAVR). Nevertheless, most of the work concern extension service capacity to diffuse the technologies, and research programmes prior to this diffusion.

A major concern is the capacity of absorption of additional projects or programmes within the public institutions which chronically suffer from the limited human resources and infrastructure enabling the proper implementation of such programmes. Therefore, the proposed technology action plans require international assistance with the participation of local NGOs, research institutions and international organizations that have a long expertise in transfer and diffusion of these technologies. The ownership of these technologies by the MoA is crucial for further development of projects aiming at overcoming barriers related to the transfer and diffusion of these technologies. So far, all the selected technologies fall under the framework of the Agriculture Strategy 2010-2014. The Ministry of Agriculture is being active in encouraging conservation agriculture, elaborating communication tools for GAP and developing a seed policy, which would be a perfect ground for enhancing SAVR and resolving constraints related to Intellectual Property Rights.

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.

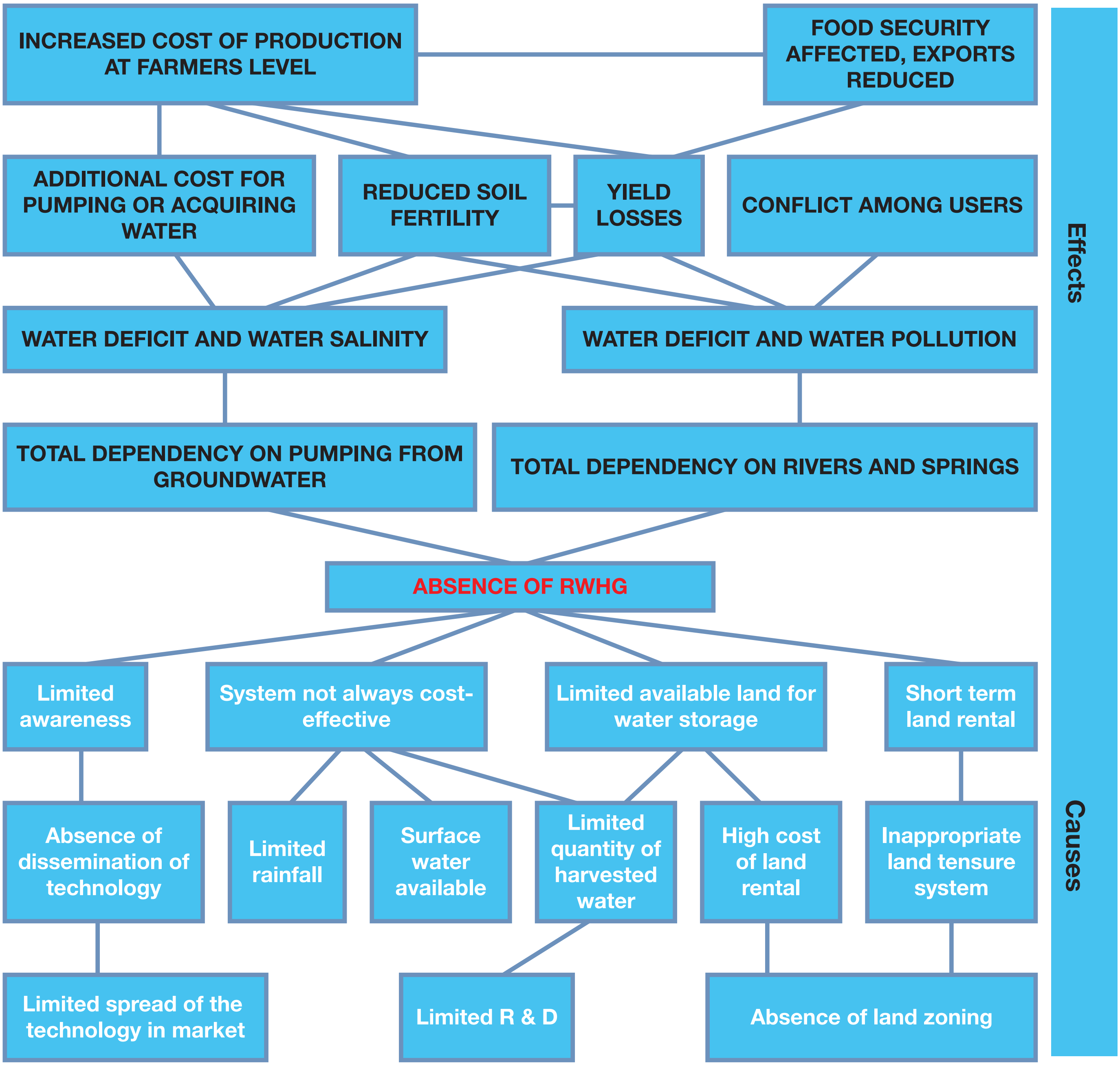

Fig. 66 - Problem tree for RWHG.

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

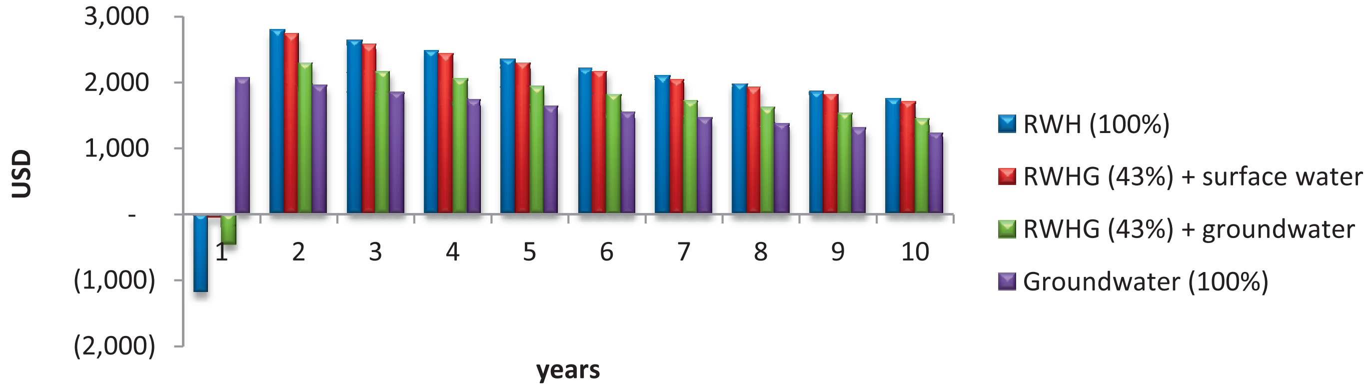

Fig. 67 - Discounted benefits over a period of 10 years for different water source scenarios

Source: Author's own design

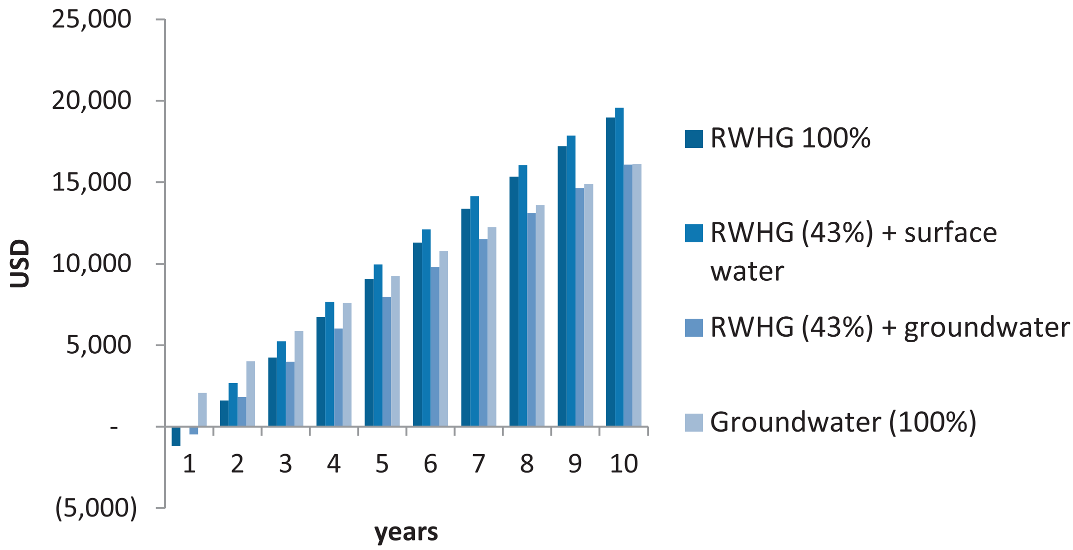

Fig. 68 - Cumulated discounted benefits over a period of 10 years from different water source scenarios

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.

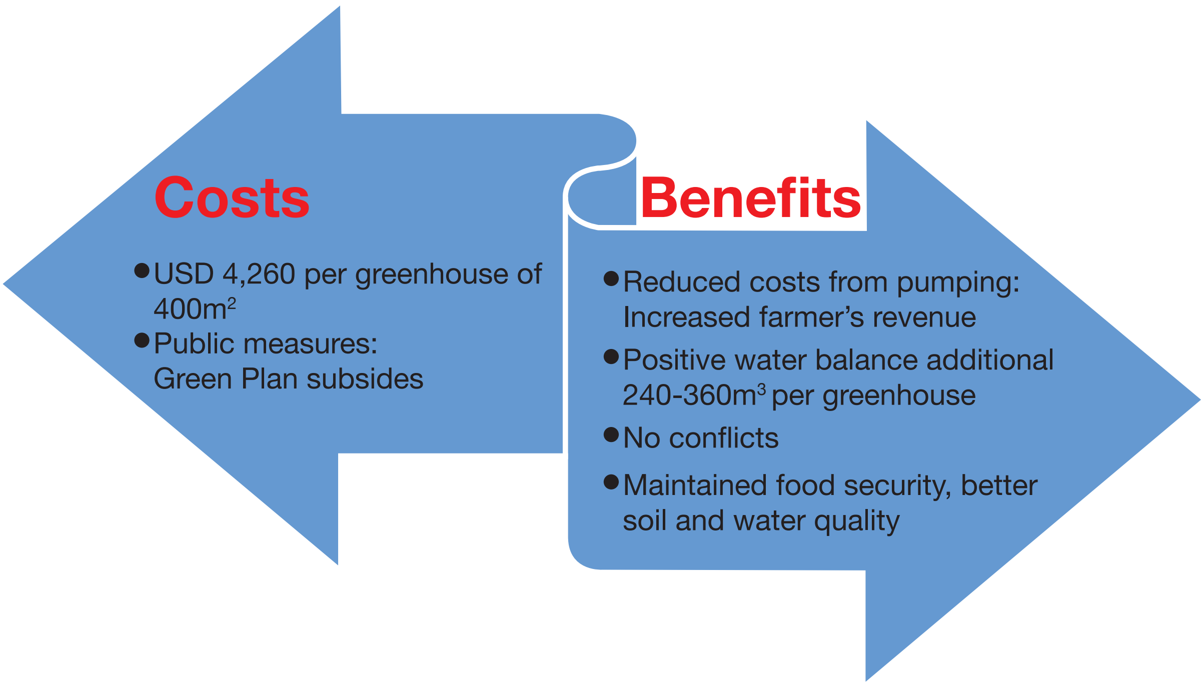

Fig. 69 - Cost and Benefits of RWHG

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:

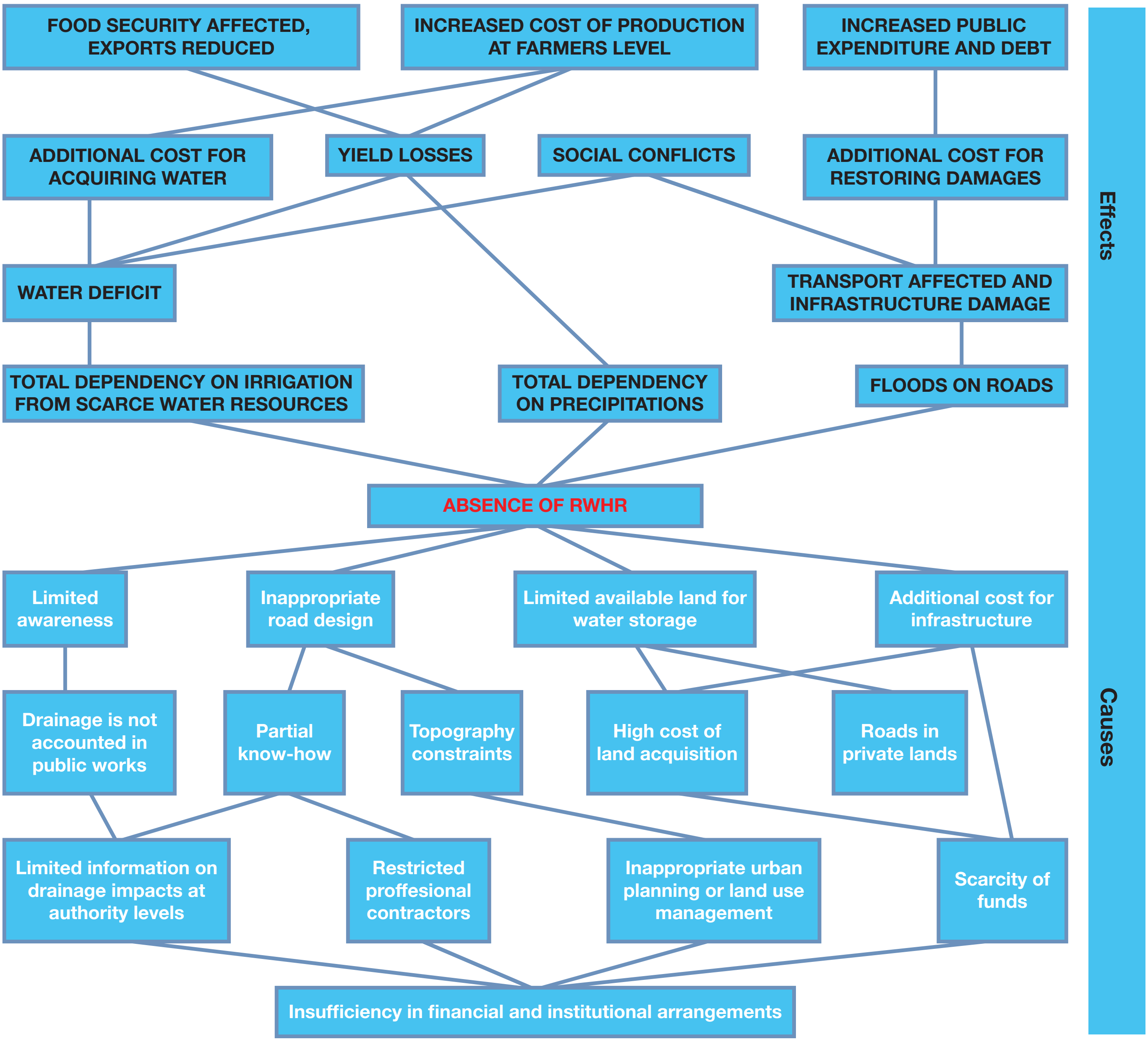

Fig. 70 - Problem tree of RWHR.

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.

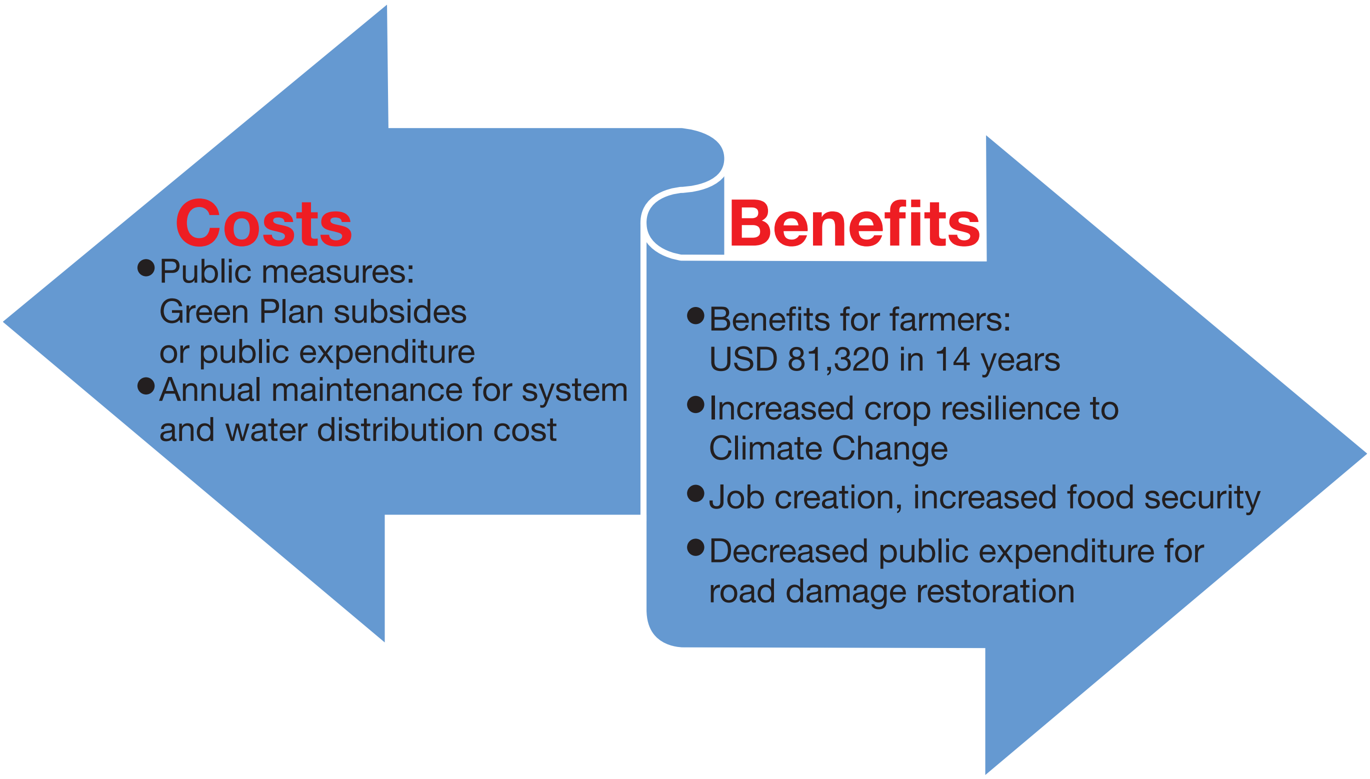

Fig. 71 - Cost and benefits of transfer and diffusion of RWHR

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.

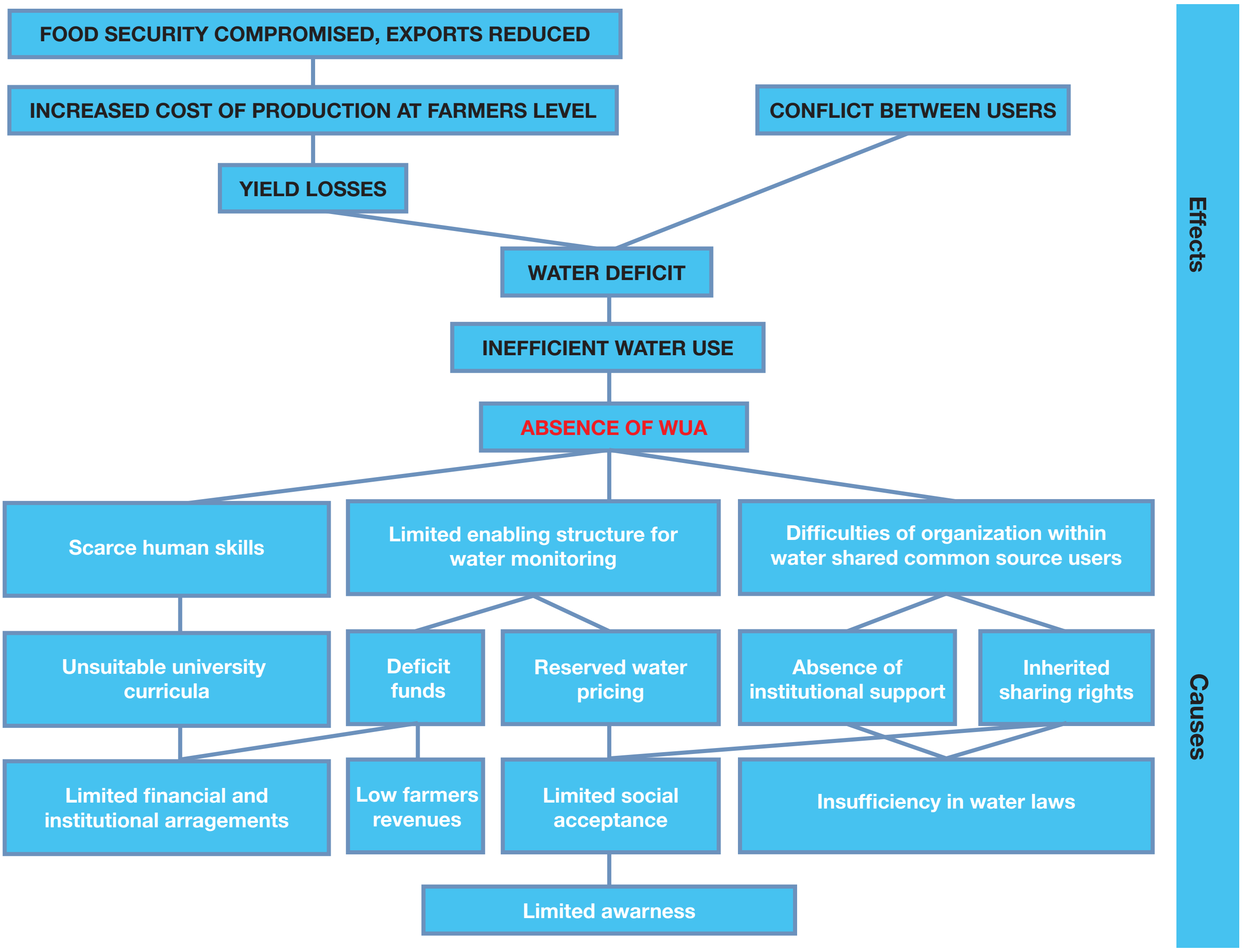

Fig. 72 – Problem tree of WUA

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

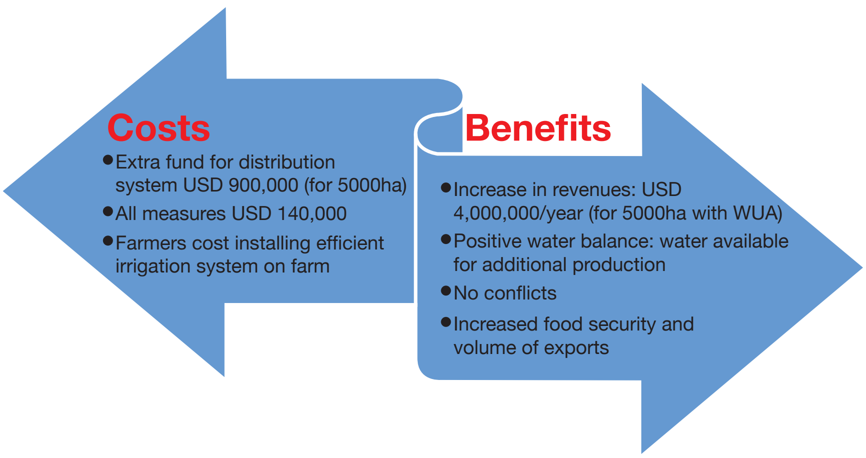

Fig. 73 – Costs and benefits of WUA

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	