Some aspects of irrigation systems performance in Palestine

Nofal I., Dudeen B., Rabi A.

in

Lamaddalena N. (ed.), Lebdi F. (ed.), Todorovic M. (ed.), Bogliotti C. (ed.).
Irrigation systems performance

Bari : CIHEAM
Options Méditerranéennes : Série B. Etudes et Recherches; n. 52

2005
pages 167-177

SOME ASPECTS OF IRRIGATION SYSTEMS PERFORMANCE IN PALESTINE

I. Nofal[*] , Basim Dudeen[**], A. Rabi[***]
[*]Palestinian Ministry of Agriculture, E-mail: issamnofal@hotmail.com
[**]Land Research Center (LRC); E-mail: lrc@palnet.com , basim.dudeen@lycos.com
[***]Palestinian Hydrology Group (PHG), E-mail: phg@netvision.net.Il

SUMMARY – In this paper are presented the main aspects of irrigation systems in Palestine including also the data related to the availability of water resources, distribution of irrigable and irrigated lands and agricultural water demand projections. In year 2000, agricultural water demand was about 190 million cubic meters of water necessary for irrigation of about 22,000 hectares. It is estimated that for each one million of people there is a need to irrigate additional 7,500 hectares which will require about 61 million cubic meters of water each year. There is a consensus that a significant amount of water could be saved through rehabilitation of water infrastructure (wells, springs, ponds, etc.) increasing the efficiency of water delivery and irrigation systems and intensifying and strengthen extension and research activities and the transfer of technology. A particular attention should be given to the substitution of open earthen or lined canals with the closed conduits delivery network which could contribute to the reduction of losses up to 25%. Further initiatives should comprise promotion of modern irrigation techniques at wider scales, especially in citrus orchards, construction of more storage reservoirs closed to the farms, improving the withdrawal capacity of existing wells and drilling of new substitute wells and development of a modern institutional and legislative framework for sustainable use and management of water resources.

Key words: irrigation systems, water availability, conveyance systems, storage facilities, field application efficiency, water distribution methods, Palestine.

INTRODUCTION.

There is a deep understanding and appreciation of the water scarcity problem in Palestine. This understanding lead to an intensive searching for various approaches to save water for its traditional uses. In the arid and semiarid regions as in Palestine, plants require comparatively large amounts of water for high productivity. Managing irrigation to achieve the best possible water-use efficiency is essential for the crop to remain competitive for water supplies both within and outside agriculture.

Agricultural sector plays a crucial role in the social well being of the Palestinian people due to the fact that it is considered for a lot of people the main source of their living, and to others, it is considered as an additional income because they can save nutritional materials. Total current water use in the West Bank and Gaza Strip (WBGS) is estimated to be about 286 million cubic meters (MCM) per year. Agriculture continues to be the largest consumer of water accounting for about 60 percent of total use (167 MCM, about half each in the West Bank and in the Gaza Strip).

Groundwater wells constitute the only source of irrigation water in the Gaza Strip. In the West Bank, wells and springs contribute almost equal amounts of irrigation water, though the vast majority of springs are concentrated in the Jordan Valley (Jericho District). The relationship between the amount of discharged water from wells and springs with the available arable land that could be irrigated combined with climate is displayed as an entrance for evaluating the most efficient irrigation systems.

There is a consensus that a significant amount of water could be saved through rehabilitation of water infrastructure (wells, springs, ponds, etc.), increasing the efficiency of water delivery and irrigation systems, reuse of wastewater and intensifying, enhance soil properties through soil ameliorants and strengthen extension and research activities and the transfer of technology.

WATER AVAILABLE FOR AGRICULTURE VERSUS IRRIGABLE LAND IN THE WEST BANK/PALESTINE

It is of paramount importance to have an idea about the amount of water available for irrigation in the West Bank and its distribution over the prospected irrigable land to have an appreciation about how important to save water for agriculture. In this regard a GIS analysis was performed distributing the wells over land units (Dudeen, 2003). In this regard, land systems were selected as the land units to overlay the available springs and wells in the West Bank. This selection is adopted to help in further analysis which would encompass other parameters related to land physical features.

The land systems classification of the West Bank is shown in Figure 1. This classification at the system level is based on geomorphology and climate. The following systems were classified mainly according to climate and/or geology characteristics:

1. Plain of Jenin.
2. Qalqilya Hills.
3. Tulkarm Hills.
4. Nablus Heights.
5. Jerusalem-Hebron Foothills.
6. Hebron Heights.
7. Jerusalem-Ramallah Heights.
8. Aldahiriya Hills.
9. Jerusalem Desert.
10. Jordan Valley.
11. Far Northeastern Heights.
12. Mid Northeastern Heights.

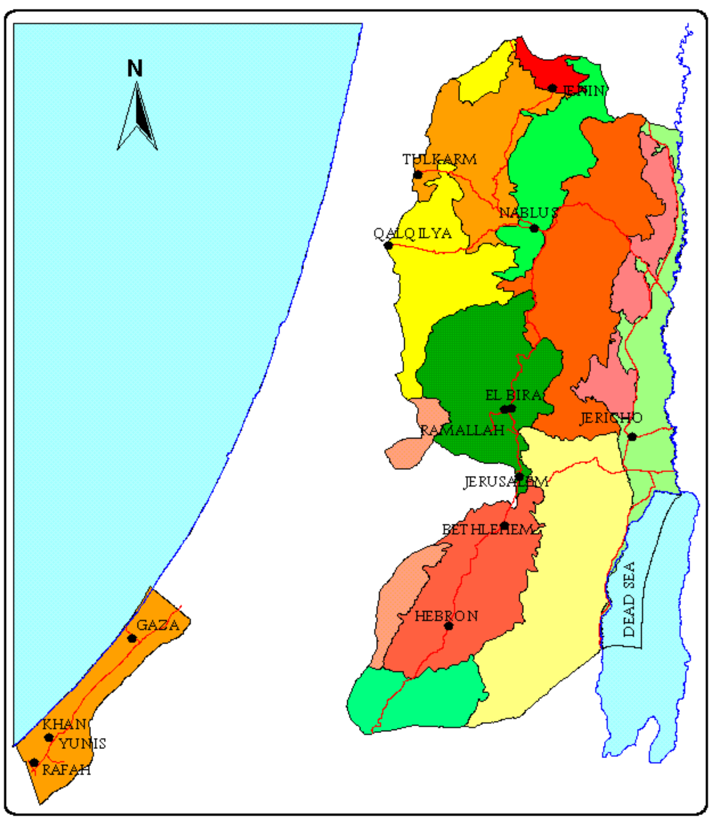

Fig. 1. Land System Classification of the West Bank and Gaza strip.

The available irrigable land and agricultural water at each system is shown in Table 1. The irrigable land is composed mainly of the plains and valley floors that are either planted with permanent or perennial crops. It is worth mentioning that summit surfaces, hillcrests and all currently uncultivated units in Jordan Valley were excluded. Also, urbanized, forests and nature reserve areas were excluded. The total irrigable land as shown in the table is equal to 796.5 km^2. This land represents about 14.5% of the land area of the West Bank. The current irrigable land percent is about 5%.

Table 1 reports the irrigable land in addition to the available water for agriculture from the wells in the West Bank.

Table 1. Irrigable land distribution among Land Systems in the West Bank

System's Name	Average Rainfall [mm]	Agricul. wells Capacity [m^3/year]	System Area [km^2]	Irrigable Area [km^2]	Irrigable Area [%]
Plain of Jenin	300-500	1,877,257	71	51.5	72.5
Qalqilya Hills	500-650	6,350,547	544	102.5	18.8
Tulkarm Hills	500-600	9,953,466	484	89.5	18.5
Nablus Heights	350-600	1,974,280	385	69.8	18.1
Jerusalem – Hebron Foothills	300-600	-	195	16.3	8.0
Hebron Heights	350-700	-	601	19.3	3.2
Jerusalem - Ramallah Heights	100-500	-	623	32.1	5.2
Aldahiriya Hills	100-500	-	277	30.0	10.8
Jerusalem Desert	<100-400		910	101.7	11.2
Jordan Valley	<100-300	11,101,566	434	87.9	20.2
Far Norh-Eastern Heights	150-250	-	295	7.3	2.0
Mid North-Eastern Heights	100-400	3,026,589	855	188.6	22.0
Total		*34,283,705*	*5498*	*756.5*	*14.5*

Figures 2 and 3 display the distribution of wells and springs in the West Bank, respectively. The productivity of these well and springs is 34,283,705 and 22,010,230 m^3/year, respectively. Palestinian wells were nearly all drilled prior to the Israeli occupation in 1967, as the Israeli authorities have banned the drilling of new wells and imposed a quota on the quantity to be discharged from each well. Furthermore, they have taken a hostile stand in relation to all efforts aimed at the renovation and rehabilitation of new wells. Such efforts have been further hampered by the nearly total lack of credit and technical support facilities. From these Figures and the data given in Tables 1, 2 and 3, we can conclude the following:

1. From the amount of the available agricultural water and the irrigable land in each system, it is clear that the available water is far below the required for irrigation if we take the average amount required for cucumber greenhouses.

2. If we fully utilize the water from wells for irrigation over each system area, the maximum area that can be irrigated in Jordan Valley by using the drip irrigation method in greenhouses once per year is 27,754 dunums (1 dunum = 0.1 ha). The available irrigable land in Jordan Valley is 87,900 dunums. Therefore, the percentage of the prospected irrigated area to the irrigable land is 31.6%.

3. The current irrigated land in the West Bank is estimated at 116,913 dunums in 2001/2002. Table 2 displays the distribution of irrigated land among Districts. This means that we are utilizing about 15.4% of the irrigable land in the West Bank.

4. Looking at the Palestinian communities' distribution and the distribution of wells and springs, it can be deduced that some of the water from wells is utilized for domestic use rather than agricultural use.

5. The figures indicate that most of the irrigated areas are concentrated four land systems in the West Bank: the Jordan Valley (Jericho area) and the northern and western systems of Jenin, Tulkarm, Qalqilia and North-Eastern heights (mainly at Faraa Valley).

6. The total agricultural water supply is reported to be nearly 80.6 MCM/year in the West Bank (CDM/Morganti, 1997). The estimated available water for agriculture from wells and springs in this study is estimated at about 56.3 MCM. This represents about 70% of the above mentioned figure. The remaining is supposed to be from other sources. Probably, the previous estimates are taking into account all the abandoned and domestic wells as a source for agricultural water. However, this report estimates excludes the domestic and the no pumping wells.

7. Rationally, the available irrigated lands are used to supply the current population with fruits and vegetables. Given that there is a proportional relation between population growth and the need for more food, the future agricultural water demand will likely increase. Table (3) shows the population projection, irrigated lands, and the agricultural water demand figures developed by GTZ (1998) and modified in accordance with the population figures of PCBS (1998).

Table 2. Irrigated areas in the West Bank, 2001-2002 (1 dunum = 0.1 ha)

District	*Area [dunum]*	*(%)*
Jericho	37120	31.8
Jenin	17965	15.4
Tulkarm	16230	13.9
Nablus	7998	6.8
Ramallah	1053	0.9
Bethlehem	2832	2.4
Jerusalem	11	<0.1
Hebron	2597	2.2
Tubas	19788	16.9
Salfit	732	0.6
Qalqilya	10605	9.1
Total	*116913*	*100*

Table 3. Agricultural Water demand projection

	Estimation based on GTZ (1998)			Modified Water Demand Figures based on PCBS (1998) Population Figures		
year	Population [Million]	Irrigated lands [dunum]	Water demand [MCM/year]	Population [Million]	Irrigated lands [dunum]	Water demand [MCM/year]
2000	2.94[(2)]	216,144[(1)]	184.3[(1)]	3.15	224,919[(1)]	191.8[(1)]
2010	3.77[(2)]	277,164[(1)]	236.4[(1)]	4.95	353,444[(1)]	301.5[(1)]
2040	7.07[(2)]	519,775[(1)]	443.3[(1)]	9.98	712,600[(1)]	607.8[(1)]

[(1)]: Estimated by simple proportion between land, population, and agricultural water use
[(2)]: Adjusted figures of GTZ (1998) by using the recent population census (1998) by BCPS.

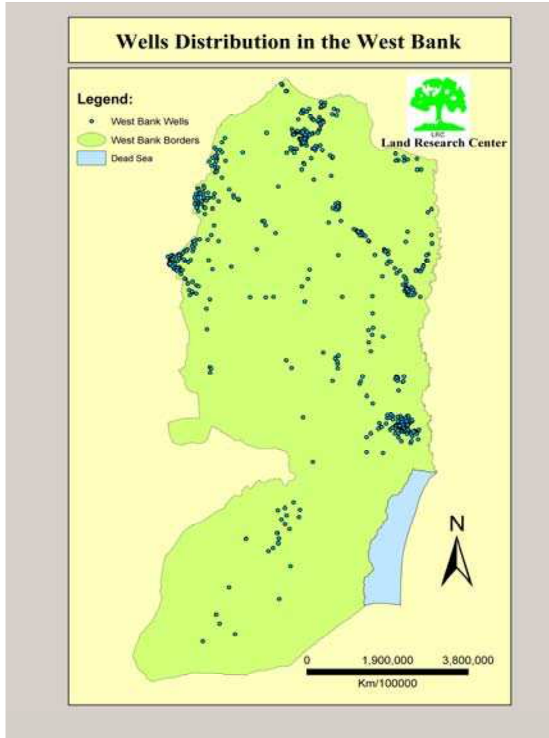

Fig 2. Wells distribution in the West Bank

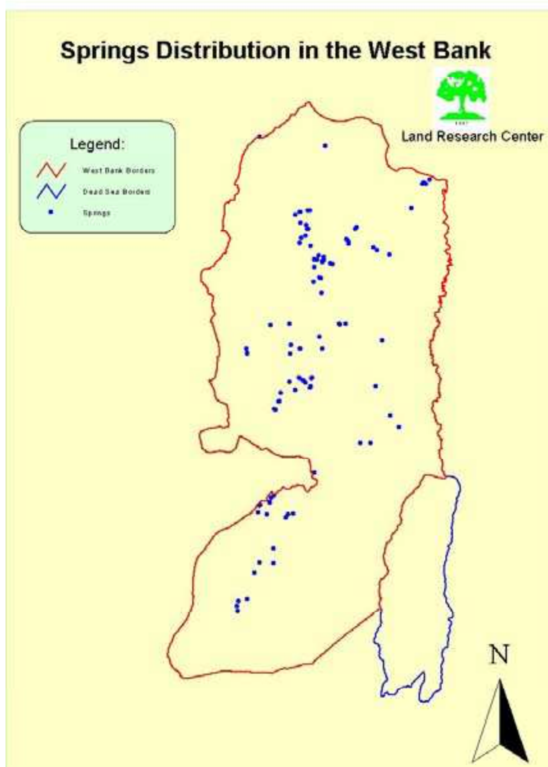

Fig. 3. Springs distribution in the West Bank

In fact, from the previous analysis it can be concluded that for each one million people there is a need to irrigate additional 75,000 dunums which will require approximately 61 MCM/year of water. From the above data, it becomes clear how important is to enhance the performance of the irrigation systems in Palestine as one of the approaches to save water for agriculture.

SOME ASPECTS IRRIGATION SYSTEM PERFORMANCE IN THE WEST BANK/PALESTINE

There is a consensus that a significant amount of water could be saved through rehabilitation of water infrastructure (wells, springs, ponds, etc.), increasing the efficiency of water delivery and irrigation systems and intensifying and strengthen extension and research activities and the transfer of technology. In this section, some aspects of the irrigation system performance in Palestine will be addressed.

Conveyance Systems

Conveyance systems may vary regarding to the source of water either wells or springs. In Palestine generally, conveyance systems from wells to the farms consist of metal pipes of different diameters ranging from 2 inches up to 8 inches.

Computation of conveyance efficiency requires information about the volume of water diverted from the pumping station (well) and information about the volume of water delivered at the inlet of the intended farm. The conveyance efficiency in the piped systems was measured in some irrigation schemes in Qalqilia district and it was around 90% (Nofal, 1998).

In principle, the existing irrigation system consists of a main lined canal, in which water flows from the spring to a main pond and from this, through PVC pipes to secondary ponds where water is pumped to the command area, or from main ponds pumped directly to the field. In other cases, the branches of the main canals, which convey water into private canals, are constructed by the farmers themselves. The water is conveyed to the farmer ponds and, then, from farmer ponds it is pumped to the fields.

The water conveyance systems from springs to farms (often several kilometers downstream) comprise open earthen or lined canals and earthen buffer pools (usually plastic lined). The bad conditions of the system are responsible for substantial losses of water through seepage and evaporation. These losses are estimated at about 25% of the total water discharge (FAO, 2001).

The construction of a closed system will not only eliminate water losses through seepage and evaporation but it also expected to deliver water under pressure within most of the irrigation command area to enable the installation of drip irrigation systems with out additional and expensive pumping.

Storage Facilities (Reservoirs)

In wells irrigation systems, storage facilities are prevailing in use in protected agriculture (green house) and rarely used in open agriculture practices. Most of the storage facilities in wells systems are metal tanks with volume ranging from 10 up to 35 m^3. Storage tanks are filled with water directly from the network. They are capable to irrigate greenhouses several times and this issue depends on the tank volume and irrigated acreage. Storage tanks to some extent raise the level of flexibility and reliability of irrigation water supply during a part of the growing season. Storage tanks with 12 m^3 volume can irrigate one dunum of greenhouse cultivated with cucumber 4 days. This means that storage tank acts as on-demand system for individual farmers in that 4 days and the farmer (the owner of the tank) can irrigate whenever he needs provided that there is available water in the storage tank.

In addition, different types of ponds are common in use: concrete ponds, earthen ponds (plastic lined) and metal ponds. Capacity of these ponds are ranging from tens of cubic meters up to hundreds depending on the financial capability of the farmer, the flexibility of irrigation water and the command cropped area.

Field Application Efficiency

Field efficiency can be defined as the part of the applied water which is beneficially used by plants. However, field efficiency varies depending on the type of the irrigation technique in use and the performance of the irrigation network. Regarding the consumptive and non-consumptive water terms, it is worthy to mention that all the irrigation water used in Palestine can be considered as consumptive type because no drainage water exists. Many methods of water application are used in large irrigation systems. There are three basic methods: surface irrigation, sprinkler irrigation, and drip irrigation. A number of irrigation methods are hard to categorize since they cross over the traditional boundaries of these three general types. Prevailing irrigation techniques and problems related to them in Palestine are described here below.

Surface Irrigation

Surface irrigation methods are the earliest methods employed for large-scale agricultural production. They have been practiced longer than recorded history. In the study area, two types of surface irrigation methods are particularly important: basin irrigation and furrow irrigation.

Basin Irrigation - Basins are small level plots surrounded by low earth dikes, within which water can be impounded to irrigate a single tree as well as vegetables or other crops grown in patches.

Furrow Irrigation - The soil surface is shaped into series of furrows separated by ridges, at each irrigation; water is conveyed into the furrows, which can be perceived as narrow basins or borders. The ridges between the furrows serve as planting bed for row crops, and they absorb water from the adjacent furrow by capillary suction.

<u>Problems related to surface irrigation</u>

Most surface irrigation systems are somewhat labor-intensive, using generally unskilled labor. Furrow irrigation is the most labor-intensive, since water must be guided into individual furrow. Intermediate borders are constructed by either borrowing soil on either side or by dragging soil from the middle of each strip and depositing it at the edge. Terrain places the most severe on the adoption of surface irrigation systems.

Sprinkler Irrigation

With sprinkler irrigation, artificial rainfall is created. The water is led to the field through a pipe system in which the water is under pressure. The spraying is accomplished by using several rotating sprinkler heads or spray nozzles or a single gun type sprinklers.

Micro-irrigation

This irrigation system includes drip irrigation, trickle irrigation, subsurface irrigation, also most of the references include micro-sprayers as part of micro-irrigation. The idea is not to wet the entire soil surface or volume, but only that portion which needs to be wetted. There are several basic types of micro-irrigation in use in this area which can be divided into fixed systems, are applied to vegetables, and moving systems, which are typically applied to citrus.

Individual emission devices are used to deliver water to individual trees at low rates of flow. These emitters can be constructed in-line in the tubing or can be inserted into the soft plastic tubing with a barb connection. Line source micro- irrigation is another common system, where flexible plastic tubing is constructed with small perforations (e.g. 1 mm holes) at a fixed interval (e.g. 0.3 m). Another system of micro-irrigation is the micro-sprayer, which is similar to sprinklers. The distinction between micro-irrigation sprayers and sprinklers is the rate of flow (typically less than 10 l/h) and the area covered is a single tree or a part of the tree canopy. This method is very common in Palestine and the study area and it is usually used for especially citrus

Micro-irrigation is common in greenhouses and for ornamental crops. Micro-irrigation is frequently used in settings where other methods might interfere with the landscaping. Micro-irrigation is suitable for soils and topographies, which are difficult to adapt to other methods and it can be adapted extremely in sandy soils or to rocky hillsides. Micro- irrigation is also applied where water is scarce or expensive and it is expected to be the most efficient method, while micro-irrigation utilizes less labor than many other systems, it requires a more skilled labor force.

Chemicals can be injected directly through the irrigation water, thus spoon feeding nutrients to the crop, micro-irrigation often minimizes weed growth since the soil surface is not fully wetted, and for some sub irrigation systems, no weed at all.

<u>Problems related to Micro-irrigation</u>

Emitter clogging is one of the main limitations of the micro-irrigation system. Line source systems are typically cleaned annually or biannually but there is no limited time for replacing new lines, lateral lines should be flushed at least annually to remove any sediments or debris in the line. Filters also need periodic cleaning (weekly) and chloride acid is used in washing the drip network from accumulation of calcium carbonate precipitated in the lateral lines and caused emitter clogging.

Typical operating pressures for most micro-irrigation systems are 100 to 250 KPa (10 to 25 meter heads), with the higher pressures associated with micro sprayer. Usually these operating pressures; 100 KPa (10 meter pressure head) are needed to operate drip irrigation system with 4l/h discharge emitters and the 250 KPa (25 meter pressure head) are needed to operate micro-sprayers (Mizyed and Haddad, 1990). In micro-irrigation systems lateral lines usually do not exceed 100 m in length. The main drawbacks of micro irrigation are the high initial cost and the high operation cost and maintenance cost. Farmers have to monitor the irrigation system in the farm to look for leaks and clogged emitters.

The results of a study conducted on irrigation in the West Bank in 1995 indicate that application efficiency of irrigation water is relatively high (Al-Juneidi and Issac, 1996). However, this not due to good management, but mainly to the shortage of water in the irrigated areas. Of the area currently irrigated in the Jordan Valley, however, about 97% of vegetables are irrigated by drip systems having an application efficiency of 78%, and 2.4% by sprinklers with an application efficiency of 85%. On the other hand, in the Jenin and Tulkarm area about 70% of the vegetables are irrigated by drip systems with 68% application efficiency. In this area, however, more extensive use of plastic houses is made for cultivation. In the Jordan Valley and the Jenin/Tulkarm area only about 0.6 and 1.5% of the area under vegetables are irrigated by furrow system, respectively. These high irrigation efficiencies may be acceptable in many other countries, but given the severe scarcity of water and the high population growth and increased demand for water in the area, more efficient systems are desirable.

The following considerations are needed in irrigation methods selection (Clemmens and Dedrick, 1994):

- Scarcity of water;
- Water price - if it is expensive;
- Familiarity of the owner, management and the labor force with the method chosen;
- Cost of system;
- Economic life of various irrigation systems plus the annual maintenance costs as a percentage of initial cost, capital cost and annual operating cost;
- Water quality.

WATER DISTRIBUTION

In wells systems, generally, there is the same type of water distribution and allocation exists, in which farmer who grows perennial trees has his allotment of irrigation water in terms of time units (hours) and usually of fixed irrigation and duration type. Each farmer individually negotiates his date and duration (hours) of irrigation with the well operator. It is found that, in general, irrigation interval is 3, 6 and 10 days for greenhouses, vegetables (open) and fruit trees respectively.

Water distribution methods

The main water distribution methods used in the wells system are analyzed by Nofal (1998) they are described here below.

On-demand system

In wells, on-demand system is rarely used in public wells while it is used in wells owned by one farmer so he can decide to irrigate whenever he wants. In springs, on-demand system is common where the farmer, usually, receives his share of water rotationally and stores it in ponds where he can use the water whenever he likes.

On-request system

This is the most common system of water distribution used in vegetables in both open and protected agriculture. Farmer requests the water from the well operator who in turn makes the necessary arrangement to accommodate it with the demands of other farmers within the limited capacity of the well and operating hours. If the demand can be met, the well operator responds to the farmer with an indication of the time of his turn. The disadvantage of this system is the high cost incurred especially in winter (low demand) where the well has to be operated for a short time period to irrigate one or two dunums of greenhouses.

Rotational system (fixed rotation)

This system operates in summer or when there is no rainfall and it is common for perennial trees. In this system; farmers receive water at pre-set time (fixed interval) and usually at fixed irrigation duration. Normally, the pre-set turns are agreed upon at the beginning of the year with the well operator.

Under warmest summer conditions exceptional irrigation may occur, in which the farmer may receive water once or twice extra irrigation's in the year. Rotational system is widely used in perennial trees farms. However, the amount of water received by the farmer is proportional to the size of his farm but this is not the case always.

Priority of Water Supply

During periods of water shortages, priority of water supply becomes a question. In wells' systems, well operator on behalf of shareholders has to decide together with farmers which crop has the priority for water. Water shortages may occur in the case of technical damage and/or in dry years. Case 1 is the most critical case where it may result in serious shortages of irrigation water, while case 2 may increase the demand for water. Generally, priority of water supply is given to vegetables particularly under greenhouses because of their high sensitivity to water stress and their economic value.

Flexibility of Irrigation and Water Allocation

Generally, where there is high demand for water, a significant part of the farmers irrigates their crops according to fixed interval and to some extent at fixed duration. However, to reduce administrative difficulties in water supply arrangement and distribution rotational system with fixed interval is used. Since crop water requirements vary over the growing season, the use of fixed intervals and/or fixed duration of irrigation may cause either over- or under-irrigation, which in turn leads to miss-management in water distribution and allocation, and consequently affects negatively crop production.

However, farmer's irrigation water share is proportional to crop type and the size of the cropped land, while farmer's water right depends on his share in the capital investment of the well. Major problems that may reduce water flexibility in the field could be the following:

a) Fragmentation of water rights: fragmentation of water rights largely coincided with fragmentation of the land holdings that occurred as a consequence of inheritance, buying and selling, etc., with every division of land, the water related to the land also divided into smaller portions.
b) Plastic houses: shifting from open agriculture to greenhouses may increase water allocation problems because greenhouses demand frequent and short interval irrigation.
c) Technical problem: generally, technical problem occurs when a farmer can not absorb the well productivity alone, as a result the well operator has to find one or more farmers to share the well productivity which reduce the irrigation flexibility.

FINANCIAL AND ECONOMIC ISSUES

Operation, Maintenance and Cost Recovery

Normally, operation and maintenance are designed to accomplish two main purposes:

a) Permanent water supplies by keeping pumping equipment in good condition in order to pump water whenever farmer needs;
b) Keeping conveyance system (metal pipes) in sufficiently good conditions to minimize losses and keeping other water control infrastructure in working conditions.

As mentioned before, irrigation schemes in Palestine either in wells or springs are private and locally managed systems in which farmers themselves bear operation and maintenance costs. Therefore, collected fees from farmers should cover the operation and maintenance cost.

In wells' systems, the well operator is officially responsible for accountings. The name of the farmer, the duration of irrigation and the date of irrigation are determined by the well operator. At the end of each month, the well operator submits such data to a special accountant to process them and to return them back to the well operator as bills to collect money from farmers. Farmers who did not pay on time are warned by the well operator that they will not receive water and which constrins them to pay.

In spring's systems, the committee of the spring is responsible for collecting the fees from the farmers which should cover the operation and maintenance cost.

Water Productivity

Financial analysis is an important issue in evaluating existing systems; benefit-cost analysis is a convenient analytical tool. Benefits, associated with irrigation water, have their total positive contributions. These contributions must be in monetary terms when benefits and costs are to be analyzed in monetary terms.

In determining costs at the farm level; the most obvious category of costs are direct expenditures, land acquisition, materials, labor, and irrigation water (quantity and price). In order to assess the productivity of water under normal conditions, the data are taken for tomatoes (cultivated under greenhouses), tomatoes (cultivated in open fields), citrus and Guwafa fruits. The input and output data used are taken from the Department of Agricultural Statistics in MOA.

The water productivity is the financial return from irrigation water in terms of US$/m^3, the following mathematical formulas can be used for the estimation of financial value of water: -

a) Gross Income = Production * Gate price
b) Farm net return = Gross income - Expenditures
c) Net financial value of water = Farm net returns / Applied water

A special spread sheet model is developed for the purpose of benefit-cost analysis. Financial return of water in terms of (US$/$m^3$) was estimated as shown in the annexed economic sheet. It is found that financial return from green houses is the highest (11.96 US$/$m^3$) and in citrus is the lowest one (0.31 US$/$m^3$).

In spite of the reality that greenhouses are the most profitable farming, there are some reasons which inhibit farmers to invest in, among them, are:

a) High capital cost of green houses, (about 8000 US$ for each dunum).
b) Intensive labor and monitoring required.
c) High input cost needed in terms of seedling, fertilizers, and pesticides, insecticides, sterilization process and other related material and labor.

CONCLUSIONS

1. Despite pronounced modernization achieved so far in regard to irrigation techniques, there is still a wide scope for further improvement, mainly in the following directions:
   - Promoting modern irrigation techniques at wider scales, especially in citrus orchards is a necessity;
   - Establishing more storage reservoirs to that water which is not pumped directly from wells to farms;
   - Effective rehabilitation of distribution networks and complete phasing out of earth canals.

2. Well rehabilitation may include one ore more of the followings:
   - Replacing old casings with new ones;
   - Acidizing old wells to restore original discharge;
   - Enlarging diameter of wells;
   - Straightening of crooked wells;
   - Drilling new substitute wells.

3. Water storage structures, pumps, channels and drains are insufficient. Also, there is an inadequate institutional and legislative framework to manage the water resources effectively for sustainable use and development.

REFERENCES

Al-Juneidi, F. and J. Issac (1996). ARIJ.

Dudeen, B. (2003). *GIS Analysis of Water-Soil Relationship for the Purpose of Enhancing Irrigation Performance.* Palestinian Soil Bureau, Land Research Center, Jerusalem, 2003.

FAO (2001). *Agricultural revitalization program in West Bank and Gaza Strip*. Draft study report , 2001.

Nofal, I. (1998). *Water management in small groundwater irrigation schemes in Palestine*.

Ministry of Agriculture (MOA) - Agricultural Statistics Department (2002). The data of the Agricultural Statistics Department of Ministry of Agriculture, 2001-2002.

CDM/Morganti (1997). *Comprehensive Planning Framework for Palestinian Water Resources Development*. Final report, Palestinian Water Authority, Ramallah, 1997.

German Technical Cooperation (GTZ) (1998). Middle East Regional Study on Water Supply and Demand Development, Phase 1 & 2, Palestine, 1998.

Palestinian Central Bureau of Statistics – PCBS (1998). *Population Census Results*. Preliminary Report, Ramallah, 1998.