Recent Trends Towards Developing a Sustainable Irrigated Agriculture in the Bekaa Valley of Lebanon

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RECENT TRENDS TOWARDS DEVELOPING A SUSTAINABLE IRRIGATED AGRICULTURE IN THE BEKAA VALLEY OF LEBANON

by F. Karam[1] and K. Karaa[2]

1. Background

An increasing population throughout the Middle East countries and a subsequent pressure for food are forcing people to crop land which is diverse and limited in nature, where the risks of environmental degradation through losses of soil and water are high, and where crop yields are unreliable. These countries are characterized by a semi-arid climate with unpredictable rainfall and current droughts. Large number of people living in the communal areas in this marginal environment depend mainly on rainfed cropping. Furthermore, rural communities have observed detrimental changes in hydrology over recent decades, groundwater levels have fallen, springs and wetlands areas have dried up, and rivers no longer flow in the dry season. The main causes are thought to be land degradation, changes in rainfall and interactions between these factors. Diminished vegetation cover and poor surface management of cultivated crops, combined with limited surface water supply, have led to reduced infiltration, increased runoff and soil erosion, and a decline in groundwater recharge.

Water, when available is unconstrained and regular quantities may be used at the discretion of the farmer. A major problem arises when water is available, as in the case of arid lands, in too small supplies so that to make its cost of procurement relatively high.

Forecasts of the impact of increased demands for water indicate that by 2025 most of the countries in the Middle East region will have only 32 to 66%

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of the renewable water resources available in 1990 (UNESCWA/FAO, 1994). According to the latter, Lebanon is expected to face severe water shortage due to declines of 66% respectively in its total renewable water resources when compared to those in 1990.

One of the features of irrigated agriculture is its predictability as to systematic and dependable crop production, if adequate storage facilities are available to assure supplies during the peak water requirements of the year, or during successive years of a dry period.

In Lebanon, accelerated development of intensive agriculture has resulted in an inexorable pressure on limited water supplies. Aside, agriculture is increasingly dependent on irrigation technologies and management.

The problem of water resource management in agricultural irrigation concerns not only technical and engineering aspects for adapting the better irrigation system or technologies, but legislative aspects about water preservation as well. In an ultimate sense, water, rather than land, might be the more limiting factor on agriculture in arid or semi-arid environments. Hence, sufficient attention should be given to water use and irrigation technologies. High productivity is due in great part to sophisticated irrigation technologies and advanced irrigation research programs.

Nowadays, there is a significant emphasis on the establishment of new irrigation projects aiming to provide a holistic approach to water and agricultural development and to be implemented as part of the irrigation programs in regions where increasing importance as the impact of climate change becomes progressively more evident.

This paper will not deal with either the technical aspects of irrigation engineering or with cost-benefit analyses of large water projects, nor with the legislative laws controlling the distribution of water across agricultural lands and the cost of water over time. It is simply limited to the discussion of the Bekaa Valley's experience in irrigation and the transfer of irrigation water to users.

It is worth also to highlight the recent achievement of the concerned authorities, the public mainly, in the process of irrigation projection and transfer to additional agricultural areas. The present Government's general policy of promoting new irrigation schemes is also a contributing factor that leads in the future to additional irrigated lands.

The limitations of surface water supplies placed an immediate restriction on economic growth. High productivity is due in great part to the utilization of modern irrigation technologies and advanced irrigation research programs can be obtained. In the Bekaa Valley, where, regardless dryness and water lack, agriculture is considered one of the most productive in the Mediterranean region.

2. History

Located at the eastern coast of the Mediterranean sea, Lebanon, like any other country in the south Mediterranean region, is suffering from soil degradation, climatic changes, water shortage and high demographic increase.

The Bekaa valley is in the forefront of inter-agricultural competition in the use of water since it represents the most productive agriculture in the region as to these water issues associated with irrigating agricultural crops.

The Bekaa valley has a long history of confronting problems of economic development in a water-scarce environment. The limitations of visible surface water supplies placed an immediate restraint on economic growth. Technological improvements in groundwater pumping opened up a vast invisible stock of water which, in turn, is considered the most developed in the country. The search for an increased supply of water was accelerated and giving urgency during the 1980s by the striking expansion in the urban-industrial activities. The increasing water scarcity is affected primarily by the irrigated agriculture sector of the national economy.

Water for agricultural use consumes 80% or more of all water used. Present estimates indicate that this region of Lebanon consumes 1.5 times the annual ground and surface water replenishment. This situation has recently led to an increased scarcity of water, a declining of groundwater tables and an increasing competition for water from nonagricultural sectors of the economy (Irrigation in the Near East Region, 1996).

Historically, the utilization of large-size pumps to lift water from deeper wells combined with the cost of pumping irrigation water have led to higher costs of irrigation waters. Added to these, the quality of water available to farmers has shown a gradual deterioration.

Economical analysis is currently being used also in studies related to environmental impacts associated with irrigated agriculture. Researches conducted at the Agricultural Research Institute of Lebanon at Tal Amara indicate that nitrogen contamination of groundwater may become an ever-greater preoccupation in the future. Underground water was sampled at different rates from different sites in test plot experiments and analysis showed an over-apply fertilizer by farmers. Much of the research programs combined with applied engineering and agronomic studies concentrated on farm management issues and production economics. These studies are of a continuing interest and represent a commitment to a further understanding of water problems as well as to assisting farmers toward improving their profit position in a water-scarce environment.

Government irrigation policy which has been pursued in the middle of the fifties has contributed substantially to agriculture growth and irrigation development. It was expected that in the second half of this century, an additional agricultural area of approximately 163 000 hectares will be brought under irrigation, which represents twice the actual irrigated land in Lebanon (table 1).

A limitation in irrigation expansion was then obtained due to the fact of not devoting substantial investments to irrigation during the period of war. Concerning the already existing projects, the lack of operation and maintenance works in the irrigation schemes has led to serious water shortages. Such water shortages are generally the result of deficiencies in irrigation systems and limited water availability from the conveyance tubes. The situation was also aggravated when unproper water management has been practiced.

Actually the irrigated area represents 25% of the total cultivable area. The new irrigation schemes are located in southern Bekaa Valley and in south Lebanon. A study covering a survey of 50 already existing schemes showed that about 46.79% of the total irrigation network need rehabilitation (Litany River Authority, 1993).

Although irrigation delivery was designed on both the on -demand method and the supply method, the latter in fact was adapted in most of the irrigation schemes. This has resulted in peak water demands, which often occur at the same time in the irrigation season and create problems of water scarcity. An informal transfer to groundwater pumping for irrigation purpose was then provided by local organizations and this dramatic change will heavily bear on the irrigated agriculture in the future.

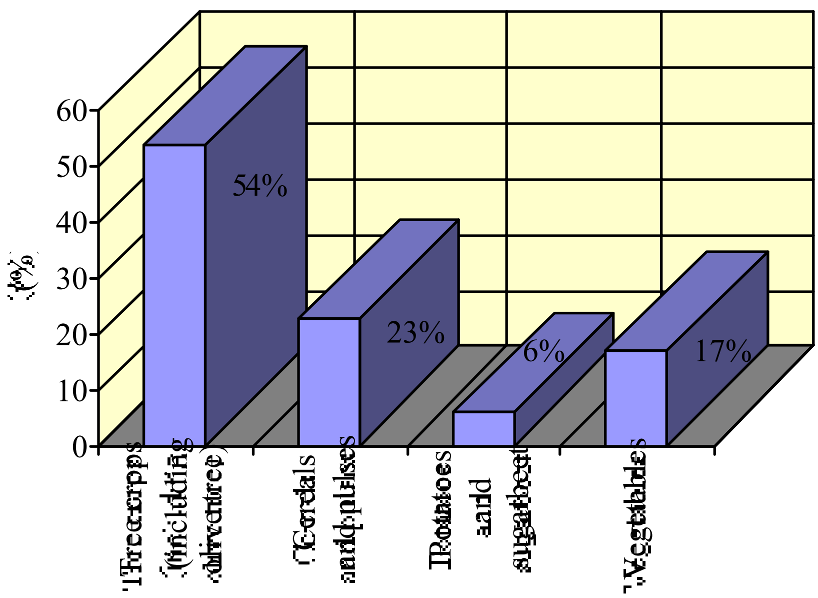
Table 1. Perspectives of irrigation development in Lebanon (*source: Irrigation in the Near East Region, 1996*).

Irrigation scheme's size	Irrigated lands (ha) deriving from both surface and underground water		
	Surface water	Underground water	**Total**
Very small	-	28 000	28 000
Small	50 000	-	50 000
Medium	8 300	2 700	11 000
Large	64 800	9 200	74 000
Total	123 100	40 000	163 000

3. Land use pattern and agricultural practices

In Lebanon, the cultivable land is estimated at 360 000 hectares, or 35% of the total area. In 1994, the total cultivated area was estimated to about 189 206 hectares, of which about 55% (104 120 hectares) are annual crops and the remaining 45% (85 086 hectares) are irrigated permanent crops (Box 2)

Figure 1 shows that fruit trees, including olives and nuts, occupy about 54% of the agricultural area, cereals and pulses about 23%, potatoes and sugar beet about 6% and vegetables account for 17% (Lebanese Ministry of Agriculture, 1994). Table 2



denotes for soil occupation in Lebanon.

Figure 1. Land use in Lebanon

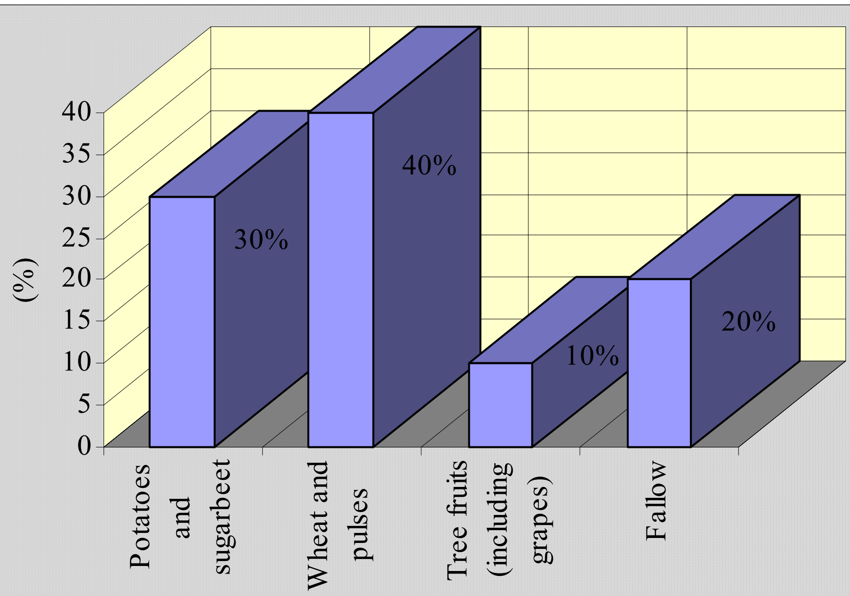
Table 2. Use of the cultivable soils in Lebanon (*source: Litany River Authority, 1993*).

Soil occupation	Area (in hectares)
Irrigated area	67 500
Seasonal irrigation	22 500

and gardening	
Pasture	100 000
Forest and uncultivated soils	80 000
Irrigable soils	90 000
Total	360 000

Data reported by the Lebanese Agricultural Research Strategy in 1996 showed a total cultivated land in Lebanon of about 215 000 hectares, 60% of which (129 000 hectares) are cultivated under rainfed conditions while the remaining 40% (86 000 hectares) are irrigated. According to the latter, 44% of the Lebanese agricultural lands are located in the Bekaa valley, among them 57% are rainfed and the remaining 43% are irrigated. Major crops include irrigated vegetables, cucurbits, potato and sugar beet, over 30% of the total cultivable area, whereas rainfed wheat and pulses over 40%. of which. Traditional fruit trees, mainly stone fruits and grapes occupy about 10% and some 20% of the agricultural lands remain as fallow widely distributed in the mild sloppy downhill (figure 2).

Cropping is relatively intensive, but suffers from poor water management and poor husbandry. Most of the agricultural lands are marginally cultivated by wheat. Cropping pattern concerns not only rainfed crops but also potato, vegetables and fruits tree. In North Bekaa, the actual cropping intensity is only 75% due to the limited surface water supply during summer period and the high cost of groundwater extraction for irrigation use. Irrigated vegetables, cucurbits and potato are used over 15% of the total cultivated area. Rainfed



(Source: Lebanese Ministry of Agriculture, 1994)

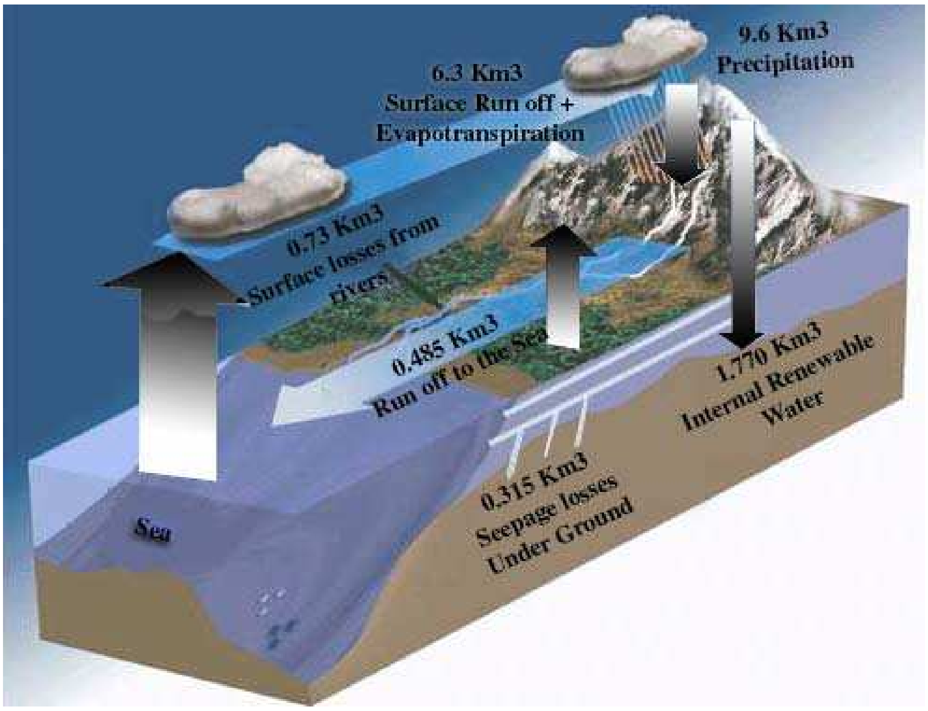
wheat and pulses over 57% and traditional stone fruits and grapes over 5%. The remaining 23% are left as fallow and used as communal grazing land.

Figure 2. Land use in the Bekaa Valley

4. Water resources

Total annual rainfall averages 9600 million m^3, however evapotranspiration and run-off to seawater reduce the potentially available flow to 3300 million m^3. Due to its relatively high elevation, water losses in Lebanon by underground seepage and run-off into the sea are estimated at 800 million m^3 distributed as follow: 315 million m^3 to the neighbor countries and 485 million m^3 into the sea. Furthermore, Lebanon loses about 730 million m^3 of surface water, which constitutes 40% of the total river water, from *Assi* and *El Kebir* rivers in the north and *Hasbani* in the south. The remainder 1770 million m^3 constitutes the internal available water (figure 3). Constraints for irrigation development consist of the limited water availability during seven dry months from May to October where nearly 100% of evapotranspiration is needed to keep the turf adequately irrigated. In this period of the year, water availability accounts for 818 million m^3 representing 24% of the total annual renewable water (Box 2).

About 80% of the total annual stream flow occur during winter, and because of a deficient water flow during summer, a stream can provide enough water if winter flow deriving mainly from watercourses can be stored into reservoirs and used



as required during the summer period.

(Source: Litany River Authority, 1993)

Figure 3. Renewable water resource in Lebanon

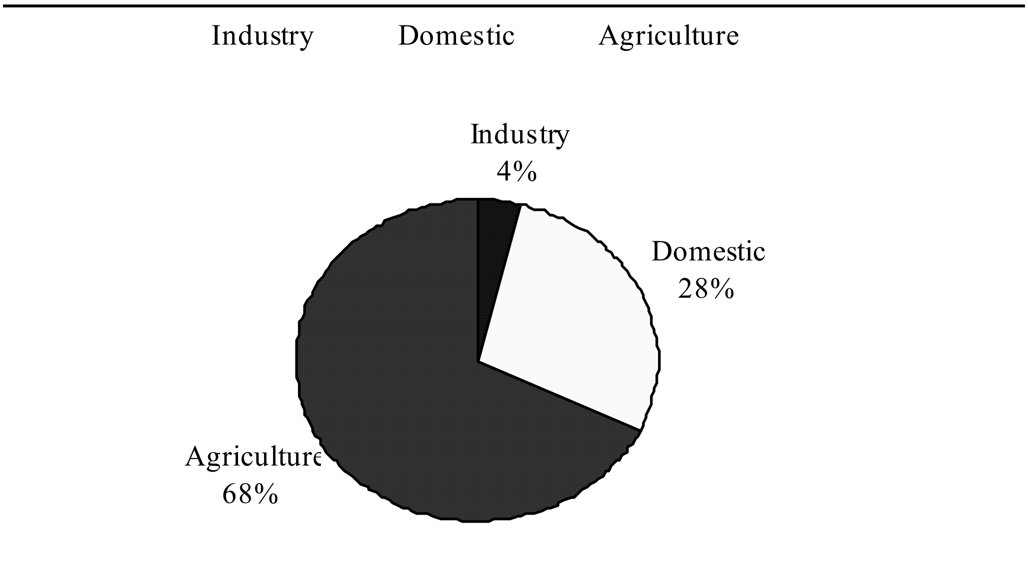
The need for full winter surface storage is necessary unless other water sources are available during the irrigation season. The net storage capacity must be sufficient to enable the maximum irrigation demand to be met whenever it occurs.

In Lebanon, the largest water storage are *Karaoun, Bisri and Khardali* dams. The first, situated on the upper Litany river in south Bekaa is considered as the largest in the country with a storage capacity of 220 million m^3, and an effective storage of 160 million m^3 from year to year. The second was designed on the Awali river in the south for a storage capacity of about 128 million m^3. The third is situated on the middle reach of the Litany river in south Lebanon and has a storage capacity of 128 million m^3.

Furthermore, the Green Plan has established during the period 1964-1992 a total of 3.5 million m^3 of earth ponds and 0.35 million m^3 of concrete storage pounds all over the country. The Litany River Authority has also implemented three hillside stock ponds in the early 1970s for a total storage capacity of about 1.8 million m^3.

4.1 Water Withdrawal

Water use in Lebanon was estimated in 1994 to 1 293 million m^3, of which almost 68% for agricultural purposes, 28.4% for domestic use and 4% for industry (figure 4). The assessment of agricultural water use is based on a water use of 11 200 m^3/ha per year from surface water and 8 575 m^3/ha per year from groundwater. Recent estimates indicate that 700 million m^3 are used for hydropower, with direct restitution to the natural river course.



(Source: Irrigation in the Near East, 1996)

Figure 4. Water use by sector in Lebanon

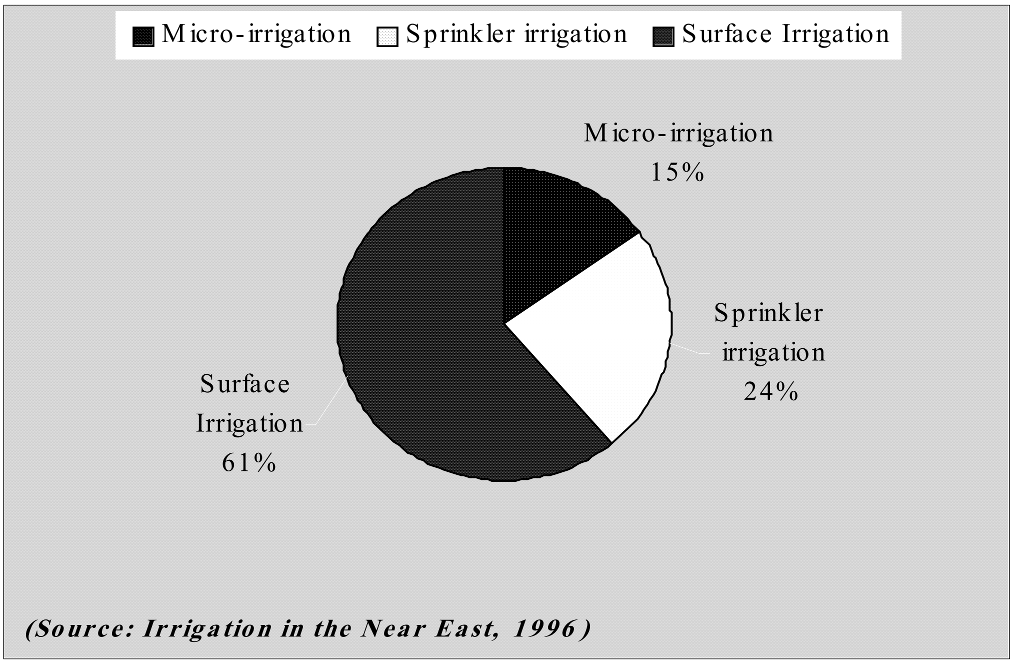
5. Current issues for irrigated agriculture in Lebanon

Irrigation potential in Lebanon, based on soil and water resources, is estimated at 177 500 ha. In 1993, the total area equipped for irrigation was estimated to 87 500 ha, of which 67 500 ha for perennial irrigation and 20 000 ha for seasonal irrigation.

Surface irrigation, mainly basin and furrow irrigation, is practiced on 53 500 ha. Sprinkler irrigation is practiced on 21 000 ha, especially for potato and sugar beet in the Bekaa Central Plain. Micro-irrigation is practiced on 13 000 ha, especially in the northern Bekaa and the coastal area, in greenhouse grown conditions (figure 5).

The main source of irrigation water is the *Litany* river and the *Litany-Awali* complex of water resources. In 1993, it was estimated that 54.3% of the agricultural land was irrigated from surface water and 45.7% from groundwater (figure 6).

The use of groundwater for irrigation has increased in the past few years in view of the delay in the implementation of governmental schemes. Individual farmers in the schemes, who face water shortages, are increasingly relying on supplementary supply from groundwater by means of private wells. During the period 1992-1995, about 2 000 wells were added to a total of more than 10 000 wells, distributed



in the southern coastal hills and in north and middle Bekaa Valley.

Figure 5. Irrigation techniques distribution

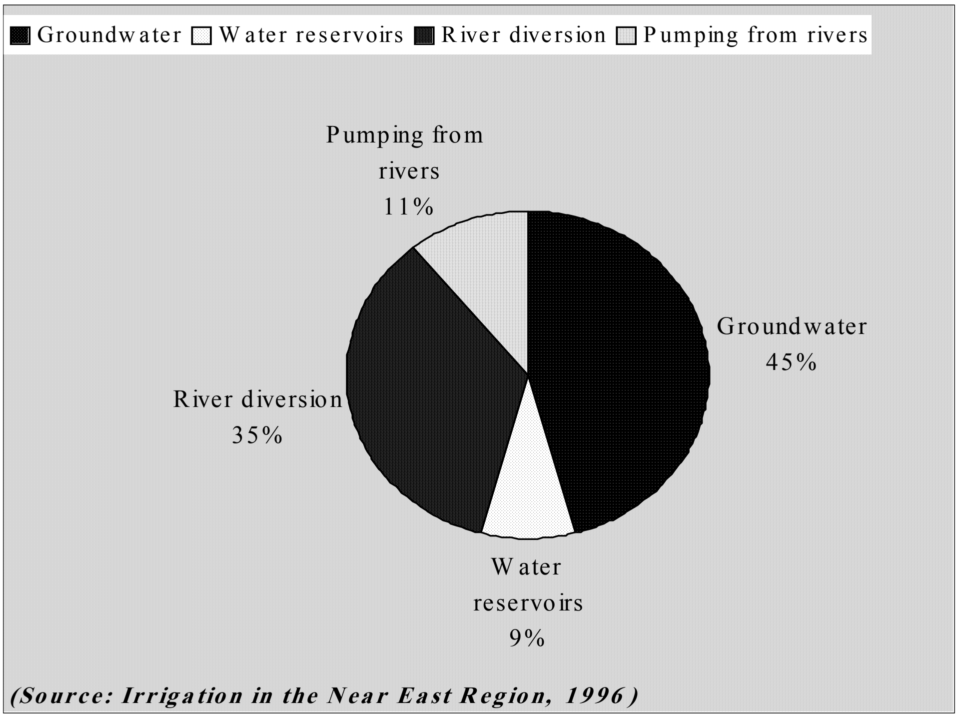
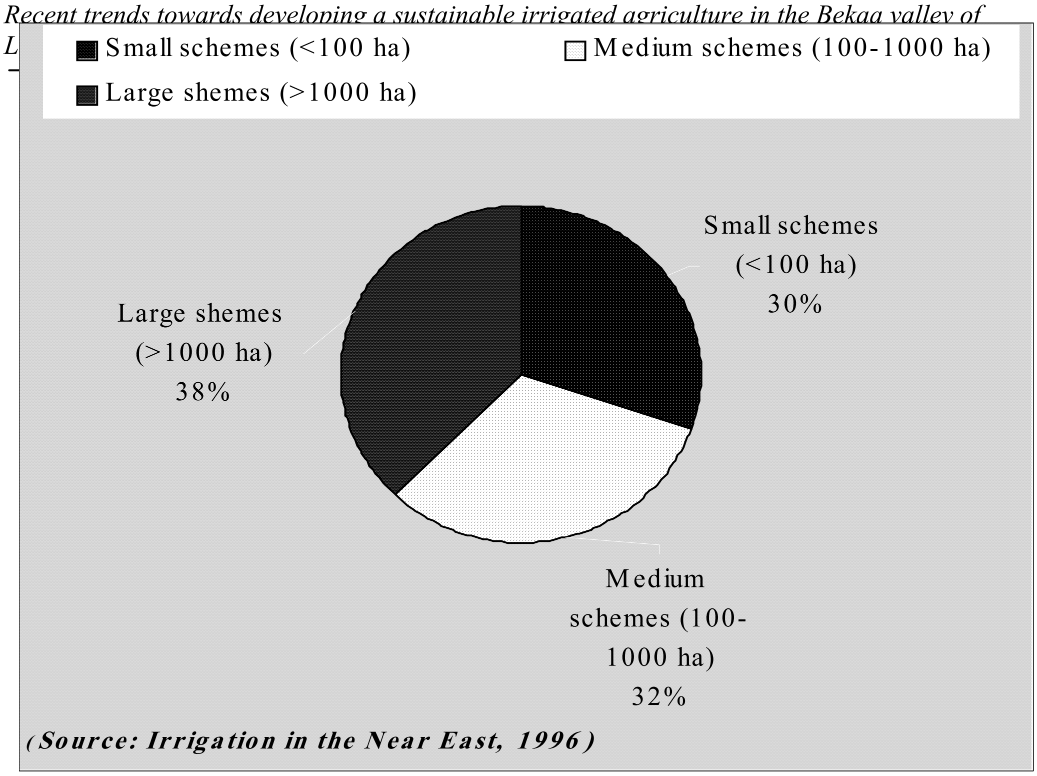


Figure 6. Percentages of water origins used in irrigation

The public irrigation sub-sector, essentially unchanged since 1970, consists of about 5 large-scale schemes (>1 000 ha) and 50 medium and small-scale schemes (figure 7). Most of those schemes are 25 to 50 years old, poorly maintained and in an advanced state of deterioration. It is estimated that most of the area irrigated by surface water needs rehabilitation.

The irrigation schemes are not on the whole regular shaped ones. They follow the contour of the land, and water is supplied by gravity from a series of local springs, or in some other case by diversions via small channels. When water is supplied by local springs with high seasonal variation of water flow, the main constraint is related to water delivery during the irrigation period, which coincides with summer. Where water is being supplied by perennial rivers or artesian springs, the major problem relies on the increasingly costly and unsustainable water extraction due to a poor surface distribution network.

Water efficiency is of a high importance when planning water management in irrigated agriculture. When an irrigation system is developed, the implementation of an irrigation scheme will depend greatly on the appropriation of water from the source to the agricultural land.



(Source: Irrigation in the Near East, 1996)

Figure 7. Irrigation scheme distribution according to size

Nowadays, new irrigation technologies have been introduced with the scope to improve water distribution and application at the farm level. These technologies consist of:

- Utilization of sprinklers and pressurized irrigation pipelines;
- Land leveling using lasers and large-scale moving equipment;
- Use of drip and trickle irrigation technologies;
- Irrigation scheduling and more advanced management techniques.

6. Irrigation development

The Lebanese Government initiated in 1994 a phased strategy for rebuilding the already existing irrigation schemes constructed during the pre-war period. For this concern, a proposed intervention was envisaged by the International Fund for Agricultural Development (IFAD) and latter approved by the World Bank to support the rehabilitation of the irrigation sector in Lebanon. The undertaken project was called Irrigation Rehabilitation and Modernization Project (IRMP). The rehabilitation program includes already existing 5 large-scale schemes and 28 small to medium-scale schemes spread all over the country. It also includes 10 hill lakes with an average storage capacity of about 77 500 m^3 each.

The large irrigation schemes of the project include (figure 8):

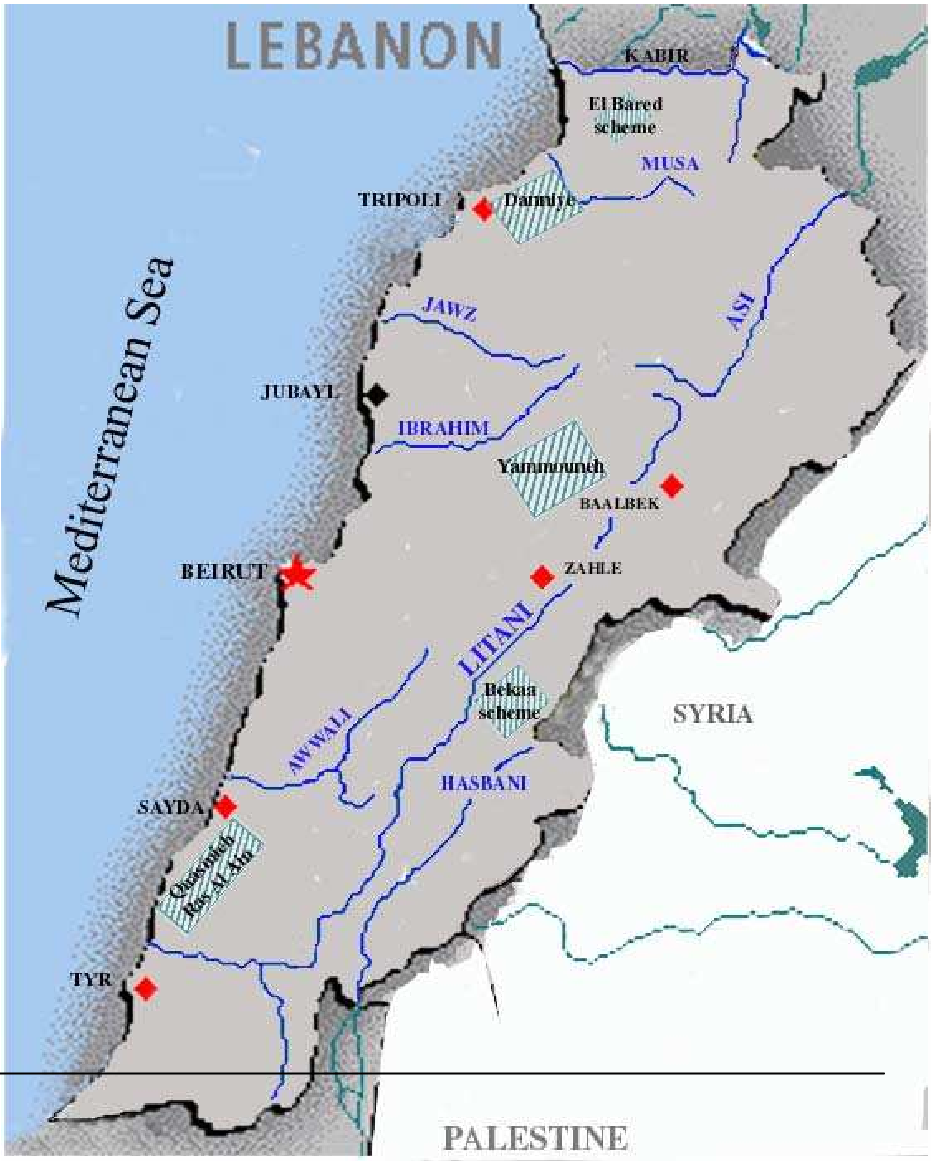
a) Yammouneh scheme in north western Bekaa Valley, (5 600 hectares);

b) South Bekaa scheme, situated on the western flank of the Anti-Lebanon mountains, (2 000 hectares);

c) Quasmieh-Ras Al Ain scheme, situated in the west southern narrow coastal extending from Sidon to Nakoura (3 800 hectares);

d) Danniye scheme in north Lebanon, located in the western flank of Mont-Lebanon mountains, (5 000 hectares);

e) El-Bared scheme in the northern plain of Akkar



(800 hectares).

Figure 8. Geographical location of the irrigation schemes

In addition, the Litany River Authority has recently studied the possibility of executing two large irrigation schemes. The first is the South Lebanon Scheme (33000 ha) and the second is the South Bekaa Irrigation and Drainage Scheme (23500 ha) and which represents the focus of this paper.

The importance of the two pre-mentioned projects can be summarized in the following points:

a) Size: Lebanon did not execute such large schemes before;

b) Network distribution: pressurized pipelines;

c) Irrigation techniques: modern techniques such as sprinkler and trickle;

d) Construction: big water reservoirs, large channels and powerfully pump stations;

e) Operation and maintenance: specialized and complete stuff will be in charge for operation and maintenance.

6.1 The South-Bekaa Irrigation and Drainage Scheme

6.1.1 Geographical location

The project area is located on both sides of the Litany River in south Bekaa, at an altitude slightly varying around 900 m above the sea level. It covers the area from the eastern down hills of Mount-Lebanon to the western down hills of Anti Lebanon.

6.1.2 Climate and soil characteristics

In the Project area, the weather conditions vary from sub-Mediterranean in the eastern slopes of the Mount-Lebanon at the right side of the Litany River, to semi-arid in the western slopes of Anti-Lebanon at the left side of the Litany River. In the first location, lands receive an average of 800 mm of rains, and in the second drier weather prevails where average annual rains of 500 mm are registered.

Soils are generally shallow, of medium to heavy texture with a high clay fraction ranging from 50 to 60% sometimes. They are well drained but suitable for irrigated agriculture. Poor organic matter content is usually encountered in both eastern lying hills of Mount-Lebanon and western lying hills of Anti-Lebanon.

6.1.3 Description of the project area

The South Bekaa Irrigation and Drainage Scheme covers an area of 21500 ha for irrigation and 5000 for drainage. In the project area, the rectification of the bed of both sides of Litany River to increase the irrigated lands has led to water logging problems during periods of high streams. Indeed, 1500 ha suffer from serious problems of flooding water needs to be drained to assure the agricultural practices (Box 1).

The scheme is situated in the southern part of the Bekaa Valley, inserted between the two levels of 900 m altitude curve of both east and west sides of Litany River. The scheme is divided into three independent districts situated on the east side, called also the Left Bank (6 700 ha), the west side or the Right Bank (9 200 ha) and the northern side (5 600 ha) of Litany River, giving thus a total area of 21 500 hectares. *Karaoun* dam is being situated on the south border of the scheme (figure 9).

Irrigation water resources are estimated to 30 million m^3 from *Karaoun* dam, 33 million m^3 from local springs and 75 million m^3 from underground water, totaling thus an amount of 138 million m^3. The *Karaoun* dam water will be used in the Left Bank only.

a) Left Canal Zone or the so-called "Canal 900"

"Canal 900" will provide the Left Bank (67 00 ha) with irrigation water. Sited at 900 m altitude, "Canal 900" has 28 km length. A main pumping station consisting of 4 pumps of 1.5 cubic meter discharge each, is situated on the foot of the *Karaoun* dam that will feed the channel with 30 million m^3 annually. In the other hand, four wells in *Kamed El Laouz* will provide an amount of 12 million m^3 as well as 2 million m^3 coming from *Chamsine* spring.

Water is then stored in a reservoir located at the upstream end. The reservoir supplies the district distribution network system and the irrigation networks branched to it. At the end of the reservoir, a control unit equipped with a gate, a flow meter and a recording venturi meter is installed. All the hydrants of the various sectors are equipped with a volume meter, a gate and a flow meter at the upstream end.

Water is distributed to farmers by hydrants which are equipped with outlets with pressure regulators. Pressure is given at 3.5 kg/cm^2 and discharge is a function of the area of land parcels served by those outlets. On-farm irrigation equipment will be accomplished using pressurized new techniques.

6.1.4 State of achievement

Phase I (2000 ha)

This scheme is divided into three sectors. The first, called *Karaoun 1*, whose area is 257 ha, the second, *Karaoun 2* has 435 ha and the third in *Jeb Jannine* with 1220 ha. The irrigation water will be given from *Karaoun* dam and four wells in *Kamed El Laouz* locality. Every well is equipped to carry out a discharge of 100 liters per second. Three pumping stations connected to an elevated reservoir will take water from canal 900 and assure a pressurized irrigation water through pipes to farms.

The irrigation module for the scheme is 6300 cubic meter per hectare and per annum. Works have already began and it is expected that water can be delivered to farmers in June 2000, being thus the first and largest pressurized irrigation scheme in Lebanon.

Phase II

The feasibility study of Phase II (6700 ha) was done and details design stage will follow up. Execution works follow directly the end execution of Phase I.

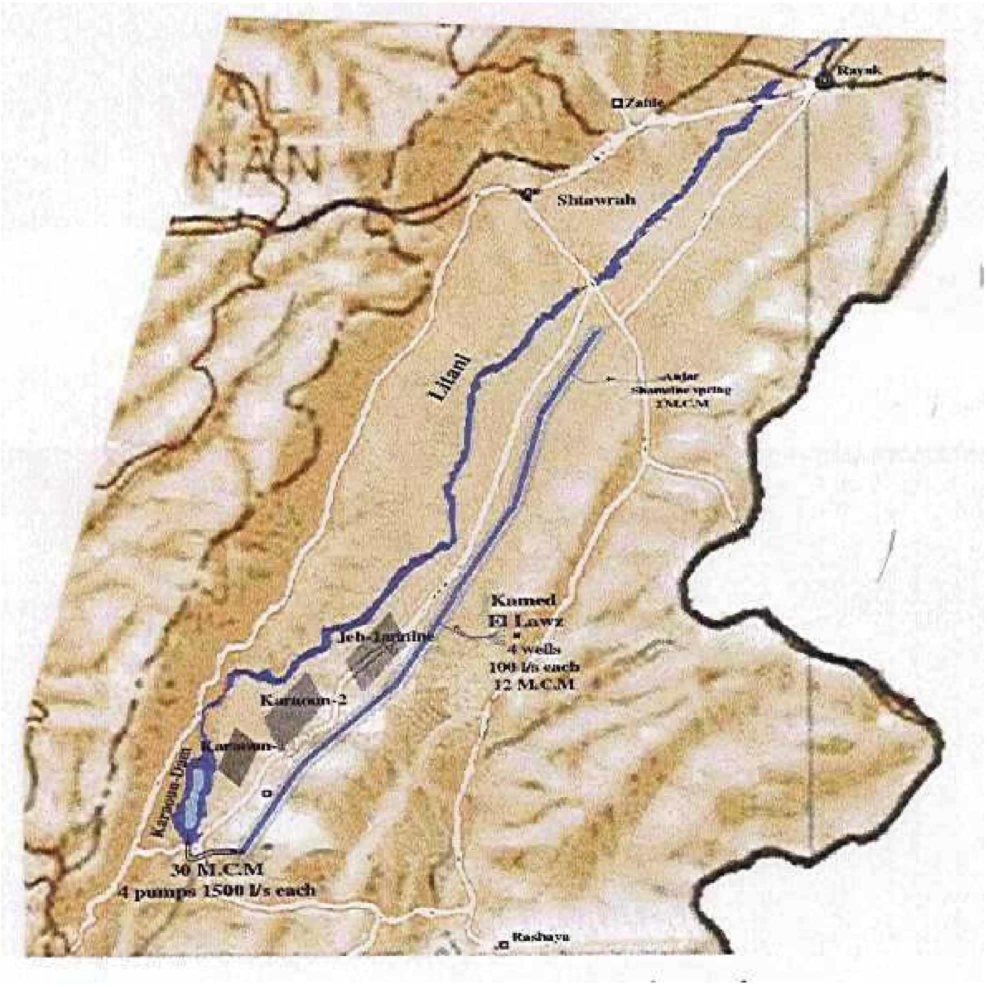


Figure 9. South Bekaa irrigation and drainage scheme

7. Concluding remarks

The irrigation potentiality in Lebanon is primarily related to the physical mobilization of water and to the rehabilitation and modernization of the already existing irrigation infrastructures. An increase of the irrigated area can be derived using surface water resources through the construction of storage dams.

The stages of technologies in water development in Lebanon's irrigated agriculture should be evolved as a function of the design capacity of irrigation systems which in turn depends on the short term peak demand and the average cropping pattern for the whole system. The ever-increasing demand of water for irrigation, together with the growing difficulties and costs for developing new resources, makes it necessary to carry out field surveys aiming at a better management of irrigation systems as well as to evaluate specific operation and management decisions.

Current recommendations of irrigation management service should be valid in both an economic and technical sense. For the short run, efforts to conserve water through quantity restrictions on surface water can greatly affect farm profits and crop-water production functions. For the long run, water quantity restrictions could encourage more efficient irrigation systems or practices. Therefore, future perspectives of efficient irrigation systems should take into account the followings:

Design of new large-scale irrigation schemes;

Rehabilitation and modernization of the already existing ones;

Application of new technologies with the scope of improving the management, maintenance and operation of pressurized irrigation systems;

Improvement of water management techniques to protect exploitable resources and to develop more efficient supply systems starting from water abstraction till the delivery to end-users. Such techniques will provide integrated tools towards the improvement of the efficiency at water use and preserving a rationalized equilibrium between demand and supply.

Studying the possibility of developing simulation models aiming at providing information on the degree of performance or failure of the irrigation networks. These models will enable some indicators such as reliability, resilience and vulnerability for the evaluation of the hydraulic performance in large-scale pressurized irrigation systems.

The South Bekaa Scheme is the first step of a series of irrigation projects in Lebanon. It will favorite the landowner to cultivate and exploit their lands. Thus farmers will receive water with a moderate price which allow them to not make high investment in order to have water from underground layers.

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Box 1. Irrigation and drainage in Lebanon: Basic statistics.

1) Irrigation		
Irrigation potential	177 500	Hectares
Irrigation area	87 500	Hectares
Surface irrigation	53 500	Hectares
Sprinkler irrigation	21 000	Hectares
Micro-irrigation	13 000	Hectares
Percentage of areas irrigated from groundwater	45.7	%
Percentage of areas irrigated from surface water	54.3	%
Large-scale schemes (> 1000 hectares)	33 000	Hectares
Medium-scale schemes (100 - 1000 hectares)	28 000	Hectares
Small-scale schemes (< 100 hectares)	26 500	Hectares
2) Cropping pattern		
Harvested crops under irrigation	87 500	Hectares
Permanent crops	29 844	Hectares
Annual crops	57 656	Hectares
vegetables	35 475	Hectares
potatoes	10 365	Hectares
cereals	5 711	Hectares
Sugar beet	3 800	Hectares
Other annual crops	2 305	Hectares
3) Drainage		
Drainage scheme		
Total drained area with surface drains	10 800	Hectares
Drained area as a percentage of the cultivated area	6	%
Area with flooding problems	1 500	Hectares

(source: *Irrigation in the Near East Region, 1996*).

Box 2. Water and land resources and use in Lebanon

1) Land resources		
Total area	1 040 000	Hectares
Cultivable area	360 000	Hectares
Cultivated area	189 206	Hectares
Annual crops	104 120	Hectares
Permanent crops	85 086	Hectares
2) Renewable water resources		
Average precipitation	9.60	Km^3/year
Internal renewable water resources	4.80	Km^3/year
Total renewable water resources	4.40	Km^3/year

Total renewable water resources per capita	1465	m^3/year
3) Water withdrawal		
Agricultural	875	10^6 m^3/year
Domestic	368	10^6 m^3/year
Industrial	50	10^6 m^3/year
Total water withdrawal	1293	10^6 m^3/year
Total water withdrawal per capita	444	m^3/year
Ratio of the total water withdrawal to the total renewable water resources	29.3	

(source: Irrigation in the Near East Region, 1996).