AN ASSESSMENT OF IRRIGATION EFFICIENCY IN THE PALESTINIAN WEST BANK

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Abstract

Water scarcity in the West Bank represents a critical constraint to further expanding, or even maintaining, present irrigated areas. There are increasing demand for agricultural water use to be restricted in favour of other water consumers, such as local communities and industry.

The fundamental question this research addresses, however, is whether irrigation water is being used wisely in the West Bank, and whether modernization of irrigation can effectively improve its performance. Another important objective in this research is to develop irrigation scheduling programs for farmers to insure more cost efficient water use.

The study indicates that water use efficiency is relatively high. This is 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 the 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 semi-coastal region (Jenin and Tulkarm) 70.5% of the vegetables are irrigated by drip systems of 68% application efficiency. About 0.6 % and 1.5 % of the vegetables in both the Jordan Valley and Semi-Coastal regions are irrigated using furrow irrigation.

Key words: Deficiency, Territory, Reaping, Evaluation.

Introduction

There is a scarcity of water in the West Bank due to the natural weather conditions, as well as the abnormal political situation of Israeli control over all Palestinian water resources. Since rainfall in the West Bank is not high enough for optimum agricultural production, irrigation is required to supplement certain crops with more water to achieve higher crop yield. Although irrigated agriculture in the West Bank constitutes less than 6% of the total Palestinian cultivated areas, it is considered to be the main consumer of water. Irrigation accounts for 67 percent of total water use, whereas industrial and domestic uses account for the remaining 33 percent. In spite of this, the current water use for irrigation is not enough for the current and future levels of development. Palestinians are currently negotiating their water right with Israel in the aim of securing more of their waters that have been exploited by Israel. Nevertheless, Palestinians need to consider improving water management at the farm level.

Methodology

Baseline data on irrigation types and practices in the West Bank were derived from field survey of 20 percent of the total irrigated area in the West Bank. Detailed analysis was conducted through farmer questionnaires, covering the various crops and irrigation methods commonly used in order to determine the farm application efficiency. In addition, an estimate of the amounts of water needed to be applied to different crops was determined using the Modified Penman-Monteith method. CROPWAT software was used to estimate crop water requirements based on different monthly weather parameters (i.e., average temperature, humidity, sunshine hours). Water use efficiency, which indicates how much food and/or fibre a cubic meter of water can produce, was evaluated by taking into consideration the agricultural water demand, areas and production for irrigated crops for the year 1994 (Palestinian Ministry of Agriculture), and actual agricultural water use in various districts of the West Bank in 1994.

Many factors were taken into consideration in calculating agricultural water demand. This includes leaching requirements, based on the average salinity of 250 different groundwater samples from wells and springs used for irrigation in various districts of the West Bank.

Sources of Irrigation Water

Water resources in the West Bank include both surface and groundwater. The only surface water body is the Jordan River, which cannot currently be used by the Palestinians because of the military closure of the area adjacent to the river by Israel.

Groundwater in the West Bank from wells and springs is currently the only source of water being used for irrigation. Table 1 shows the total quantities of water used for irrigation in various districts. Most of the irrigation wells are small in size, old in age and privately owned and operated. A comprehensive rehabilitation program is essential to increase their efficiency. About one hundred major springs, with an average annual flow discharge of 52 MCM/Yr, are being used for irrigation. The efficiency of these springs is low where large amounts of water are lost through seepage into the ground and through evaporation.

Table 1: Quantities of groundwater used for irrigation in various districts of the West Bank

District	Springs	Wells	Total
	(MCM)	(MCM)	(MCM)
Nablus	11.92	2.73	14.65
Hebron	0.17	0.00	0.17
Ramallah	1.17	0.00	1.17
Jenin	0.00	4.04	4.04
Tulkarm	0.00	16.62	16.62
Bethlehem	0.37	0.00	0.37
Jordan Valley	37.77	18.12	55.89
Total	51.40	41.50	92.9

Source: ARIJ, 1995.

Table 1 shows that about 55% of the total water used for irrigation originate from springs. Figure 1 shows the annual variations of the total spring flow discharge in the West Bank during the period 1970 to 1994.

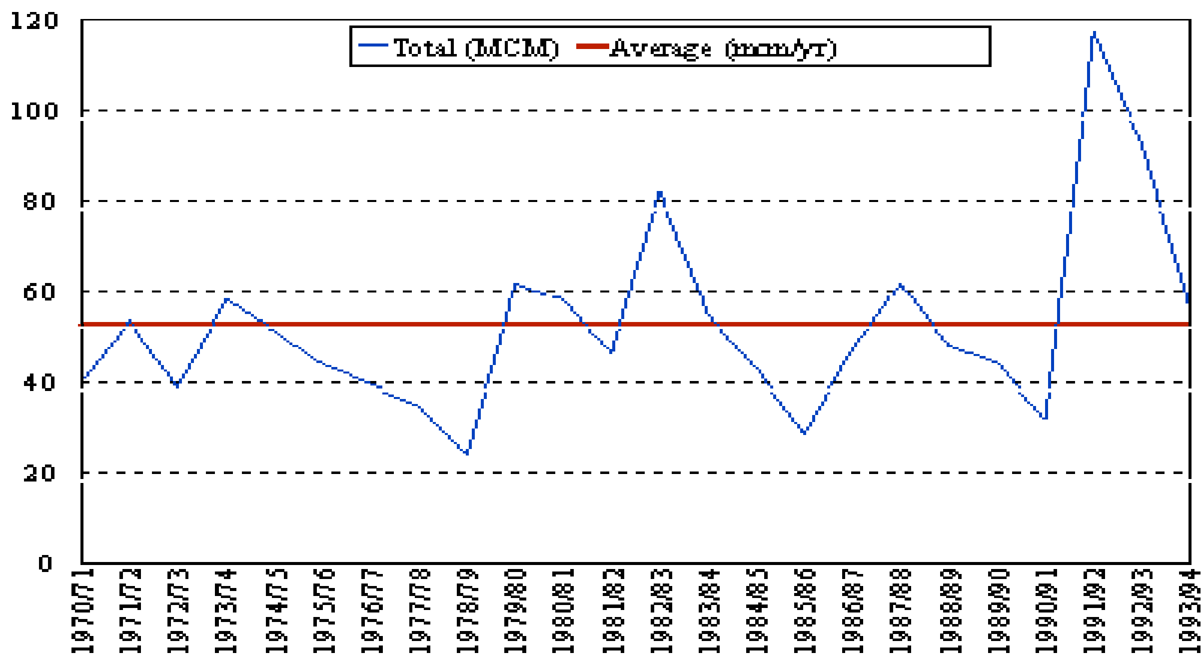


Figure 1: Annual variations of the total spring flow discharge in the West Bank, during the period 1970 to 1994, in MCM.

The figure shows that the annual flow discharge ranges from 24 MCM/yr in the 78/79 hydrological year into 116 MCM/yr in the 91/92 hydrologic year with a long term mean annual spring flow of 52 MCM/yr. Therefor, the reliability of the Palestinian irrigation on the discharge of springs has negative effects on the irrigated agriculture and the agricultural production there.

Water Development & Management Practices

The farmers in the West Bank have tried to overcome water shortage through constructing agricultural ponds to collect spring water, as well as rainfall and flood runoff, through open concrete or earth canals to be used at the time of irrigation. Flood runoff in the West Bank was evaluated in the 1960s to be about 64 MCM/yr (Rofe & Raffety, 1965). Small-scale utilisation of such surface water is practised in some Palestinian villages by constructing cisterns to fulfil their municipal and agricultural needs. Soil agricultural ponds with plastic covers are the most dominant in the West Bank. The majority of the agricultural ponds were established in the Jordan Valley, where the current total number is 200.

There is a potential to collect rainwater from the roofs of plastic houses. There is about 5,964 dunums planted with vegetables under plastic houses and high plastic tunnels in the West Bank. The majority of these are located in Tulkarm and Jenin districts, where the average annual rainfall is about 585 mm. Table 2 shows the potential water harvesting from the total area of plastic houses and high plastic tunnels based on 80% of the average annual rainfall amounts in various districts of the West Bank. That table shows that there is a potential to harvest 3 MCM/yr of rainfall from the roofs of plastic houses in the West Bank.

Table 2: Potential Harvest from High plastic tunnels and Plastic houses.

District	**Average annual rainfall**	**Total Area**	**Total rainfall volume**	**Harvested rainfall Volume(80% of rainfall)**
	(mm/yr.)	(Dunum)	(CM/yr)	(MCM/yr)
Jordan Valley	144.4	187	26931	0.02
Jenin	528	377	199056	0.16
Tulkarm	641.7	5340	3426678	2.74
Nablus	642.6	20	12852	0.01
Ramallah	722.6	25	18065	0.01
Bethlehem	579.8	7	4059	0.003
Hebron	602.1	8	4817	0.004
Total		5964		2.95

Water Use Efficiency

Two different operation efficiencies are recognised. The first one applies to the ability to accomplish a specific goal without using more water than necessary. This entails the determination of the irrigation efficiency on the farm level. The second is the return to use. This indicates how much food and/or fibre a cubicmeter of water can produce.

Irrigation Efficiency

Irrigation efficiency includes two main types: water conveyance efficiency and application efficiency of irrigation systems.

Water conveyance efficiency

The irrigation water in the West Bank is being conveyed either through open earth canals, concrete canals, or by pipes. Earth ditches are popular in Al Fara'a because of their low capital cost and ease of use, but they cause water loss through evaporation and seepage. Weeds grown along ditch banks can reduce the carrying capacity of the ditches and constitute a source of seeds which may reach the irrigated fields. Furthermore, some domestic solid waste was thrown into the canals. These pollutants have negative effects on the crops and on the irrigation system efficiency. In contrast, the conveyance efficiency is higher in the concrete canals where the losses are due to evaporation alone. This type of canal is popular in the Jericho and Al Auja areas. Most of the farmers in the West Bank deliver water to their fields by means of plastic or metal pipes. The high cost of pumping causes higher costs per unit of water. Also, the water is conveyed and distributed without any storage facility, because most farms irrigated from wells use pressurized irrigation systems. Therefore, farmers have to use the pressure head applied by the turbine pumps at the well to supply their irrigation systems with the needed pressure. The pipes are usually laid on the ground surfaces to minimize the cost of installation, but this practice reduces the life time of the pipe. Unfortunately, the availability of water gauges was found to be low in most farms of the West Bank. Without the use of water gauges, it was difficult to calculate the conveyance efficiency.

Irrigation Systems

Surface irrigation is the oldest method of irrigation used in the West Bank. Furrows and basins are the most common method in the region. Basin irrigation is used mostly for irrigating trees, mainly citrus. Furrows are used to irrigate vegetables. There is a certain difficulty involved in the management of water distribution in these installations. Pressurized irrigation techniques (drip and sprinkler systems) which are common used in the West Bank, can reduce these water losses. Usually, potatoes, onions, carrots, radishes and spinach are irrigated using permanent sprinkler systems, whereas most vegetable crops under plastic houses or in open fields are irrigated using drip irrigation. The main disadvantage of the drip irrigation system is its susceptibilitty to clogging by salt precipitation of calcium carbonate, iron oxide, algae and microbial limes. To minimize this problem, water is usually treated by adding acids to dissolve the sediments of calcium carbonates in the emitters. Screen filters are also used to separate suspended solids.

Figure 2 shows the distribution of different irrigation systems in different districts of the West Bank.

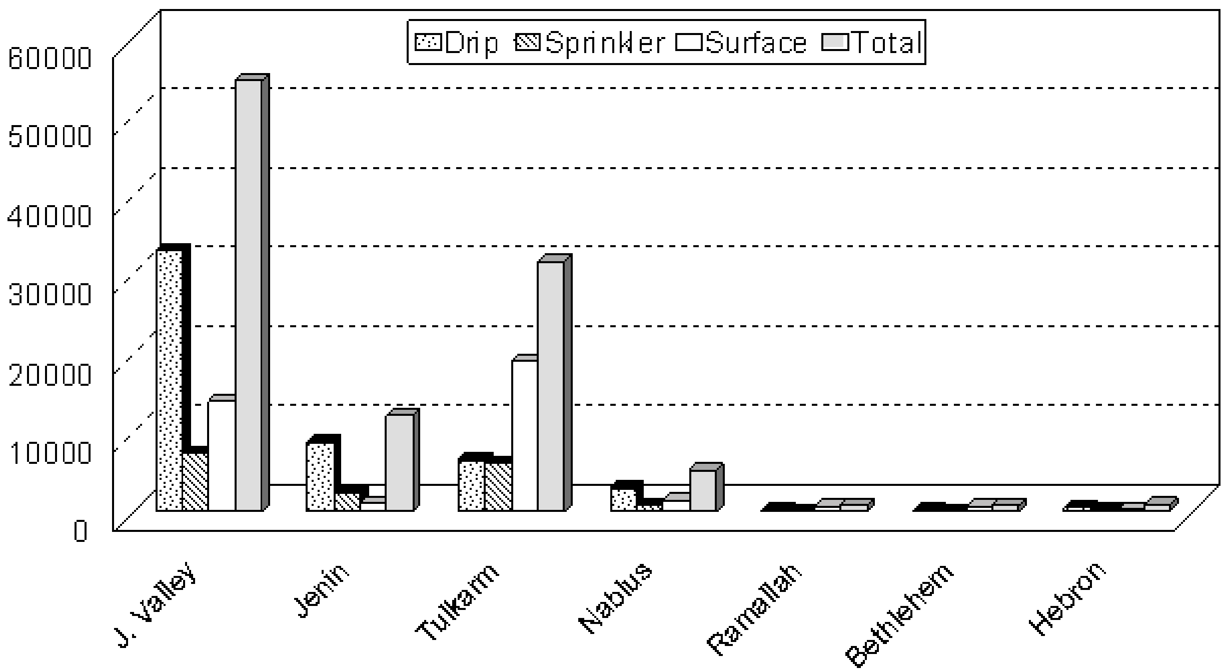


Figure 2:. Distribution of different irrigation systems, areas in dunums, in different districts of the West Bank.

Application efficiency of irrigation systems

Irrigation efficiency is influenced by the system design and management. It can be divided into two components: water losses which are predominately affected by management and uniformity of application, which is predominately affected by system design.

Table 3 shows the cropping pattern, while Table 4 shows the types of irrigation systems used in the surveyed area.

Table 3: Various cropping pattern in the surveyed area.

Cropping Pattern	**% of the surveyed area**		
	Tulkarm	Jenin	Jordan Valley
Plastic houses	25.7	8.6	1.6
Open field	45.7	83.5	59.9

Plastic Tunnels	1.3	7.9	2.5
Fruit trees	24.9	-	35.2
Filed Crops	2.3	-	0.8
Total	100	100	100

Table 4: Types of irrigation systems used in the surveyed area.

Irrigation system	**% of the surveyed area**		
	Tulkarm	Jenin	Jordan Valley
Drip	60.3	76.5	98.1
Sprinkler	29.0	23.5	0.3
Basins	7.0	-	0.9
Flooding	0.4	-	0.8
Furrows	3.4	-	-
Total	100	100	100

Water losses can occur in the form of seepage from irrigation network channels, non-uniform distribution of the network over the field, percolation below the crop root zone and evaporation from the spray and plant leaves, in the case of sprinkler irrigation. The degree of previous losses can be calculated by various types of efficiencies, including; farm irrigation efficiency, where water is measured at the farm headgate, application efficiency, where water is measured on the field site, and project efficiency, where water is measured at the point of diversion.

The application efficiency, a measure of management losses, was found using the following formula:

$$E_a = (Net_{irr.}/Q_{applied})*100 \quad (1)$$

where:

E_a = field application efficiency, %

$Net_{irr.}$ = net irrigation requirements needed, and made available, for evapotranspiration by the crop included effective precipitation and it was calculated according to the modified Penman equation, mm

$Q_{applied}$ = the amount of water applied, mm.

Crop water requirements

An estimate of the amounts of water needed to be applied to different crops was done using the Modified Penman-Monteith method. CROPWAT software was used to estimate crop water requirements based on different monthly weather parameters (i.e., average temperature, humidity, sunshine hours). Table 5 shows the average crop water requirements under different cropping patterns in various districts in the West Bank.

Table 5: the average crop water requirements under various cropping patterns in different districts in the West Bank, m^3/dunum.

Districts	**Vegetables**		**Fruit Trees**	**Field Crops**
	Open Field	Plastic Houses		
Nablus	495	735	805	413
Hebron	427	750	909	381
Ramallah	554	871	1112	500
Jenin	491	753	890	427
Tulkarm	409	718	634	404
Bethlehem	492	873	1009	402
Jerusalem	515	808	1162	501
Jordan Valley	641	596	1291	548

However, optimal water use at the farm level requires monitoring and measuring soil moisture in the field to decide when to irrigate. Measurements of soil moisture tension can be done using tensiometers, which do not exist in most Palestinian farms.

Net irrigation requirements used to evaluate the application efficiency for irrigation systems was calculated using CROPWAT software

Table 6 shows the application efficiency for different irrigation systems, while Table 7 shows the application efficiency for different irrigation systems under different agricultural patterns.

Table 6: The application efficiency for different irrigation systems, %.

District	Drip	Sprinkler	Basins	Flooding	Furrows
Jordan Valley	78	85	207	55	-
Jenin	106	53	-	-	-
Tulkarm	68	80	64	-	131

Table 7: Breakdown of the application efficiency for different irrigation systems under different agricultural patterns, %.

District	Plastic houses			Open field			Plastic Tunnels			Fruit trees			Filed Crops		
	Dri.	**Spr.**	**Sur.**	**Dri.**	**Spr.**	**Fur**	**Dri**	**Spr**	**Sur.**	**Dri**	**Spr**	**Bas**	**Dri**	**Spr**	**Flo.**
Jordan Valley	53	-	-	129	85	-	48	-	-	83	-	207	-	-	55
Jenin	93	65	-	107	41	-	117	-	-	-	-	-	-	-	-
Tulkarm	80	60	-	90	31	131	32	115	-	68	87	64	-	106	-

To add perspective to these efficiencies, Table 8 shows the attainable efficiencies for different irrigation methods. Attainable efficiencies are those that can be achieved with reasonable design and management (i.e., efficiencies to be achieved by most farmers).

Table 8: Water application efficiencies for irrigation methods.

Type of system	Attainable efficiency

Surface Irrigation:	
Basin	80-90%
Border	70-85%
Furrow	60-75%
Sprinkler Irrigation	65-75%
Drip Irrigation	75-90%

It was observed that the application efficiency for irrigation systems is relatively high. This is not due to a good management, but rather to the shortage of water in the most irrigated areas. It was observed that the percentage of crops suffering from water shortage increases from a low average of 22% in the Jericho district to a high average of 32% in Tulkarm district. On the other hand, about 25% of irrcrops in Jenin district are sufferinfrom water shortage. Table 9 shows the percentage of crops suffering from water shortage under different agricultural patterns in the surveyed area.

Table 9: The percentage of crops that suffering from water shortage under different agricultural patterns in the surveyed area.

	Jordan Valley	**Jenin**	**Tulkarm**
Plastic houses	17	32	15
Open field	25	17	54
Plastic Tunnels	18	27	50
Fruit trees	35	-	18
Filed Crops	13	-	25
Average	22	25	32

For the crops planted under open field, the application efficiency was low during winter months, mainly in the Northern districts of the West Bank where part of the irrigation requirements can be compensated from rainfall. Crops planted under protected agriculture in the Jordan Valley, however, have an application efficiency for drip irrigation significantly below the attainable efficiencies. It was observed that the availability of water gauges is low in most farms. Some farmers are using an extra amount of water than the ideal quantities believing that additional water would increase crop yield. The additional water applied is high in comparison to the actual amount needed for vegetables mainly under protected agriculture and some fruit trees like avocadoes. However, the amount of water applied is insufficient with respect to that needed for citrus.

In Tulkarm district the average application efficiency values for citrus under surface irrigation (Basins) was 84%. While the E_a value for the same crop under sprinkler irrigation was 87% and 90% under drip irrigation. It is noticeable that drip systems has approximately the same E_a value with comparison to that of surface and sprinkler irrigation. This could be due to the high amount of water required for citrus, which in turn caused a high efficiency under different irrigation systems. Besides, good field practices for surface irrigation can be found under citrus crop (canals, basins, and weed control). This lead to more efficient use of water by citrus with lower loss of water. Although E_a values are nearly equal under different irrigation systems, it is still higher for drip than surface and sprinkler systems. This may related to more developed techniques and services for drip irrigation than other irrigation systems. Under surface irrigation, these values are acceptable and lie within the accepted range while for sprinklers it has attained a high value.

Technical & Economic Efficiencies Of Irrigation Systems In The West Bank

Technical efficiency of irrigation systems was determined through correlating yield with volume of water used under the current cropping patterns in the West Bank. While economic efficiency of irrigation systems was determined through correlating crop production with cost of irrigation under similar cropping and physical conditions. The economic returns to water use were computed as gross margin as shown in the following equation;

$$G_m = (\text{price} * \text{yield} - \text{variable costs}) / (Q_{applied} + P_{eff.}) \quad (2)$$

Where:

G_m = gross margin

$Q_{applied}$ = the amount of water applied for irrigation

$P_{eff.}$ = effective precipitation.

Table 10 shows the water use efficiency in different districts of the West Bank.

Table 10: Water use efficiency in different districts of the West Bank.

District	**Yield**	**W.U.E**	
	(Kg/dun.)	($/m^3)	(Kg/m^3)

Jenin	2298	0.81	4.47
Tulkarm	3577	0.76	3.81
Nablus	2419	0.13	0.69
Jordan Valley	2322	0.51	2.13
Ramallah	1431	0.24	0.83
Bethlehem	1553	0.42	2.14
Hebron	1719	0.70	3.47

The table shows that the lowest yield was in Nablus, 0.69 Kg per one cubic meter of water applied. The yield decreases as the quantity of water applied exceeds the actual amounts results of disease, poor aeration, cooler soil temperature, and fertilizer leaching. In contrast, the farmers believe that more water gives higher yield.

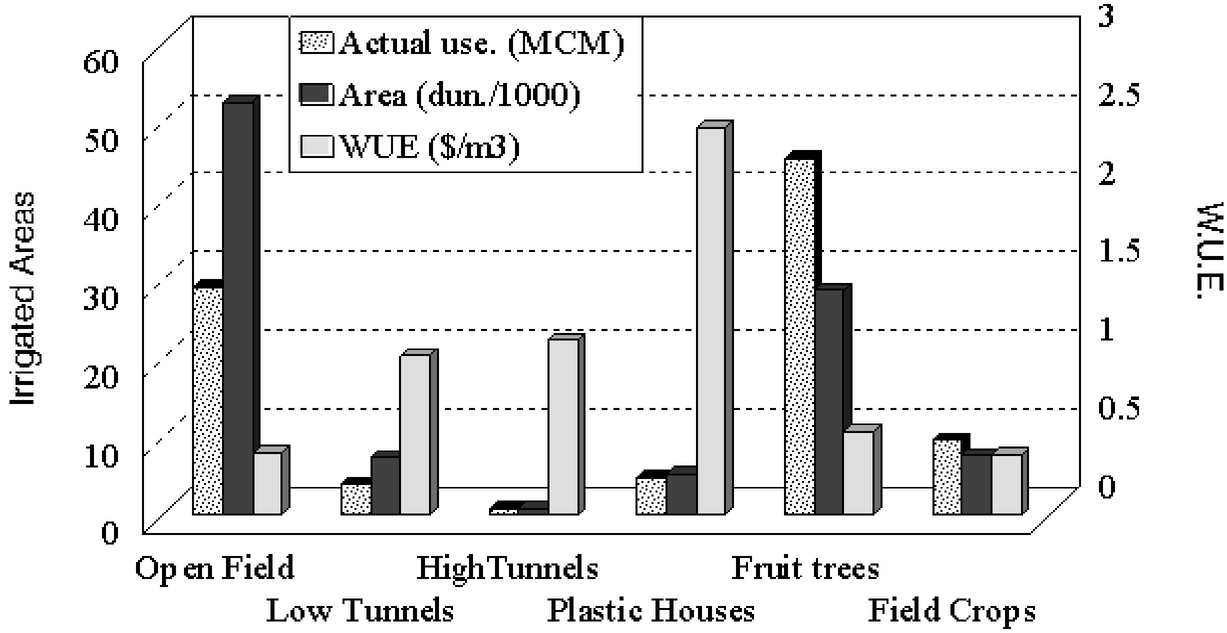
On the other hand, the return to water use for the other districts can be increased if the quantity of water applied achieved the ideal amounts.

The yield also is affected by the time of irrigation. For some plants, such as grains, the timing of the water stress is more important than the annual deficit. Fore example, if corn wilts for only tow days during the pollination stage, grain yield can be reduced as much as 20% (Burt, C. , 1994).

Water Allocation Efficiency

Allocation efficiency addresses how water should be allocated among crops in order to achieve the most worthwhile overall use. If large volumes of water are allocated to a crops producing low value, the total amount of value generated will be low. For example, it has been noticed that fruit trees consume large amounts of water before reaching the productive stage and the output value during the production is low about 0.5 $ per cubic meter of irrigation water applied. Figure 3 shows the water use efficiency in relation to the irrigated areas under different cropping patterns in the West Bank and actual water consumption

Figure 3: Water use efficiency in relatio*n to the irrigated areas under different cropping patterns in the West Bank and actual water consumption.



Agricultural Water Demand

Most districts of the West Bank are suffering from water shortage where more quantities of water are needed to achieve the optimal crop yield. However, Hebron is basically a mountainous region and irrigated agriculture is negligible in this district. In the Jordan Valley, more water quantities are needed to overcome water salinity problems. In Nablus more quantities of water can be saved since the optimal water use is much lower than the water applied for irrigation. In general, these figures indicate that Palestinian farmers are using water wisely for irrigation .Table 11 shows the total agricultural water demand in relation to the actual water use for agriculture in various districts of the West Bank

Table 11: Total agricultural water demand in relation to the actual water use for agriculture in various districts of the West Bank.

District	Total area (Dun.)	Actual Water Use (MCM)	Optimal Water Use (MCM)		Water Deficit/ Surplus (MCM)	
			(without LR*)	(with LR)	(without LR)	(with LR)
Jenin	11779	4.04	9.82	10.55	-5.78	-6.51
Tulkarm	29345	16.62	22.33	22.53	-5.71	-5.91
Nablus	4639	14.65	3.28	3.33	11.37	11.3

Jordan Valley	53155.5	55.92	48.99	60.24	6.93	-4.32
Ramallah	890	1.17	0.70	0.72	0.47	0.45
Bethlehem	814	0.37	0.45	0.45	-0.08	-0.08
Hebron	993	0.17	0.32	0.32	-0.15	-0.15
Total	101615.5	92.9	85.89	98.14	7.05	-5.2

*LR = Leaching requirements

Conclusions & Recommendations

1. The application efficiency for irrigation systems is relatively high. This is not due to a good management but mainly due to the shortage of water in the most irrigated areas. Drip and sprinkler irrigation methods have an application efficiency of 84% and 73% for both systems respectively which are within the range of attainable efficiency. Low application efficiency for flooding irrigation (55%) is due to high evaporation, seepage losses and unavoidable losses.
2. Application of new irrigation techniques on vegetable farms is much more common than it is in tree orchards in the West Bank. Drip irrigation is used chiefly on vegetable crops, while sprinklers are common in orchards especially in citrus orchards, and on some leafy vegetables such as cabbage, onions, spinach, and on field crops and forage.
3. The return to water use for vegetable crops under plastic houses can be increased if the quantity of water applied achieved the ideal amounts. It is still higher than other agricultural pattern. This is related to substantial improvements in the levels of production technology such as planting improved crop varieties, using drip irrigation techniques and applying fertilizers and pesticides.
4. In the West Bank there is a lack of extension services to work with farmers to improve the operation and maintenance of irrigation systems. Pressurised systems like drip and sprinklers requires a much higher level of knowledge on the part of the farmer to achieve high efficiency. The survey showed that most of the systems were dand installed by the farmers.
5. It is economic to convert from surface to pressurised systems. Although the cost of physsystem is high in addition to the training costs of farmers but it remain much lower than the cost of water and the farmers can repay the loan with increased production.
6. It is economic to plant date palm trees especially in the Jordan Valley. Date palm is salt-tolerant crops and require low quantity of water in comparison with other crops. The local demand for dates is higher than the yield, and the price is relative high.

7. Good water management is the most important alternative to increasing economic revenues, that is, increasing the production per each unit volume of the water applied for irrigation.
8. In order to maximise the efficiency of water use in irrigation, crops with low transpiration rates or crops that produce high dry matter yield per unit of water transpired should be selected. For instance, corn requires relatively small quantities of water to produce one Kg of dry matter, in comparison with alfalfa that requires large quantities of water to produce one Kg of dry matter. The cereal crops, such as wheat and barley, and vegetables, such as potatoes, are intermediate in their requirements.
9. In order to increase the irrigation water conveyance and distribution systems efficiency, the canal irrigation systems must be replaced with piped systems.
10. As the water resources the West Bank are scarce and fluctuating and with an over increasing demand, a water allocation strategy needed to be build so as to make the best possible use of water resources available
11. Changing planting dates to reduce the crop water requirement: for example, growing any crop during the cool months of the season when the vapour pressure gradients are apt to decrease the crop water requirements and increase the efficiency of rainfall in irrigation.
12. Also a farmer must plant at the right depth, manage labour properly, apply pesticides in a proper time and at the proper rate, and must do other things correctly in order to have high yields.
13. Enhancing the penetration of water into the soil by practices that keep the soil surface open, like tilling at suitable times. Excessive tillage that destroys the surface roughness should be avoided in all cases. Tillage across slopes results in small ridges and encourages water infiltration. Terracing can help in controlling the amount of water lost in runoff.
14. Using of minute irrigation technology which refer to low application rate of irrigation water. Such technologies allow the infiltration of all the irrigation water into the soil without runoff, even in heavy soils where infiltration capacity is extremely low: a very slow and continuous water movement down the soil profile is achieved. At the same time, a favourable environment for root development is maintained with only minute fluctuations in soil moisture during the intervals between irrigations. Such conditions seem to be optimal for plant growth and may contribute to higher production and more efficient water use.

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