American Journal of Water Resources, 2018, Vol. 6, No. 5, 207-211
Available online at http://pubs.sciepub.com/ajwr/6/5/4

DOI:10.12691/ajwr-6-5-4

Water Management Practices Based on Crop Oriented Approach for Facing Water Scarcity in Palestine

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Received October 11, 2018; Revised November 15, 2018; Accepted December 04, 2018

Abstract The use of water for agricultural production in water scarcity regions requires innovative and sustainable research, and an appropriate transfer of technologies. This paper discuss some of these aspects, mainly relative to on-farm irrigation management including the use of water management practices that can enhance water efficiency, gaining an economic advantage from water unit. In some cases, the necessary knowledge has been provided against several crops and efficient water needs, helping farmers to adapt and implement viable solutions for water scarcity and profitability, thus gaining more benefits from irrigation management. Different scenarios were illustrated in this study to improve irrigation water productivity, water revenue and nutritional value of different strategic crops cultivated in open field (lentil, potato, wheat, olive and dates), and those cultivated under greenhouse conditions (tomatoes, cucumber, eggplants, green beans, sweet pepper). This study indicated that, when farmers use one cubic meter of water in producing different crops cultivated in open field, the higher productivity was indicated for potatoes and olive crops, while for the crops cultivated under greenhouse conditions, the higher productivity was gained for tomatoes then cucumber crops compared to the other investigated crops. Moreover, the highest nutrition revenue from protein by using one cubic meter of water was indicated for lentil and wheat crops comparing to the other investigated crops. Concerning the economic revenue, the highest revenue from one cubic meter of water for open field crops was gained from olive then dates crops, while for protected crops the highest revenue was gained from tomatoes then cucumber crops compared to the other investigated crops. This indicated several polices and scenarios for management of available water demand for facing water scarcity in Palestine. These scenarios aiming in maximizing water productivity, as well as, water profitability from the same unit of water, by selecting a suitable cropping patterns for optimizing crop water use efficiency, maximizing economic water productivity and improving nutritional water productivity. On this basis, more water-efficient management could combine wider productivity benefits with economic advantage for farmers.

Keywords: *water productivity, protected crops, field crops, nutrition revenue, economic revenue*

Cite This Article: Istaitih Y.H., and Rahil M.H., "Water Management Practices Based on Crop Oriented Approach for Facing Water Scarcity in Palestine." *American Journal of Water Resources*, vol. 6, no. 5 (2018): 207-211. doi: 10.12691/ajwr-6-5-4.

1. Introduction

Sound policies for food security and agricultural water management are critical for national economies particularly for dry land areas [1]. Water resources are already scarce, and millions of people throughout the world do not have enough water to sustain their livelihoods, so they have reduced capacity to lift themselves out of poverty [2,3,4]. The relationship between poverty and water is complex, but water is such a valuable resource that it must be managed responsibly, to ensure long term sustainability for future generations [5]. Water is essential for life, and an adequate water supply is a prerequisite for human and economic development [6]. It has been recognized that human behavior can impact both water, and global ecosystem, resulting in the need to regulate human behavior in order to stabilize and sustain our future [7].

Water security is closely link to sustainable development of human economic society and ecosystem. Rapidly increasing water consumption, worsening water pollution and excessive extraction of water resources due to competition of different sectors aggravated the water shortage problem and deteriorated water ecosystem around the world, threatening the development of social economy and human well-being [8]. Ever-diminishing water supply poses great risks to national security, economic development and social stability and adversely affect human health, energy reserve, and food supply across the global [9].

The Palestinian water resources are already scarce, the climate in Palestine is Mediterranean in its basic pattern, and varies from semi-arid in the west to extremely arid in the east and southeast. Palestine is a predominantly agricultural area with limited and scarce natural resources, especially the water. Groundwater is the main source of water for the Palestinians in the West Bank and Gaza Strip and provides more than 90% of all water supplies. The mean annual rainfall in the West Bank varies from about 700 mm in the western part to less than 100 mm in the east; the long-term annual average is about 450 mm [10].

Irrigated agriculture consumes around 93 MCM/year of water or 65% of the total water resources in the West Bank of Palestine [11]. Therefore, improving agriculture water productivity is an important measure for ensuring water safety and food security. That's leaded us thinking creatively in every drop of water and efficiently estimates the revenue from water unit to produce essential and economic food unit [12,13]. Irrigation water productivity (kg/m^3) from one cubic meter used in different crops, is a ratio between a unit of output and a unit of input [14,15,16]. Here, the term water productivity is used exclusively to denote the amount or value of product over volume or value of water depleted or diverted [17], where the value of the product might be expressed in different terms (biomass, grain, protein, calories and money). Therefore, how to reduce the irrigation water use while maintaining or even increasing agricultural production with available irrigation water is essential for improving water productivity.

Water productivity potential can be improved through three major pathways: 1) to select drought tolerant and water saving verities to improve yield production while reducing water consumption; 2) to adopt appropriate irrigation technologies and other management practices for achieving higher yield with low water use; 3) to improve water delivery efficiency, and coordinate water resource allocation at regional scale for higher use efficiency and lower water losses [18,19].

Accordingly and under these circumstances, Palestinian people started creating some methods to avoid continuous shortage of water in agriculture, like some methods of water management systems and some informal ways and behaviors, representing the suggestion policies about rainwater harvesting [20,21,22]. Water policies adaptation is now widely discussed within development planning as a means of reducing risks posed by resource scarcity, environmental change, and increasingly as the result of climate change, and limited resources available [23].

Water efficiency in agriculture has been extensively investigated for many years. Universally applicable solutions are however difficult to come by, particularly due to different contexts and high specificity of agricultural practices. Water use efficiency often possible through suitable crop selection, proper irrigation scheduling, effective irrigation techniques, and using alternative sources of water for irrigation [24,25,26]. It should be noted that increasing water efficiency often provides benefits that go far beyond reduced amount of water use.

The aim of this study was to manage the water demand by offering different options and scenarios for increasing the efficiency of available water quantities by practicing a suitable agricultural investment and diverse cropping patterns from the same unit of water. Different scenarios were illustrated in this study to investigate the water productivity, water revenue and nutritional value of the same unit of water using different strategic crops cultivated in open field (lentil, potato, wheat, olive and dates) and those cultivate under greenhouse conditions (tomatoes, cucumber, eggplants, green beans and sweet pepper). These scenarios focusing on the efficient use of one cubic meter of water for producing several crops according to our needs and strategies (weight, calories, protein, and price).

2. Methodology

The study methodology was depend on data collection from different farmers directly, where a questionnaire has been used for collecting essential technical and socio-economic data, consolidate water-related data, simulate current and future management, and allocation rules for water management approach as provided by farmers. Other technical data gathered from selected farmers (key farmers) from different benchmark sites in the West Bank.

Several crops cultivated in open field like (lentil, potato, wheat, olive and dates) and in greenhouse as (tomato, cucumber, eggplants, green beans and sweet pepper) were investigated for estimating water productivity, economic revenue, nutrition revenue from protein and calories. Two farmers were selected for each crop and every farmer cultivated five dunums as a unit under coordination of research team at Deir Abu Daef and Tammon villages as case study areas, which represent the northern part of Palestine.

Secondary data were collected from previous studies. These data sources, depends on literatures review from international and national publications, and the local data base from related institutions about most methods and innovations participating in water management development and some policies in dry areas. The analysis of these data was powerful technique for understanding our strengths and weaknesses points; suggesting different water scenarios, and applying some innovative water management policies in the dry areas.

3. Results and Discussion

3.1. Average Annual Water in Palestine

Results of this study indicated that, the average available water per capita in Palestine is very limited comparing to the other countries in the world as presented in Figure 1. This leads us to actual thinking about real solutions for improving our water resources more efficiently. Moreover, this results explaining the declining percentage of available water for agricultural purposes according time, as a result of declining water resources, climate change, and bad distribution of rainfall which is highly variable and unpredictable both spatially and temporally mainly in the dry areas of Palestine. This increase the risks and uncertainty involved in agricultural production. It is found that, it takes around 2000-3000 liters of water to produce enough food to satisfy one person's daily dietary needed. This is a considerable amount, when compared to the water amount required for drinking, which is estimated between two and five liters per capita per day [27].

Climate change models predicted that, west Asia and north Africa will become hotter and drier with changes in seasonal and spatial distribution of rainfall and increasing incidence and magnitude of extreme weather events (droughts and floods). Countries in the dry areas with predominantly rural economies and high dependence on agriculture will be at most risk, as they are highly vulnerable to shifts in seasonal climatic patterns and changes in hydrological cycles. The dry areas' share of the world's fresh water resources is very limited with many of the countries already below the water poverty line of 500 m^3 per capita per year. The current allocation of over 75% of available water for agriculture is decreasing with increased population and competition from the expanding domestic and industrial sectors [28].

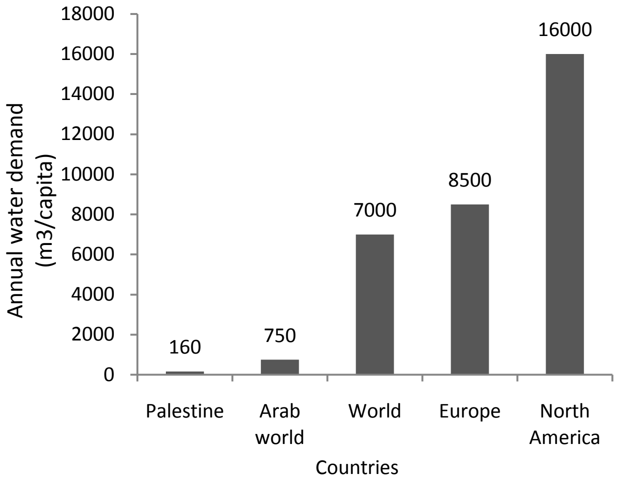

Figure 1. Average annual available water amongst different countries in the World

3.2. Water Productivity

Productivity is a ratio between a unit of output and a unit of input. Here, the term water productivity is used exclusively to denote the amount or value of product over volume of water applied to the crop. The value of the product might be expressed in different terms (biomass, grain, money). For example, the so-called 'crop per drop' approach focuses on the amount of product per unit of water. Another approach considers differences in the nutritional values of different crops, or the same quantity of one crop that feeds more people than the same quantity of another crop. When speaking on food security, it is important to account for such criteria [29]. Another concern is how to express the social benefit of agricultural water productivity.

All the options that have been suggested can be summarized by the phrases 'nutrient per drop', 'capita per drop', 'jobs per drop', and 'sustainable livelihoods per drop'. There is no unique definition of productivity and the value considered for the numerator might depend on the focus as well as the availability of data. However, water productivity defined as kilogram per drop is a useful concept when comparing the productivity of water in different parts of the same system and also when comparing the productivity of water (one m^3) in agriculture with different possible crops [28].

In this study, the water productivity of different crops cultivated in open field (lentil, potato, wheat, olive, dates) is presented in Figure 2. It is indicated that, when farmers use one cubic meter of water in producing different crops, the higher productivity was indicated for potato then olive crops comparing to the other investigated crops. This means if our production strategy looking for increasing the weight productivity from every cubic meter of water, farmers should invest in potatoes then olive production, if all other production factors are suitable. Figure 3 shows the water productivity of different crops cultivated under greenhouse conditions (tomato, cucumber, eggplants, green beans, sweet pepper). Results of this study indicated that, the higher water productivity was observed for tomatoes, then cucumber crops comparing to the other investigated crops.

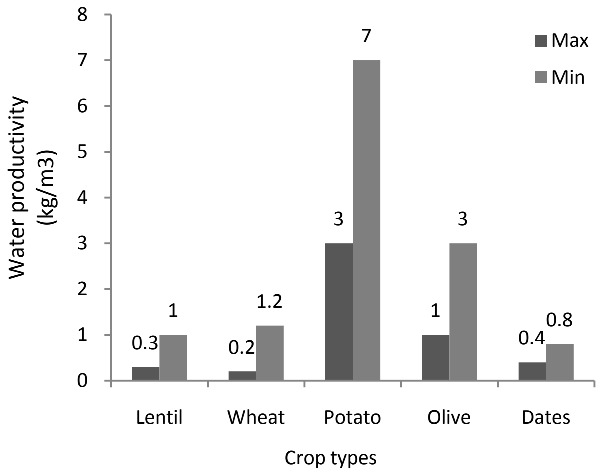

Figure 2. Water productivity of different crop cultivated in open field

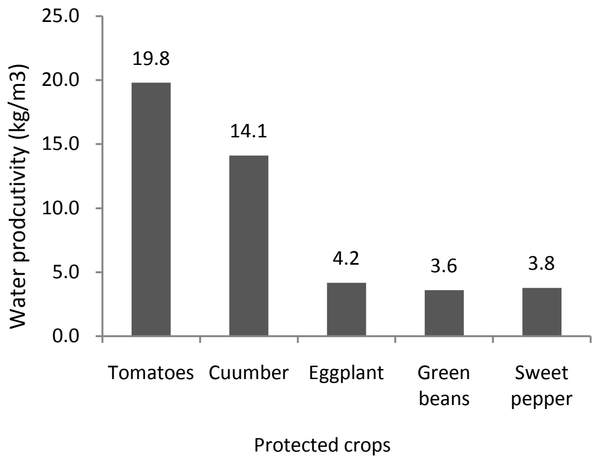

Figure 3. Water productivity of different crop cultivated in greenhouse

3.3. Economic Water Productivity

This study indicated that, when one cubic meter of water was used in producing different crops cultivated in open field, the highest revenue was gained in olive then dates crops as presented in Figure 4. In case of protected crops, the highest economic revenue was indicated in tomatoes then cucumber crops compared to the other field crops as shown in Figure 5. This means that, if our production strategy looking for increasing the revenue of every one cubic meter of water consumed, the farmers encouraging to invest in the cultivation of olive then dates cultivation in open field, and tomatoes and cucumber crops under greenhouse condition, if the other production factors like climate, labor, soil and others are suitable. Table 1 indicated that, even though, the cost of water for producing one dunum of protected tomatoes was very high comparing to the other crops, but it has high economic revenue, because of its highest productivity.

Table 1. Water cost of different crops cultivated under greenhouse

Crop type	Production (Kg/du)	Water requirements (m^3/du)	Water price (USA\$/m^3)	Water cost
Tomatoes	19600	990	0.60	594
Cucumber	8185	580	0.60	348
Eggplant	2800	670	0.60	402
Green beans	2300	640	0.60	384
Sweet pepper	3740	990	0.60	594

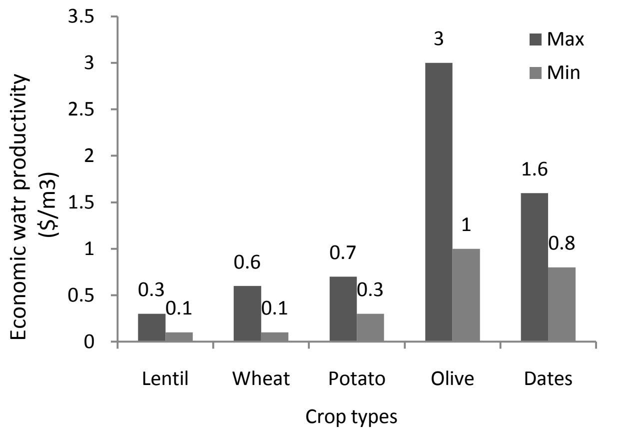

Figure 4. Economic water productivity of different crop cultivated in open field

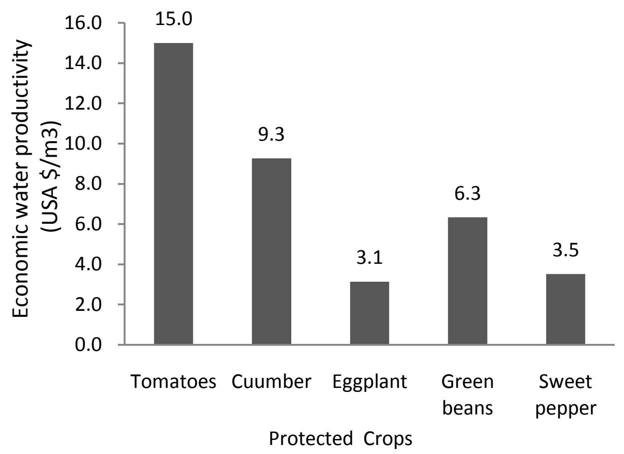

Figure 5. Economic water productivity of different crop cultivated in greenhouse

3.4. Water Productivity from Protein

Figure 6 shows that, the highest nutrition revenue from protein by using one cubic meter of water was observed from lentil and wheat crops comparing to the other investigated crops. This means if our production strategy looking for increasing the revenue from protein for every cubic meter of water, the suitable investment could be in lentil and wheat production, if the other production factors are constant, therefore, we can increase the productivity of protein from water unit, and leading to high efficiency of production, after installing all the other production factors.

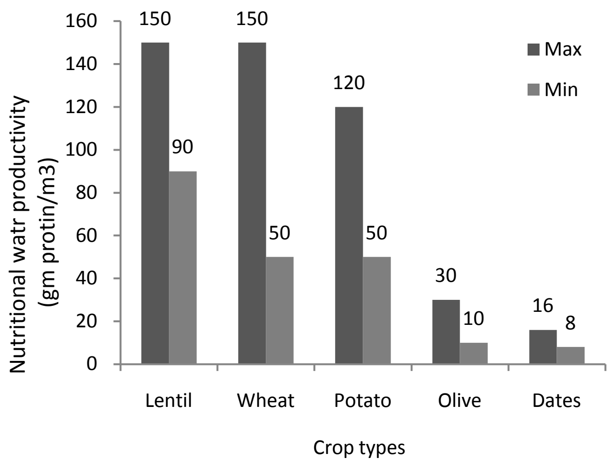

Figure 6. Nutrition-water productivity from protein of different crops

3.5. Water Productivity from Calories

Results of this study indicated that, the highest nutrition revenue from calories was observed in potato followed by wheat crops production, and low return revenue from calories in dates production as presented in Figure 7. This means if our production strategy looking for increasing the revenue from calories for every cubic meter of water consumed, the suitable investment in potato then wheat production, when the other production factors are constant. Therefore, we can increase the productivity of calories from unit water used, and leading to the high efficiency of production, after installing all the other factors.

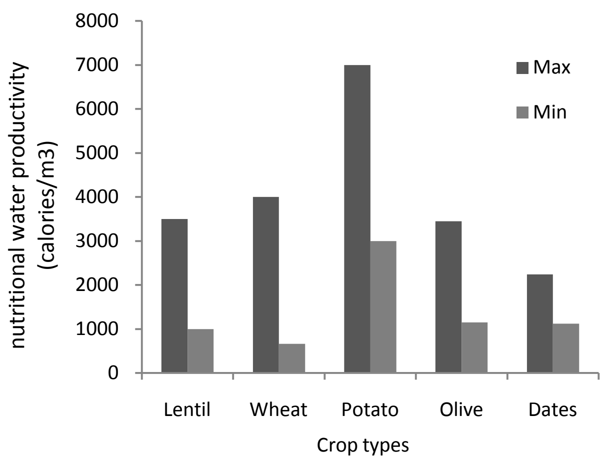

Figure 7. Nutrition-water productivity from calories of different crops

4. Conclusions

This study indicated several polices and scenarios for management of available water demand for facing water scarcity in Palestine. These scenarios aiming in maximizing water productivity, as well as, water profitability from the same unit of water, by selecting a suitable cropping patterns for optimizing crop water use efficiency, maximizing economic water profitability and improving nutritional water productivity.

Different cropping patterns in open field like (lentil, potato, wheat, olive and dates), and in greenhouse as (tomatoes, cucumber, eggplant, green beans and sweet pepper) were investigated in this study. In case of open field crops, the highest water and economic productivity was indicated for potatoes followed by olive crop. However, the nutrition water productivity of protein was indicated in lentils and wheat crops, while the water productivity of calories was observed in potatoes crop. In case of protected agriculture, the highest water productivity and economic revenue was gained in potatoes and cucumber crops.

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