Impact of Irrigated Agricultural Practices on Environmental Quality and Human Health in the West Bank

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Abstract. *This paper examines the effects of irrigation practices and related activities on the environment and human heath in the West Bank. Irrigated agriculture in the West Bank covers an area of 9,473 ha and utilizes 93 million cubic meters of irrigation water annually. The current annual use of fertilizers in the irrigated areas is 18,980 tons of chemical fertilizers and 198,900 to 265,200 tons of organic fertilizers. The total annual use of pesticides (excluding methyl bromide) in irrigated agriculture is 153 tons, of which 27 tons are internationally banned products. Methyl bromide is a dominant soil fumigant in the West Bank with a total estimated annual use of 400 tons, 44% of which is used on vegetables planted in plastic houses and high plastic tunnels. The soil solarization method to control soil-borne diseases is used by only 0.5% of the surveyed farmers. This study indicates that some farmers have suffered health problems due to exposure to pesticides, from the lack of protective clothing. Of the surveyed farmers, 19% suffer from poisoning symptoms and 1% are affected by methyl bromide fumigants. The total quantity of plastic sheets was estimated at 4,750 tons, at least 50% of which becomes waste. Eighty-eight percent of the surveyed farmers collect and burn the plastic wastes on the field, which could harm both the environment and human health through toxic fumes. Some water-related diseases occurred in the study area. Seventy-nine people were affected by leishmaniasis and 14 others by dysentery. Despite the heavy use of fertilizers, water quality analysis did not show high concentrations of nitrate.*

Key words: groundwater, pollution, fertilizers, pesticides, fumigation, agricultural colonies.

Introduction

The optimal environmental conditions (i.e., temperature and humidity) for plant growth in irrigated agriculture, especially for vegetable crops, is easily regulated under plastic houses. High and low plastic tunnels provide a favorable environment for various plant diseases and pests. Therefore, farmers need to apply agrichemicals to improve both the quantity and quality of the products. Irrigated agricultural practices by Palestinian farmers in the West Bank may have a negative effect on both the environment and human health. The aim of this study was to identify and assess these effects.

Methodology

Environmental impacts of irrigated agricultural practices in the West Bank were examined by field surveys of an area of 2,030 ha, which involved 415 farmers and a total of 22% of the irrigated area in the West Bank. Data were analyzed to determine the quantity and quality of different agrichemicals, plastic sheets, and other irrigation by-products, using Statistical Package for Social Science (SPSS) software. Water sample analyses were taken from the Applied Research Institute – Jerusalem (ARIJ) database related to the International Development Research Center (IDRC) – funded project on water resources and irrigated agriculture in the West Bank. Statistical data about production areas and cultivated crops were obtained through integration of the analysis of aerial photographs and data records of the Palestinian Ministry of Agriculture.

Results and Discussion

The current irrigated area in the West Bank is 9,473 ha or 5% of the total cultivated area; the remaining 95% is devoted to rainfed agriculture (Isaac and Gasteyer, 1997). The irrigated area has an annual agricultural crop production of 270,570 tons or 47% of the total. Productivity of the irrigated crops has increased in the last 25 years from the use of new irrigation technologies and systems, intensive cultivation under plastic houses, improved crop varieties, and application of agrichemicals (fertilizers, pesticides, and soil fumigants).

Irrigated agricultural lands in the West Bank are mainly concentrated in two regions: the Jordan Valley and the northern part of the West Bank, which includes the Jenin, Nablus, and Tulkarm districts. Vegetable crops, citrus, bananas, dates, and field crops and forage are the major irrigated crops in the Jordan Valley, whereas vegetable crops, citrus, and other fruit crops dominate the irrigated crops in the northern part of the West Bank. Total irrigated areas and crop production patterns in the West Bank are shown in Table 1.

Table 1. Irrigated areas of various cropping patterns and annual crop production in the West Bank, 1995-96.

Cropping pattern	Area (ha)	Production (tons)
Vegetable crops		
Open fields	4,900.6	100,810
Plastic houses	776.2	58,464
High plastic tunnels	112.1	6,022
Low plastic tunnels	306.9	10,009
Subtotal	6,095.8	175,305
Fruit trees	2,814.2	90,744
Field crops and forage	562.8	4,521

Grand total	9,472.8	270,270

Source: Palestinian Ministry of Agriculture (1996).

The following parameters were taken into consideration.

Quality of water for irrigation

At present, there is no indication that groundwater is being affected by agrichemicals and other irrigation practices. Table 2 shows the descriptive statistics from the results of the analysis of water samples taken from 250 wells and springs for pH, electrical conductivity (EC), bicarbonate (HCO_3^-), chloride (Cl^-), nitrate (NO_3^-), and sodium absorption ratio (SAR). Guidelines for interpretation of water quality for irrigation are shown in Table 3.

Table 2. Results of analysis of 250 water samples from the West Bank study area.

	pH	EC (µS/cm)	HCO_3^- (ppm)	Cl^- (ppm)	NO_3^- (ppm)	SAR
West Bank main springs						
Minimum	7.0	214.0	60.4	16.0	1.9	0.6
Maximum	8.0	381.0	400.2	1,037.9	19.8	10.6
Average	7.5	296.7	181.1	85.9	3.9	2.1
Wells of Jordan Valley						
Minimum	5.8	369.0	128.2	9.9	1.3	1.2
Maximum	7.4	2,280.0	3,720.7	2,424.1	52.0	12.5
Average	7.0	1,013.8	1,209.5	458.6	10.0	4.4
Wells of Nablus						
Minimum	6.8	203.0	295.2	16.1	0.3	0.5
Maximum	7.7	903.0	644.3	91.8	12.9	1.8
Average	7.1	566.4	406.9	46.4	5.6	1.0
Wells of Jenin						
Minimum	6.5	268.0	49.4	22.2	0.6	0.5
Maximum	7.6	1,922.0	277.0	752.4	13.2	3.9
Average	7.0	785.5	141.2	128.7	6.6	1.7
Wells of Tulkarm						
Minimum	6.6	242.0	135.6	7.8	2.8	0.2
Maximum	8.0	1,623.0	1,387.9	275.9	16.4	4.4
Average	7.1	648.0	496.4	66.3	8.9	1.2
Wells of Qalqilya						
Minimum	6.7	152.0	33.9	10.7	3.9	0.1
Maximum	7.7	1,432.0	968.0	215.8	12.9	2.9
Average	7.0	598.5	492.0	60.0	9.6	0.8

Wells of Ramallah District						
Minimum	7.5	508.0	195.6	31.0	13.0	0.5
Maximum	7.8	585.0	244.8	36.0	21.0	0.6
Average	7.7	539.7	225.9	33.7	16.7	0.6
Wells of Bethlehem District						
Minimum	6.9	260.0	205.3	3.8	1.1	0.0
Maximum	7.3	373.0	445.8	11.8	3.2	1.3
Average	7.1	340.6	353.3	76.9	2.3	0.5
Wells of Hebron District						
Minimum	7.1	389.0	426.8	32.0	12.2	0.5
Maximum	7.3	412.0	478.0	37.6	12.2	0.7
Average	7.2	400.5	452.4	34.8	12.2	0.6

Source: Isaac and Sabbah (1998)

Table 3. Guidelines for interpretations of water quality for irrigation.[1]

Potential irrigation problem	Units	Degree of restriction on water use		
		None	Slight to moderate	Severe
ECw[2]	µS/cm	700	700-3,000	>3,000
Sodium Absorption Ration (SAR)		<3	<3	
Chloride (Cl^-)	Ppm	<106.4	>106.4	
Nitrate (NO_3^-)	Ppm	<21.7	21.7 to 132.7	>132.7
Bicarbonate (HCO_3^-)	Ppm	<91.6	91.5 to 518.8	>518.8
pH		Normal range (6.5 – 8.4)		

[1] Adapted from University of California Committee of Consultants (1974).

[2] Electrical conductivity of irrigation water.

Based on the average water quality values in Table 2 and comparing them with the quality standards for irrigation water in Table 3, the following points were observed:

- There is no restriction on water use from the main springs with respect to pH, EC, Cl^-, NO_3^-, and SAR, but, there is slight to moderate restriction on spring water use, with respect to HCO_3^- for irrigation.
- There is no restriction on use of water from wells for irrigation, with respect to pH and nitrate levels in all districts of the West Bank.
- In the Jordan Valley there is slight to moderate restriction on irrigation water use from wells, with respect to SAR and EC values, and severe restrictions with respect to HCO_3^- and Cl^-.

- In Jenin, Tulkarm, Qalqilya, Nablus, Ramallah, Bethlehem, and Hebron, there is slight to moderate restriction on water use from wells for irrigation, with respect to HCO_3^-, and no restriction on water use with respect to EC, Cl^-, and SAR values.

Use of fertilizers

Currently, there are two kinds of fertilizers being used in the West Bank: organic fertilizers (animal manure) and inorganic (chemical) fertilizers. In the growing season of 1995-96, the total annual quantity of organic fertilizers applied to the irrigated areas was estimated to range between 198,900 and 265,200 tons based on an application rate of 21 to 28 t/ha. The average amount of chemical fertilizers applied per ha per growing season for irrigated crops is shown in Table 4. the total quantity of applied chemical fertilizers was estimated at 18,980 tons in the 1995-96 growing season (Table 5).

Table 4. Average types and quantities of chemical fertilizers applied to irrigated crops in the West Bank.

Type of fertilizer	Quantity (kg/ha)		
	Vegetable crops	Fruit trees	Field crops & forages
Super phosphate	750	500	500
Compound fertilizers (N,P,K)	500	500	300
Ammonium sulfate	800	300	200
Urea	250	200	-
Micro-nutrients	15	30	-
Total	2,315	1,530	1,000

Table 5. Total quantity of chemical fertilizers utilized in West Bank cropping systems during the 1995-96 growing season.

Cropping pattern	Quantity (tons)
Vegetable crops	14,102
Fruit trees	4,308
Field crops and forage	570
Total	18,980

The application of irrigation water, which contains varying amounts of soluble salts, creates the potential for the accumulation of soluble salts and exchangeable sodium in the soil. Excessive use of soluble fertilizers has raised the accumulation of soluble salts and exchangeable sodium in the soil, leading to saline soils. Problems of salinity become more acute when rainfall is low and the rate of evaporation is high, or when the application of irrigation water is insufficient to carry the salts away from the root zone. Saline soils have sufficient soluble salts to impair plant growth and to alter soil properties.

Nitrogen fertilizers are mostly water soluble, and in the nitrate form (NO^{3-}) are highly mobile in the soil and able to leach below the soil-root zone. During heavy rainfall or irrigation, nitrate is readily carried into the soil. The nitrate from N fertilizers, however, might move downward through the soil with percolating water to the groundwater. Nitrogen as nitrate can be harmful in surface or ground waters used from human or animal consumption. The danger of nitrate pollution is greatest on sandy soils with high percolation capacity. In these cases it is important to use modest amounts of N fertilizer and to apply fertilizer only when crops are actively growing. Large amounts of ammonia can be released from manure and other nitrogenous compounds through volatilization, which can bum plant leaves and pollute the air; volatilization also increases with higher temperatures.

Phosphate from fertilizer, in contrast to nitrate, reacts with soil constituents to form insoluble compounds that are immobile in soil. For this reason there is little possibility that groundwater would become polluted from the use of P fertilizer. Erosion of soil particles can, however, carry P absorbed on soil particles into surface waters. Algae are the most abundant plants growing in surface waters and their growth in commonly limited by a lack of N and/or P. consequently, and activity that enriches surface waters with N or P might contribute to excessive algal growth or an algal bloom (Foth and Turk, 1972).

Currently, there is no evidence for direct adverse effects of fertilizers on groundwater resources in the study area because water samples show low values of nitrates. However, due to the current application rates of organic and inorganic, chemical fertilizers, the West Bank water resources may be affected in the future.

Use of pesticides

Pesticides used in irrigated agriculture in the West Bank in the 1995-96 growing season totaled 153 tons, of which fungicides and bactericides were 52%, insecticides were 30%, herbicides were 10%, and acaricides were 8%. The average application rate of pesticide per growing season was about 1.4 kg/ha on field crops and forages and 46 kg/ha in plastic houses (see Table 6). In Israel the average application rate is 40 kg/irrigated ha (Gabbay, 1994). A total of 123 pesticides is currently used in the West Bank (Saleh et al., 1995); a total of 790 pesticides is registered in Israeli (Gabbay, 1994). Among the pesticides used in the West Bank, 14 types have been internationally suspended, cancelled, or banned (Hassoun, 1991) because of their negative impacts on human health and the environment. Table 7 shows the quantity of internationally suspended, cancelled, or banned pesticides that are still used by farmers in the study area. Folidol, thionex, benlate, and manebgan are usually used in vegetable crops. Supracide is commonly used in citrus orchards. Albersuper is mainly used in field cereal crops such as wheat and barely. Dukatalon, katalon, and stomp are used in open vegetable fields, low plastic tunnels, and fruit tree orchards.

Table 6. Average and total quantity of pesticides applied in the West Bank by the cropping pattern.

Cropping pattern	Average quantity (kg/ha)	Total quantity (tons)	Total quantity (%)
Vegetable crops			
Open fields	19	93	61
Plastic houses and high Tunnels	46	40.8	26.8
Low plastic tunnels	22	6.7	4.3
Subtotal		140.5	92.1
Fruit trees	4	11.2	7.4
Field crops and forage	1.4	0.8	0.5
Total		152.5	100

Table 7. Total use of banned pesticides in the West Bank.

Trade name	Active ingredient	Quantity (tons)
Insecticides		
Folidol	Parathion	0.9
Supracide	Methidathion	0.1
Thionex	Endosulfan	10.8
Subtotal		11.8
Fungicides		
Benlate	Benomyl	4
Manebgan	Maneb	5
Subtotal		9
Herbicides		
Albersuper	2,4-D	0.3
Dukatalon, Katalon	Paraquat, Diqnat, and Simazole	5.9
Stomp	Pentachlorophenol	0.1
Subtotal		6.3
Grand total		27

Nineteen percent of the surveyed farmers had suffered from poisoning symptoms, such as headache, dizziness, tiredness, and irritation of skin, nose, and throat, during the spraying of pesticides. Eight percent of the farmers were affected by spraying of pesticides through inhalation, whereas 4% were affected through skin exposure and irritation.

Some 65% of the farmers in the study area do not adhere to the label instructions on pesticide containers, because they are usually labeled in Hebrew. Most of the farmers depend on their experience or on the advice of the pesticide supplier. Some 79% of the farmers do not wear appropriate protective clothing during spraying operations, about 90% do no adhere to the safety period (i.e., period between the last spray and the harvest), and about 47% believed that they had developed immunity against pesticides through repeated usage and exposure.

The severity of impact on human health from exposure to a pesticide depends on many factors including: toxicity of its active ingredient and its formulation, dose and method of application, length of time and degree of exposure, nature of the pesticide effect, weather conditions, metabolites and their accumulation and persistence in the body, and age and health status of the person. Spraying operations and volatilization of some pesticides may cause serious air pollution.

Seventy-five percent of the farmers dispose of empty pesticide containers by burning them at the farm borders, and thus releasing toxic smoke into the air. Twenty percent discard them at the farm borders. These containers can reach irrigation water through open canals and ponds, causing water pollution. Three percent of the farmers bury them in the soil, causing soil pollution, and 2% collect and discard the empty containers at a dumping site.

Soil can be polluted with pesticides by direct application of the pesticide, as in soil fumigation, or by indirect application from spraying operations. It has been calculated that as much as 50% of the pesticides sprayed on crops or used as herbicides miss their targets and fall onto the soil surface or are transported downwind. Some pesticides, notably organochlorines, may persist in the soil for years (Edwards, 1986), though large amounts evaporate.

Soil fumigation

Methyl bromide (active ingredient CH_3Br) is a dominant material used for soil fumigation in the West Bank. The total quantity of methyl bromide used for agriculture in the West Bank during the 1995-96 growing season was 400 tons, and 44% of this was used on vegetables grown in plastic houses and high plastic tunnels. Methyl bromide application affected about 1% of the surveyed farmers. Inhaling methyl bromide can cause a variety of acute problems including chest pains, difficulty in breathing, and congestion of the lungs. After a short time, neurological symptoms such as headache, nausea, shortness of breath, muscle tremors, and visual disturbances occur. Exposure to slightly higher levels of the fumigant can lead to death just hours or days after exposure (WHO, 1991). Its use can also adversely affect the activity and populations of beneficial microorganisms within the soil.

Methyl bromide is an extremely potent destroyer of the ozone layer, which protects humans and other living organisms from harmful ultraviolet (UV) solar radiation (Clark et al., 1994). The U.S Environmental Protection Agency has classified methyl bromide as a category I acute toxin, a label reserved for the most deadly acute substances (US EPA, 1986). Moreover, the earth's food chains, which rely on the support of sunlight for food production, are also affected by changes in UV light irradiation exposure. The increased intensity of UB irradiation reduces plant production and, therefore, can endanger both humans and animals that depend on these plants for nutrition (Clark et al., 1994; Ishtayia and Hamad, 1995).

The Montreal Protocol, an international agreement established in 1987 to eradicate ozone-depleting substances, attempted to achieve a global phase-out of methyl bromide in 1995. In November 1992, at the fourth meeting of the parties to the Montreal Protocol, methyl bromide was officially recognized as a serious ozone-depleting substance. At the fifth meeting of the parties to the Montreal Protocol in November 1993, 17 countries (including the U.S., Zimbabwe, Israel, Botswana, and Italy) stressed the need to strengthen the proposed phase-out plan. They declared their intention to reduce their consumption of methyl bromide by at least 25% by the year 2000, and to completely phase out the pesticide as soon as technically possible (UNEP, 1993). The current regime gave the developing countries an additional 10 years to use this chemical. Consequently, the lack of immediate action means that methyl bromide will still be used until 2005 in the West Bank, thus potentially adding more pollutants to the environment and endangering human health.

In 1985 the Palestinian Agricultural Relief Committee used the soil solarization method (solar heat treatment) to control soil-borne diseases, instead of methyl bromide. Good results were achieved by this experiment. Although this method is relatively cheap and effective and has no negative impacts on human health and the environment, only 0.5% of the surveyed farmers used this method. Therefore, extension workers and farm advisors should play an important role in encouraging farmers to apply this safer method of pest control.

Disposal of used plastic

The development of irrigated agriculture, especially for vegetables, has resulted in extensive use of plastic pipes in irrigation networks, and plastic sheets for covering the plants, soil mulching, and other agricultural practices. The total quantity of plastic used in irrigated agriculture in the West Bank is 4,750 tons. At least 50% of the total quantity of the plastic used in agriculture becomes solid waste.

Approximately 88% of the surveyed farmers collect and burn the plastic waste on the field, releasing large amounts of toxic gases into the atmosphere, while about 5% of the farmers collect the plastic waste of disposal at dumping sites. Others either bury the plastic waste in the soil, which may change the physical characteristics of the soil, or they dispose of it at the farm borders where it may be eaten by grazing animals, causing health problems and even death. Thus, current disposal methods of plastic waste have negative effects on the environment, as well as on human and livestock health.

Irrigation impacts on public health

Pesticides, methyl bromide, and the toxic gases released from burning plastic sheets and empty containers are potentially harmful to the physical environment and also to humans. Another impact of irrigation on human health is represented by water-related diseases such as dysentery and leishmaniasis (fly-borne disease). Table 8 shows the number of persons affected by water-related diseases in various districts of the West Bank.

These parameters take into consideration Palestinian practices. The activities of Israeli colonies also harm the Palestinian environment. The Israeli agricultural colonies in the West Bank are mostly concentrated in the areas with available water resources. About 92% of these colonies are concentrated in the Jordan Valley. Based on data provided by the Central Bureau of Statistics of Israel (1996), the aggregate of agricultural areas of Israeli colonies in the West Bank amounts to 2,730 ha, with total production of 42.750 tons, in addition to 69.3 million flowers produced in these colonies (Table 9).

The current use of agrichemicals in the Israeli colonies was estimated based on the area provided by the Central Bureau of Statistics of Israel (1996) and data published by Gabbay (1994). The estimated annual amount of agrichemicals used in the Israeli colonies is approximately 110 tons of pesticides and 45 tons of methyl bromide.

Table 8. Number of people affected by water-related diseases in districts of the West Bank.

Disease	Jordan Valley	Jenin	Nablus	Other Districts
Dysentery	0	12	0	2
Leishmaniasis	50	21	4	4
Total	50	33	4	6

Source: Palestinian Ministry of Heath (1995).

Table 9. Irrigated areas of various cropping patterns and their annual crop production in the Israeli colonies in the West Bank.

Cropping patterns	Area (ha)	Production (tons)
Field crops	270	2,673
Flowers	180	69.3[1]
Vegetable crops	690	21,011
Citrus	280	7,560

Other	1,310	11,501.8
Total	2,730	42,745.8

Source: Adapted from Central Bureau of Statistics of Israel (1996).
[1]In millions.

Conclusions

- The main springs used for irrigation are of suitable quality for all cropping patterns without any restriction. Slight to moderate restrictions are indicated with respect to the bicarbonate (HCO_3^-) content of the water.
- In the Jordan Valley, the quality of irrigation water from groundwater wells in the West Bank shows that there are slight to moderate restrictions on irrigation water use with respect to SAR and EC values, and severe restrictions with respect to HCO_3^- and Cl^-. In Jenin, Tulkarm, Qalqilya, Nablus, Ramallah, Bethlehem, and Hebron, there are slight to moderated restrictions on well water use for irrigation, with respect to HCO_3^-, and no restrictions on water use with respect to EC, Cl^-, and SAR values.
- Various practices (i.e., chemical fertilizer/pesticide use) in irrigated agriculture of the West Bank have not yet shown severe environmental degradation. As to water quality, there is no evidence for a direct effect of agrichemicals on groundwater resources of the study area. however, due to the current application rates of organic and inorganic, chemical fertilizers and pesticides, it seems only a matter of time before water quality, food quality, human/animal health, and soil properties may be adversely affected. The disposal of pesticide containers and spent plastic is a special problem that already has adverse effects. Meanwhile, the 5% irrigated portion of the total cultivated land in the West Bank in running out of water, which could vastly change cropping patterns, i.e., the use of crops with higher water-use efficiency.
- Agricultural practices in the Israeli agricultural colonies located in the West Bank could have a negative effect on the long-term sustainability of Palestinian land and water resources.

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