# JORDAN WATER DEMAND MANAGEMENT STUDY

## Water Demand Management in Mediterranean Countries: Thinking Outside the Water Box!

## Jordan case study

## Water Valuation in Jordan Report

## Final Report

**Prepared for**
**French Agency of Development (AFD)**

**August 2011**

# Table of Contents

## List of Tables

## List of Figures

## List of Abbreviations

| | |
|---|---|
| CBJ | Central Bank of Jordan |
| DOS | Department of Statistics |
| GDP | Gross Domestic Product |
| GVA | Gross Value Added |
| IMF | International Monetary Fund |
| JVA | Jordan Valley Authority |
| KAC | King Abdulla Canal |
| KTD | King Talal Dam |
| LP | Linear Programming |
| MCM | Million Cubic Meter |
| MEMR | Ministry of Energy and Mineral Resources |
| MOA | Ministry of Agriculture |
| MoPIC | Ministry of Planning and International Cooperation |
| MW | Mega Watt |
| MWI | Ministry of Water and Irrigation |
| NGO | Non-Governmental Organization |
| NRW | Non Revenue Water |
| OS | Operation Surplus |
| RIM | Residual Imputation Method |
| UFW | Un-Accountant for Water |
| VA | Value Added |
| WAJ | Water Authority of Jordan |
| WIS | Water Information System |
| WWTP | Wastewater Treatment Plant |

# 1 Introduction

Water provides benefits as a commodity for agriculture, industry, and households--and as a public good for scenic values, waste assimilation, wildlife habitats, and recreational use. However, even as the nature and needs of economies change, water continues to be allocated to other than high priority uses, water quality continues to decline, environmental uses get inadequate attention, and floods and droughts take an unnecessarily severe toll. One reason for this is that price signals that reflect scarcities of goods and thereby guide investments and resource allocation in the private sector are usually distorted or absent in decision-making relating to water

Young (2005) provide the most comprehensive exposition to-date of the application of nonmarket economic valuation methods to proposed water resources investments and policies. He provides a conceptual framework for valuation of both commodity and public good uses of water, addressing valuation techniques appropriate to measuring public benefits--including water quality improvement, recreation and wildlife habitat enhancement, and flood risk reduction. However, we will emphasis on the commodity uses of water by agriculture, industries, and households.

Water is being essential for life and for numerous human activities and industries, water provides a range of ecological life-support systems that are often difficult to value. The economics of water involves understanding its scarcity and its value, as well as human needs, and ensuring that the costs and benefits of choices are clear and that the impacts of alternative pricing schedules are determined

Insight into the value of water is essential to support policy decision making about investments in the water sector, efficient allocation of water and water pricing. However, information on irrigation water values at small-scale schemes is scarce and in general little attention is paid to the determinants of these values.

The choice of appropriate pricing levels, the design of efficient allocation systems, the removal of subsidies that cause high financial costs and adverse environmental impacts, the implementation of new irrigation projects and the estimation of opportunity costs to industrial and domestic water uses are some of the reasons that justify the necessity for the valuation of irrigation water.

Appropriate water resource allocation in water depressed and scare dry land area is very important for farm management. Although very few systems for water distribution have efficient pricing, water resources should be allocated so that the marginal cost equals the marginal value product of water for all uses and users. When the marginal values are not equal, it is always possible to find a reallocation of water that increases net social benefits. Microeconomic techniques used for estimating the value of water and determining farmers' willingness to pay include: net-back analysis, hedonic models, and optimization models

Rational decision making about water management issues requires reliable estimates of the economic value of water (Hellegers & Perry, 2006; Hussain et al., 2007). Knowledge of this value is necessary when, for instance, making investment decisions concerning water resources development, policy decisions on sustainable water use and water allocations, or when the socio-economic impacts of water management decisions must be determined (Hussain et al., 2007). Specifically for the agricultural sector, this knowledge is important to design fair, informed and rational pricing systems, providing incentives to irrigators to use water rationally and efficiently and allowing recovering operation and maintenance costs (Lange, 2007; Perret & Geyser, 2007).

The main objective of this part was to set value of water by suggest appropriate methodology to evaluate the economic value of water. The methodology involved the use of agricultural sector models incorporating water as a scarce input. Therefore, the objective was to estimate the marginal value product of irrigation water derived from residual imputation approach from crop budgets and to measure the efficiency of water use on farms.

In Jordan, irrigation in agriculture is seen as an important rural development factor, creating employment opportunities, generating income and enhancing food security. Therefore, huge investments are made in the sector, construction of new irrigation project, dams and rehabilitating existing irrigation system. On the other hand, the growing water scarcity causes increasing pressure on farmers to allocate water more efficiently. Moreover, to formulate a new water policy, water subsidies currently received by farmers shall be gradually decrease and become negative, i.e. in the near future farmers will have to pay for the water they use. In this context, knowledge about water values can contribute to the objective of improving efficiency through better water allocation at the farm level, but is also crucial when water pricing policies that do not undermine the role of small-scale irrigation are to be designed.

In addition, knowledge about irrigation water values can provide indications about the soundness of the large government investments in the sector. In an attempt to contribute significantly to this knowledge, this study applies the residual imputation approach to provide estimates of the water values at crop, farm and regional level.

## 2 Background

Jordan is considered among low-middle income countries, within the Middle East Region, with an average per capita GDP of about JD 2,979 in 2009, and its population reached 6.1 million inhabitants in 2010 [DOS,2010]. It suffers from a chronic lack of adequate supplies of natural resources including fresh water, crude oil and other commercial minerals. Thus, Jordan depends heavily on imports of crude oil, refined products and natural gas from neighboring Arab countries as main sources of energy

## 2.1 Jordan’s Economy: Overview

Jordan's economy is among the smallest in the Middle East, with limited water, oil, and other natural resources, underlying the government's heavy reliance on foreign assistance. Other economic challenges for the government include chronic high rates of poverty, unemployment, inflation, and a large budget deficit. Since assuming the throne in 1999, King Abdullah has implemented significant economic reforms, such as opening the trade regime, privatizing state-owned companies, and eliminating most fuel subsidies, which in the past few years have spurred economic growth by attracting foreign investment and creating some jobs. The global economic slowdown, however, has depressed Jordan's GDP growth and foreign assistance to the government in 2009 plummeted, hampering the government's efforts to reign in the large budget deficit.

Jordan has a service-based economy with a moderate Gross Domestic Product (GDP) per capita of 2,979 JD in 2009, which increased from 1,333 JD in 2002. The services sector account for over 70 percent of GDP and more than 75 percent of jobs. Since the late 1990s Jordan has undertaken broad economic reforms in a long-term effort to improve living standards. Since Jordan's graduation from its most recent International Monetary Fund (IMF) program in 2002, Jordan has continued to follow IMF guidelines, practicing careful monetary policy, making substantial headway with privatization, and opening trade. Jordan's exports have significantly increased under the free trade accord with the US, which allowing Jordan to export goods duty free to the US. Jordan’s economic relationship with the US also extends to its currency, the dinar, which is pegged to the US dollar at $1.41 per dinar (DOS, 2010, and World Bank 2010).

Recently, Jordan used privatization proceeds to significantly reduce its debt-to-GDP ratio. These measures have helped improve productivity and have made Jordan more attractive for foreign investment. The government ended subsidies for petroleum and other consumer goods in 2008 in an effort to control the budget. The main economic challenges facing Jordan are reducing dependence on foreign grants, reducing the budget deficit, attracting investments, and creating jobs (CIA World Fact Book, 2010).

The Kingdom consistently invests more than 25 percent of GDP on human development including education, health, pensions, and social safety nets. The investments in education are important for a resource-poor, yet demographically young country to develop a competitive knowledge-based economy (World Bank 2010).

## 2.2 Industrial Sector in Jordan

Industry plays a key role in the process of modernization and economic development as it provides the framework within which national resources and factors of production are utilized, know-how acquired, technology transferred and new skills developed. It links all the economic activities of society together and interacts with all sections in meaningful ways. Industry is one of the key contributors to economic growth and main generators of national income in Jordan. Some 17.7 per cent of Jordan's GDP in 2009 or JD 3.12 billion was contributed by the relatively fast-growing industrial sector (CBJ, 2010). More importantly, industry contributes about 83 per cent of the total value of national exports, a very significant and welcome phenomenon for a country keen to establish itself in world markets.

Jordanian industry has also developed a significant degree of diversity. The Amman Chamber of Industry classifies its associated range of productive activities into 10 sub-sectors. These include several traditional sectors, such as the mining of national resources (potash and phosphate), and a number of new ones, such as engineering and manufacturing industries that provide products to meet consumer needs and other requirements, both local and export. The total value of national exports reached about JD 3.58 billion in 2009 of which JD 2.97 billion was made up of industrial products (CBJ, 2010).

Industrial water use includes water used to manufacture products such as steel, chemical, and paper, as well as water used in petroleum and metals refining. Industrial water use includes water used as process and production water, boiler feed, air conditioning, cooling, sanitation, washing, transport of materials, and steam generation for internal use

Industrial water-use activities include water withdrawal from ground and surface water; deliveries from public water suppliers. Large industrial water users are more likely to obtain water directly from private wells and may supplement this with water purchased from public water suppliers. Small industries, especially in cities, are more likely to obtain water from public water suppliers. Even if water is purchased from a public water supplier, the water may be treated by the industry before use, especially if pure water is required, as in boiler feed.

## 2.3 Agricultural Sector in Jordan

The agriculture sector is a major consumer of water, and the returns to water from crop production tend to be low in comparison to other sectors. Below is a summary of the importance of the agricultural sector to the Jordanian economy.

Jordan’s economy has continued to perform well over the last five years. The GDP growth at market prices reached 10% in the years 2009. The main contributing sectors were services, manufacturing and producers of government services. The percentage share of agriculture in Jordan's gross domestic product (GDP) has stagnated around 2.5 during the last three years. The annual growth rate of agricultural GDP was fluctuating during the last decade.

The importance of the agricultural sector stems from the fact that it is the major source of food items especially fruits and vegetables and also one of the sources of hard currencies originated from exports. In addition, the agro-industrial sector is characterized by a large number of small enterprises.

Despite its low contribution of 2.5% in the GDP, agricultural exports represent about 9% of Jordan's total exports of which fruit, vegetables and nuts represented 67%. The main destinations of most of these exports are United Arab Emirates, Kuwait, Bahrain, Syria, Lebanon, Qatar and Oman. In contrast to the sophisticated markets in the EU, these destinations do not have high quality and packaging requirements. In the last two years vegetable and fruit exports have jumped and that together they represent almost 70 percent of total agricultural exports. This indicates that there is a high potential for increasing horticultural exports. This potential can be realized in the future depends on tackling major obstacles related to water quantity and quality. Expanding horticultural exports require the availability of additional water resources of high quality to meet sanitary requirements such as the EuropGap and SPS regulations.

Jordan is one of the leading countries of the region in horticultural exports to traditional Arabian Gulf countries and to some EU countries. Total exports amounted to JD 3,579 million whereas agricultural exports amounted to JD 574 million (16% of total exports). The value of vegetable exports amounted to JD 280 million (48.7% of total agricultural exports or 8% of total export) in 2009 (CBJ, 2010). However, Total volume of horticultural exports amounted to a record figure in 2009 which is 816 thousand tons of which 741 thousand tons are vegetables and 60 thousand tons fruits (DOS, 2011). While the total volume of exports in 2006 was 578 thousand tons of which 538 thousand tons were vegetables (DOS,2011). Total agricultural production of vegetables in 2009 amounted to 1,508 thousand tons. While the production of fruits amounted to 419 thousand tons of which one third is olive. In other words, the vegetable exports in 2009 represented one half of Jordan production of vegetables. While fruits exports constituted only 10 percent of the national production of fruits.

The vast majority of irrigated agricultural production is in the form of fresh fruits and vegetables. As indicated in Table 1 more that ninety percent of the irrigated areas in Jordan is under fruits and vegetables. Therefore the analysis will focus the status of the competitiveness of fresh vegetables.

**Table 1: Irrigated and non-irrigated areas under tree crops, field crops and vegetables in 2009**

| Crops | Total Area (Dunum) | Irrigated Area (Dunum) | Nob-Irrigated Area (Dunum) |
|---|---|---|---|
| Tree Crops | 822,562.9 | 442,681.3 | 379,881.6 |
| Field Crops | 1,007,550.2 | 116,834.3 | 890,715.9 |
| Vegetables | 411,794.2 | 388,679.8 | 23,114.4 |
| Total | 2,241,907 | 948,195 | 1,293,712 |

*Source DOS, 2010. Annual Agricultural Statistics.*

Volume of irrigation water used in the production of the export crops and the value added there for the period (1994-2002) averaged 74 mcm and JD 0.35 $m^{-3}$, respectively (Haddadin, 2006) Jordan's commodity exports in 2000 earned JD 1,080 million of which agricultural exports accounted for JD 116 million or 10.7% of the total. Vegetables' export value amounted to JD 59 million or 50% of total agricultural exports value in 2000. The picture soon accelerated thereafter, Jordan's commodity exports in 2010 earned JD 4,214 million of which agricultural exports accounted for JD 614 million or 14.5% of the total. Vegetables' export value amounted to JD 323 million (52% of total agricultural exports value) or 7.7% of total national export in 2010.

Total volume of horticultural exports peaked in 2009 at $816 \times 10^3$ tons of which $740 \times 10^3$ tons were vegetables and $64 \times 10^3$ tons were fruits, up from $399 \times 10^3$ tons in 2000 of which $353 \times 10^3$ tons were vegetables and the balance was in fruits.

Vegetable exports in 2009 accounted about one half of total vegetable production of the country (1,508 $\times 10^3$ ton) while fruit export accounted for about 15% of the country's fruit production (419 thousand ton).

Furthermore, previous studies on the competitiveness of agricultural production and production trends have shown that Jordan enjoys strong comparative advantage in the production of almost all types of vegetable crops and selected tree crops. The calculated comparative advantage indicators in the form of domestic resource coefficients showed a strong comparative advantage for seedless table grapes, green beans and strawberries that are mainly produced during the winter season in the Jordan Valley (Jabarin, 2000). In contrast, some other studies concluded that Jordan lacks a comparative advantage in production field crops such as irrigated wheat and barley, in comparison with neighbors like Syria (Jabarin and El-Habbab 1996).

## 2.4 Domestic Water Sector

The Water Authority of Jordan (WAJ) is the responsible organization to provide the water and wastewater services in Jordan. In order to ensure service sustainability, the cost of service should be recovered through tariffs. However, WAJ is not able to cover all the costs through tariffs and is still receiving subsidy from the treasury and the donor funding agencies for their capital investment projects. There are several factors that affect the cost recovery of WAJ:

- The rapid population increase and the unplanned growth due to several refugee waves in the nineties; contributed in increasing the costs of supplying water since the sudden waves of refugees and displaced persons left practically no time for any organized population settlements planning and they all settled in or nearby the urban areas that are distant from sources of water.
- The capital costs of developing new water projects, which require massive conveyance systems far away from populated areas in Amman and Zarqa such as the Disi Amman water conveyor project with estimated costs ranged between 0.75 to 0.9 JD per m3.
- High operation and maintenance costs of water and wastewater projects which are electricity intensive and require pumping and treatment;
- High capital investment in state-of-the-art technologies for wastewater treatment in many parts of Jordan;
- Inefficient operations of the water utilities including staffing levels, Unaccounted for Water, and low collection rates; and
- Low water tariffs that do not target cost recovery of the services.

In recent years the government of Jordan has implemented several measures to increase the cost recovery of WAJ and enhance its financial sustainability that include increasing the water and wastewater tariff, reduce water losses and relative improvement of performance. Even thought, the revenues do not cover the full of services but only cover the O&M cost and small part of the capital cost. The average return received from the direct water and wastewater tariff per cubic meter for water billed is JD 0.42 and for billed wastewater is JD 0.16. The overall all return including the other revenues per cubic meter for billed water is JD 0.6 and for billed wastewater is JD 0.42.

The current level of costs and revenues resulted in covering only 110% of the O&M cost and 65% of the full cost recovery. In fact, WAJ achieved better levels of cost recovery during 2004-2006, which then dropped due to the high inflation rates in 2007-2009, the additional cost accrued by the new As-Samra wastewater treatment plant, introducing new expensive water supply source (mainly Zara Ma'in water desalination plant) and limited performance improvement. The historical cost recovery levels are presented in Figure 1.

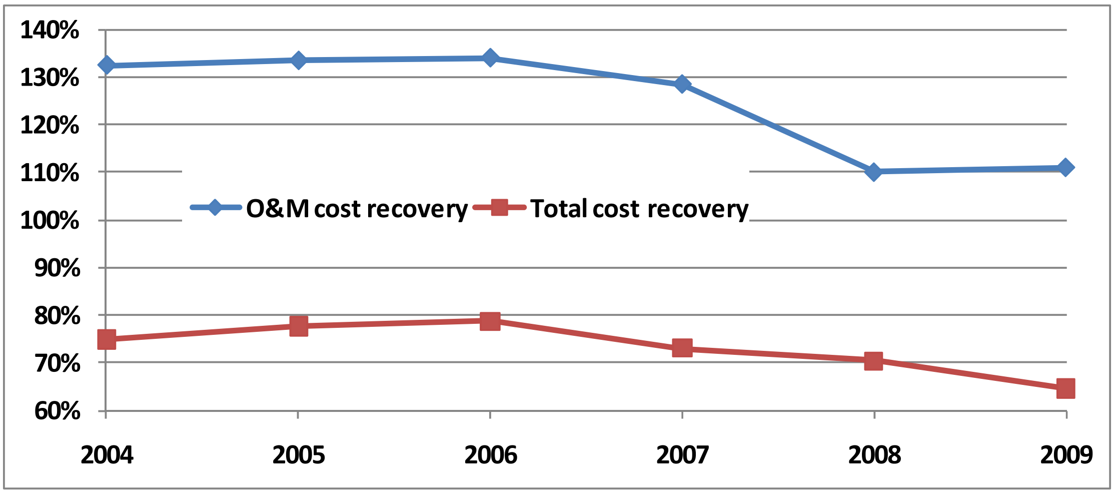



**Figure 1: Historical O&M and full cost recovery levels of WAJ**

## 2.5 Impact of Economic Growth on Water Sector

Economic growth is a general rise in a nation's Gross Domestic Product. A positive growth typically implies greater economic activities and productions and, thereby greater use of different inputs including water. Economic growth creates severe competition among the various components of an economy for water resources. In other words, there appears to be an intuitive positive correlation between economic growth and water consumption, with industry, agriculture and households all vying for a larger share of a depleting resource. Some evidences are provided in Section 3 where the impact of the economic growth and income level on water consumption is investigated. Moreover it was asserted that prudent management of the resource was the only way to make economic growth coincide with existing water limitations.

# 3 Methodology of Valuations

In an economic system most goods are allocated according to its highest value use. In other words, those who are willing to pay the most for it should have first claim to its use. While one price may exist for water (be it the cost of the last unit supplied to a region or an administered price) there is no reason to believe that all users of that water value it to the same degree, or think of it as being of infinite value. In theory water managers could achieve a better allocation of water, one that improves social net welfare, if they know the value of water by use, region and season as they can distribute water in a manner that society values it or at the very least calculate the foregone benefits of allocating water in some less optimal manner (Hellegers and Davidson, 2010). Young (2005) and Turner et al. (2004) have undertaken comprehensive reviews of the methods employed to calculate the value of water to various users. While both these studies highlight the limitations of the residual method, they emphasize the fact that the approach goes some way towards solving the problems regarding complexity and a lack of data

The value producers place on water can be thought of as being derived from what they use it for. Given that a variety of crops are produced over a wide area and at different times, determining a single value for such a complex production process is a difficult task. In addition there is often a lack of data to make definitive estimates and crop prices vary over time (Turner et al., 2004).

Neoclassical economic theory predicts that, in a competitive market, the economic value of a good corresponds to its market price, which reflects individuals' willingness to pay for that good. For water, however, due to the limited role played by markets, valuation techniques must be used. Several methods for estimating the value of water have been developed. They can be grouped according to whether they rely on observed market behavior and data to infer economic value (indirect techniques), or alternatively use survey methods to obtain valuation information directly from water users (direct techniques) (Turner et al., 2004). A detailed discussion of water valuation methods can be found in Young (2005) and more recently in Lange & Hassan (2007).

In general, the most scientifically accepted methods are those based on actual market behavior and information (Hussain et al., 2007). In the case of Jordan, since farmers in the Jordan Valley are paying for water a neglected portion of production costs, it is difficult to establish a relationship between price and demand from actual behavior to generate demand functions. Moreover, because water is provided by the government with heavy subsidy, strategic biases or simply the belief among farmers that water is a free gift from God (Abu-Zeid, 2001), could probably lead to erroneous estimations of water values when using direct methods such as contingent valuation (salman et a. Wasike & Hanley, 1998). Therefore, following Lange (2007), Speelman, et al., 2008), the Residual Imputation Method (RIM) was used in this study. Although this method clearly has its shortcomings, which are discussed in the next section, it was considered the most suitable technique to estimate water values for the studied irrigation schemes.

Therefore, this we will describe and analyze some of the existing methods of estimating the value of water in inter-sectoral economic activities. Agudelo (2001) categorized water valuation methods into three

1. Methods that infer value from information regarding markets of water and water-related benefits
2. Methods that estimate values from the derived demand for water, where water is used as an intermediate good, and
3. Methods that estimate the value of water from a direct consumer demand, as in the case where water is used as a final good.

As a market good, value is derived from rentals and sales of water rights or land in case of a riparian ownership of water. As an intermediate good, value is derived from the producers' demand function, residual imputation, value added or alternative costs of water use. If used as a final private good, the value of water is determined from the consumers' demand function. If water is used as a public final good, its value is derived from the embedded travel costs or as bundle of other goods in a hedonic property value or the use of contingent valuation method to determine the value consumers place on the its use (Agudelo 2001). This study focuses on the use of water as an intermediate good, used as an input in the production of other goods and services. It also attempts to analyze the benefits of inter-sectoral water use in a country where water markets are ill-defined and prices are distorted, because of government intervention or because of the absence of completely defined user rights.

When used as an intermediate good, the value of water must be assessed from the producers' point of view. The conceptual valuation framework for the welfare benefits of increases or decreases in water use is provided by the producers' demand for inputs, including water. The following valuation methods are among the many that could be used to assess the value of water as an intermediate input in an ill-defined or dysfunctional water market Discussion on each of these methods are presented in the Appendix. These methods are:

I. Estimating the Producers Water Demand Function,
II. The Production Function Approach
III. Optimization methods using mathematical programming
IV. The Residual Imputation Method,
V. The Value Added Method and
VI. Financial and Economic Returns

## 3.1 Methodology of Valuation of Water Used in Domestic Sector

This part describes the basic concepts behind the determination of the economic value of water for domestic water. The benefits associated with the provision of improved domestic water supplies include direct benefits to the water users and indirect benefits to all of society. Indirect benefits are derived from the knowledge that a community that once did not have adequate water supplies and as a result suffered some type of hardship does not have to suffer that hardship with the project. Direct benefits to water users are easily identified but may be difficult to measure accurately. Indirect benefits are very difficult to identify and measure because they do not accrue to the water users themselves

A variety of approaches can be used to estimate the value of water for municipal and industrial water supply benefits. These approaches are described in Appendix I: Methodology of Valuation of Water Used in Domestic Sector. Each of these approaches to estimating the value of water has advantages and disadvantages that influence which method is most appropriate for a particular situation. The following section is explaining the applied approach.

### 3.1.1 Adopted Methodology – Value in Use

Water value is estimated through the value in use of water which consists of two components: The use values, which is known as the economic values or (extrinsic values and direct use values), and from non-use values, which is called intrinsic values, passive use values, or existence values). Use values come mainly from the use of water in the different sectors such as agriculture, industry, hydropower, navigation and households. Non-use values come mainly from not using water through aesthetics, culture, religion, geomorphology and nature (Agudelo, 2001). The intrinsic values are hard to estimate and thereby will not be evaluated nor discussed further.

The general principle of the value in use of water is illustrated in Figure 2. The value in use of water is the sum of the economic and intrinsic values. As shown in the figure, the components of economic value are: value to users of water, net benefits from return flows, net benefits from indirect use, and adjustments for societal objectives. In this study and due to data and scope limitation, the value to users of water is the only component that will be estimated (Rogers, 1998).

One of the common ways to estimate the value to users of water is the willingness to pay for water, which represents a lower bound on water value, as there is additional value to the water. In this approach, the economic value is a measure of the maximum amount an individual is willing to forego in other goods and services in order to obtain some commodity, service, or state of the world. The trade-offs people make when they choose less of one and more of some other commodity reveal something about the values people place on these goods. The money price of market goods is simply a particular case of a trade-off ratio, because the money given to purchase one unit of one element of the package is a proxy for the quantities of one or more of the other elements in the package that had to be reduced in order to make the purchase. The value measures based on substitutability can be expressed either in terms of someone's willingness to pay (WTP) for beneficial changes (Agudelo, 2001).

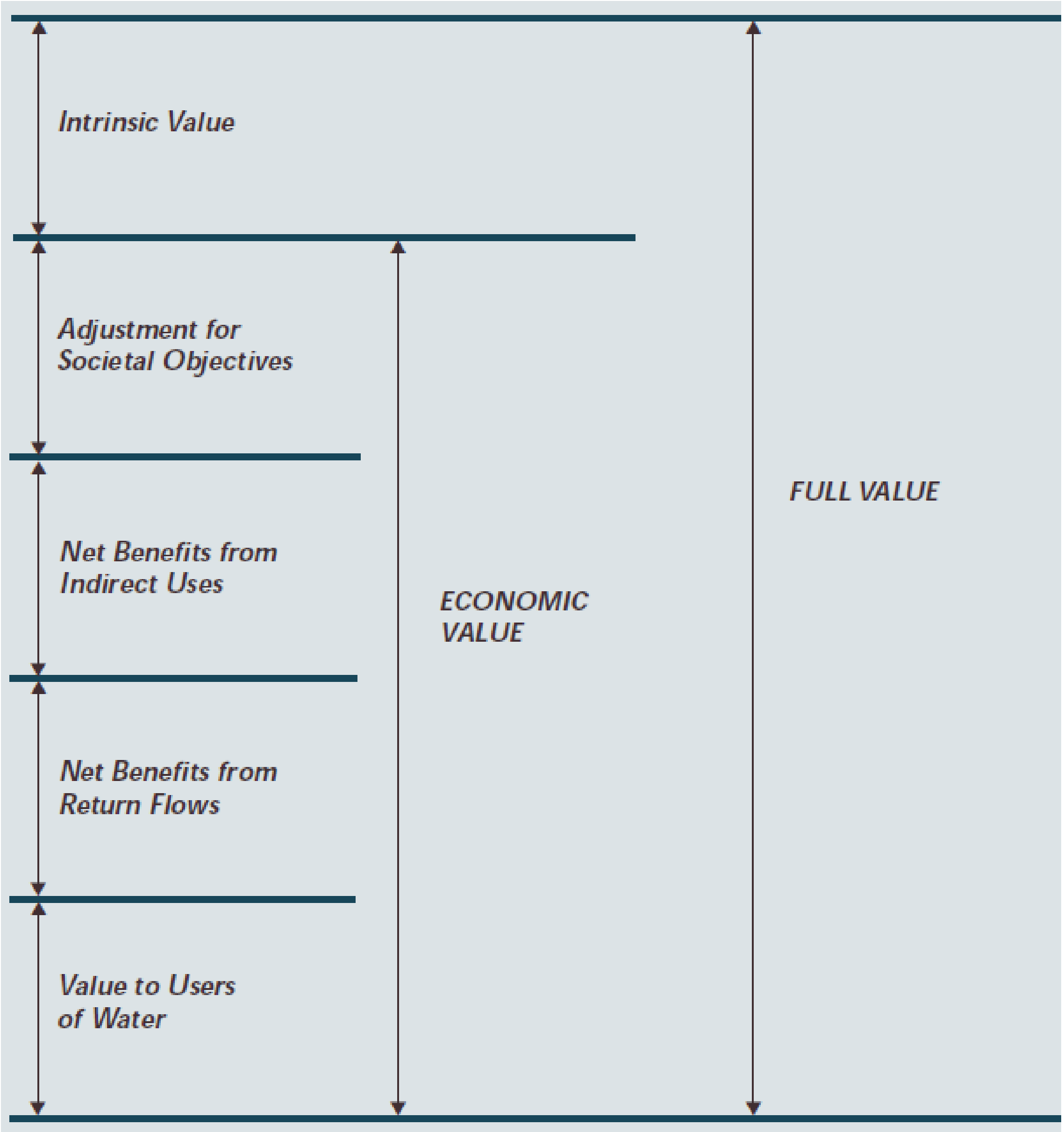



**Figure 2: General principles for value in use of water (Rogers, 1998)**

The WTP is defined by Littlefair (1998) as an economic concept which aims to determine the amount of money a consumer will pay for the supply of water. The WTP is normally measured through conducting surveys to measure the customers' WTP for specific product. Since there is neither appropriate survey nor assessment of the WTP by the domestic customers in Jordan, an alternative approach should be used.

From the definition of the WTP, the actual cost of water paid directly and indirectly by the water user would be close to the amount that the water user is willing to pay. Therefore, the cost of water on users can be used to express the value of the WTP although both are not equal. The cost of water has different components which are illustrated in Figure 3. Estimating the full supply cost and the opportunity cost components is relatively easy as the data is available and the approach is straightforward to measure, while estimating the other components requires using complex approaches and many unavailable data sets. The data of the cost of supply through public network in Jordan is available. These data are published in the income statements issued by WAJ for itself and its subsidiaries; Miyahuna Company, Yarmouk Water Company and Aqaba Water.

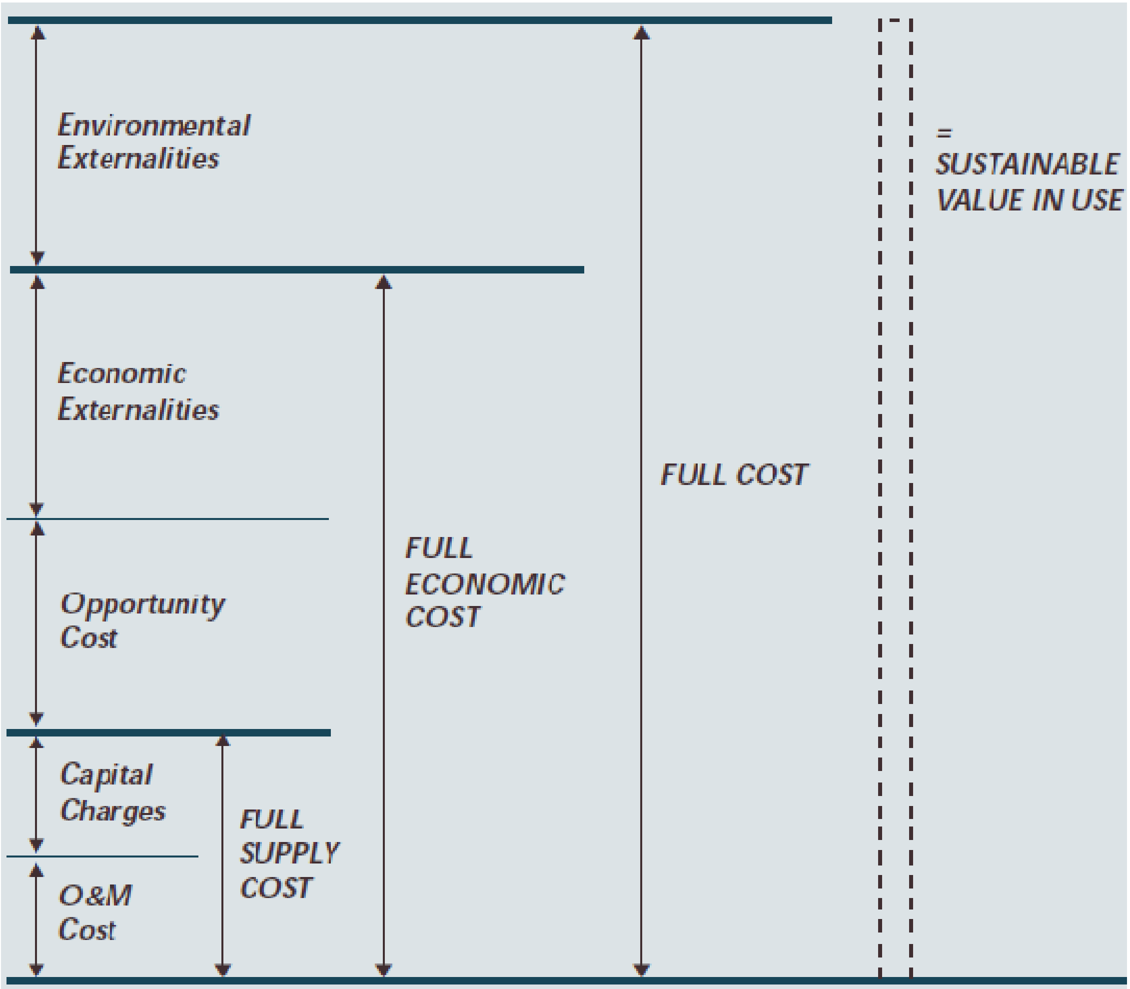



**Figure 3: General principles for cost of water (Rogers, 1998)**

***The Full Supply Cost*** includes the costs associated with the supply of water to a consumer without consideration neither of the externalities imposed upon others nor of the alternate uses of the water. Full Supply Costs are composed of two separate items: Operation and Maintenance (O&M) Cost, and Capital Charges (Capital Cost), both of which should be evaluated at the full economic cost of inputs.

***O&M COST:*** These costs are associated with the daily running of the supply system. Typical costs include purchased raw water, electricity for pumping, labor, repair materials, and input cost for managing and operating storage, distribution, and treatment plants. In practice, there is typically little dispute as to what are considered O&M Costs and how they are to be measured.

***Capital Cost:*** These should include capital consumption (depreciation charges) and interest costs associated with reservoirs, treatment plants, conveyance and distribution systems. There is some disagreement about the calculation of Capital Cost. Older methods use a backward accounting stance and look for the costs associated with repaying the historical stream of investments.

***The opportunity cost*** addresses the fact that by consuming water, the user is depriving another user of the water. If that other user has a positive value for the water, then there are some opportunity costs experienced by society due to this misallocation of resources. The opportunity cost of water is zero only when there is no alternative use – that is no shortage of water. Ignoring the opportunity cost undervalues water, leads to failures to invest, and causes serious misallocations of the resource between users. The opportunity cost concept also applies to issues of environmental quality, which are discussed further in the paper. In Jordan, there are different alternative sources of obtaining drinking water by the domestic users other than the public water network such as water tankers, water treatment shops and bottled water. Many users are willing to pay more to get water from these resources as alternative source when water supply quantity is not sufficient and/or when the water quality is not satisfactory.

As a summary the economic value of domestic water can be evaluated using the following equation

$$EV_{Do} = FC + OC + EcX + EnX + NBRF + NBIU + ASO \qquad \textbf{Equation 1}$$

Where $EV_{Do}$ is he Economic value of domestic water, FC is the full cost of water supply, EcX is the economic externalities cost, EnX is the environmental externalities cost, NBRF is the net benefits from return flows, NBIU is the net benefits from indirect uses and ASO is the adjustment for societal objectives. All those are measured in JD/m$^3$. The last five terms in the above equation will not be evaluated in this study and the opportunity cost can be estimated using the following equation:

$$OC = WC_{non-public\ water} - WC_{Public\ water} \qquad \textbf{Equation 2}$$

Where $WC_{\text{non-public water}}$ is the water cost of the cheapest water source on domestic water consumers other than pubic water network and $WC_{\text{Public water}}$ is the cost of public water network on domestic water consumers. Using Equation 1 with eliminating the last five terms and Equation 2, the economic value of domestic water can be estimated using the Equation 3:

$$EV_{Do} = FC + WC_{non-public\ water} - WC_{Public\ water}$$ **Equation 3**

## 3.2 Methodology of Valuation of Water Used in Industry

A variety of approaches can be used to estimate the value of water in industry. These approaches are further explained in Appendix II. Mainly these methods are: Estimating the Water Demand Function, Production function approach, Optimization using mathematical programming approach, Residual imputation methods, Financial & Economic Returns. Each of them has its own context of applicability, which depends largely on the nature of the data available for performing the valuation exercise.

The Residual Imputation Method (RIM) based on the Gross Value Added technique (GVA) will be extensively applied in this study. The GVA estimates will be compiled through product approach. Accordingly gross output/gross sale of product plus other income will be been taken as gross output on basic prices. Intermediate consumption (purchaser prices) will be deducted from gross output to arrive at gross value added at basic prices.

We measure the economic contribution of water to industry according to a "value-added" concept using RIM methods. This contribution is assessed as the monetary value of industrial production that is attained per unit of water used or consumed throughout the production process.

## 3.3 Methodology of Valuation of Water Used in Agriculture

The economic approach to decide about the most desirable allocation of water is to use the principles of economic efficiency to ensure that water is supplied to its most valuable uses. Therefore, it is necessary to have theoretically sound estimates of the economic value of water in its different uses. The same economic principles can be used within this sector to guarantee that water is efficiently allocated among the different crops, looking at each crop as one individual water user for that purpose.

A variety of approaches can be used to estimate the value of water in agriculture. These approaches are further explained in Appendix II: Methodology of Valuation of Water Used in Agriculture and Industry, since these approaches can be used for both industry and agriculture and any other water consuming activities used water as intermediate input.

Given the analyses of the five main methods used to estimate the economic value of water, the Residual Imputation Method (RIM) and the value added approaches will be extensively applied in this study. However, Optimization using Mathematical programming was applied too in this study by attempting to present a practical approach to manage and optimize the irrigation water use in the JV region. The ultimate objective is to minimize the outside water and to manage the irrigation water use under geographic, socio-economic, and demographic constraints. This approach uses the added value of one cubic meter of water concept in evaluating different irrigation water use management. This case study which targets the Jordan Valley shows that water scarcity can be incorporated in irrigation water management by proper choice of crops and farming patters. The objective function is to maximize the net revenue from the agricultural production process subjected to limitation on water and other production and marketing factors. Results of analysis showed that net water saving of about 9% occurred if the objective function is to minimize water use under the same level of profitability. Sometimes virtual water is widely exported in form of crops that consumes large amounts of water without full economic consideration to the added value of water. In some cases, food imports may be a feasible option in water-poor countries instead of water export in a form of water embodied in exported agricultural commodities.

This study will used the water allocation model developed by Salman et, al., 2000 , where they introduced a linear programming optimization model for analyzing inter- seasonal allocation of irrigation water in quantities and qualities and their impact on agricultural production and income in the Jordan Valley. The SAWAS model is a developed version of agricultural Sub-Model (AGSM). In that paper, water scarcity was streesed on as a problem that arises when water is not available in proper quantity and quality at the appropriate place and time. The model is designed to serve as a decision making tool for planners of agricultural production in both district and regional level. It generates an optimal mix of water demanding activities that maximizes the net agricultural income of the districts and gives the water demand under various places. It also provides the planner with tools to carry the “what if” experiments and to generate optimal water demand curves. A principal feature of SAWAS is the use of demand and the benefits from water together with costs and optimization within the agricultural sector to specify the optimal usage of different water qualities. Hence the agricultural planner can use the output of SAWAS in order to bridge the gap between the limited water resources and the increased agricultural production in an area that suffers from severe water scarcity. The paper applies the SAWAS model to the Jordan Valley in Jordan.

The study aims at measuring the effects of using two different qualities of irrigation water on the productivity and the profitability of the different vegetable crops in downstream of Amman Zarqa Basin. The study area includes two locations, the first one is irrigated using high quality of surface water comes from King Abdullah Canal (KAC) and the second is irrigated by blended surface water with recycled wastewater comes from the King Talal Dam (KTD), a stratified random sample of 150 farms was taken, distributed equally for each location. Descriptive and quantitative analyses were used in this study, mainly parametric linear programming and least square regression analysis to estimate the demand elasticities

A single farm enterprise budget for main crops was done, and the data collection took place during the period of 200-2007. The data were update to represent the current price level of

2009, since the production technology will not change rapidly within a short period of time. As for the data related to production technologies in addition to necessary information of irrigation system, water quantity and quality, the data was gathered by means of questionnaires by MSc. students.

The parametric linear programming model was used of which water demand functions for both water qualities were derived and demand price elasticities estimated. In the normative analysis, a linear programming (LP) was used (Salman, et al. 2001, Doppler et al. 2002, Salman and Al-Karablieh, 2004; Al-Assaf, et al., 2007; Al-Karablieh and Salman 2006; A-Karablieh et al., 2006)

The mathematical structure of the LP model is consisted of the objective function (Salman et. al, 2001) which can be written as follows:

$$Max\,Z = \sum_{j}\sum_{m}\sum_{K} X_{jmk} * \left[ WRC_{jmk} - \sum_{i}\ \sum_{m}\left(P_{im}W_{im}\right)\right] \qquad \textbf{Equation 4}$$

where *(Z)* is the total Gross Margin (GM), ( $X_j$ ) is total planted area by crop (J), *and(m)* is the water quality (fresh or fresh blended with TWW), (*k)* is the basin (number 21 and 22), (*i) is* months (12 months started from October), (*j)* is vegetable crop types, ( $WRC_{jmk}$ ) is the Water Related contribution which is the GM of Crop (J) using water quality (m) in basin (k) without subtracting the costs of irrigation water, ( $P_{im}$ ) is the price of one cubic meter of irrigation water in month (*i*) of water quality (m), and ( $W_{im}$ ) is the available water supply in cubic meters in month (*i*) according to water quality (*m*).

The **model constraints** can be represented as follows:

The **water constraints** are represented by the Equation 5;

$$\sum_{j}\sum_{m}\sum_{k} a_{ijmk} X_{jmk} + \sum_{i}\sum_{m}\left(-W_{im}^{0} - W_{i-1,m}^{+} + W_{i+1,m}^{-}\right) \le 0 \qquad \textbf{Equation 5}$$

where ( $a_{ijmk}$ ) is the water requirements of crop (*j*)in cubic meters in month (*i*) irrigated by water quality (*m*) in basin *(k)* , ( $W_{im}^{0}$ ) is the total water supply quantity in cubic meters in month (*i*) of water quality (*m*). ( $W_{i-1,m}^{+}$ ) is the water quantity transferred from month (*i* -1) of quality (*m*).( $W_{i+1,m}^{-}$ ) is the water quantity transferred to the later month (*i* +1) of quality (*m*).

The **labor constraint** represented with Equation 6;

$$\sum_{j}\sum_{m}\sum_{k} l_{jk} X_{jmk} \ge 0 \qquad \textbf{Equation 6}$$

where ($L_{jk}$ ) is the requirements of labor of crop (*j*) in hours in basin (*k*).

The **fertilizer constraint** represented with Equation 7,

$$\sum_j \sum_m \sum_k f_{jk} X_{jmk} \geq 0) \qquad \textbf{Equation 7}$$

where ($f_{jk}$ ) is the requirements of crop (*j*) of fertilizer in basin (*k*).

Finally the **land constraint** which is represented with Equation 8;

$$\sum_j \sum_k \sum_n X_{jmk} \leq A_{kn} \qquad \textbf{Equation 8}$$

where ($A_{kn}$ ) is the total allocated area for all crops in basin (*k*) for crops in the sample (*n*).

# 4 Data Collection

Data collection and data bases accessed in the frame of this study relied predominantly on secondary information from official Jordanian sources, which included, beside the Ministry of Water and Irrigation (MWI) and the Department of Statistics (DOS), also other relevant ministries and administrative units. The current state of official data sources includes data from 2008 as the last year of finalized data entries.

An exception is information on the agricultural sector, where ATEEC has access to additional information from continuous monitoring processes due to its professional linkages with the sectoral research and monitoring activities.

## 4.1 Data on the sectors industry, tourism and domestic water use

The DOS provides data on different performance indicators and water consumption in the sectors of industry, services and tourism. These data are the result of annual sample surveys, which rely on stratified sampling plans according to geographic locations and characteristics of enterprise size. The establishment of nation-wide data bases by DOS started around 1988. However, consistent comparisons are possible only for records after the end of the process of consolidation and standardization, i.e. from approximately 1998/99 onwards. The purpose of these data collections is to provide the basis for National Accounts according to the United Nations standards.

Data on the industrial sector comprise the sub-sectors *(1)* mining and quarrying, *(2)* manufacturing and *(3)* production and distribution of electricity. Information on this sector is complemented by separate data on the following sectors:

- internal trade, which covers indicators for wholesale and retail enterprises,
- finance and insurance,
- transport, storage and communication and
- construction

Data on the touristic sector, i.e. hotels and restaurants, are included in the records of the DOS survey on the sector of services, which covers profit and non-profit oriented establishments.

Data on domestic water use were obtained from records of the Water Authority of Jordan and recent studies on household water use in Jordan.

DOS data used in this study are drawn from the data bases of the recent economic surveys. The survey data provide information about characteristics of the main industry classified as a homogenous group of industry according to ISIC3 (2-3 digit level) for the last six years 2003-2008.

Published information from DOS allows for analyses of water productivities in the concerned sectors, but is too highly aggregated for in-depth analyses of water values within the individual production processes. Consistency checks during the analysis of the accessible data bases indicated the occurrence of some probable data problems, which should be subject to closer inspection before more detailed calculations take place.

## 4.2 Data on the Agricultural Sector

The basic source of data was the records of the Department of Statistics' (DOS) agricultural survey. Data on producer prices (farm gate price) and production included also most recent and hitherto unpublished information on the year 2009. Further information was obtained from ongoing programs at The Water and Environmental Research and Study Centre (WERSC) and other research units of the University of Jordan.

### 4.2.1 Horticultural and Field Crops

The estimation of the value of water for agriculture is performed on a per crop basis. The crops selected for the application are those for which available information exists on maximum and average yields and yield-response factors. The main field crops, vegetables and fruit trees in Jordan will be selected. A total of 70 crops were used in the analysis.

15 field crops are: Wheat, Barley, Lentils, Vetch, Chick-peas, Corn, Sorghum, Broom millet, Tobacco, Garlic (as classified by DOS in field crops list), Common Vetch, Sesame, Clover, Alfalfa and other field crops.

The vegetables consist of 22 crops, these are : Tomatoes, Squash, Eggplants, Cucumber, Potato, Cabbage, Cauliflower, Hot pepper, Sweet pepper, Broad Beans, String Beans, Peas, Cow-peas, Jew's mallow, Okra, Lettuce, Sweet melon, Water melon, Spinach, Onion green, Onion dry, Snake cucumber, Turnip, Carrot, Parsley, Radish and other vegetables crops.

Citrus fruits are consisting of 12 crops; these are Lemons, Oranges-local, Oranges-navel, Oranges-red, Oranges-Valencia, Oranges-French, Oranges-shamouti, Clementine, Mandarins, Grapefruits, Medn. Mandarins, Pummelors,

Fruit trees consist of 14 crops, these are Olives, Grapes, Figs, Almonds, Peaches, Plums, prunes, Apricots, Apples, Pomegranates, Pears, Guava, Dates and other fruit trees as well as Bananas.

Figure 4 shows the production and cultivated areas of horticulture crops in Jordan, the figure is restricted to 300,000 tons, whereas the tomatoes production is 598,200 tons.

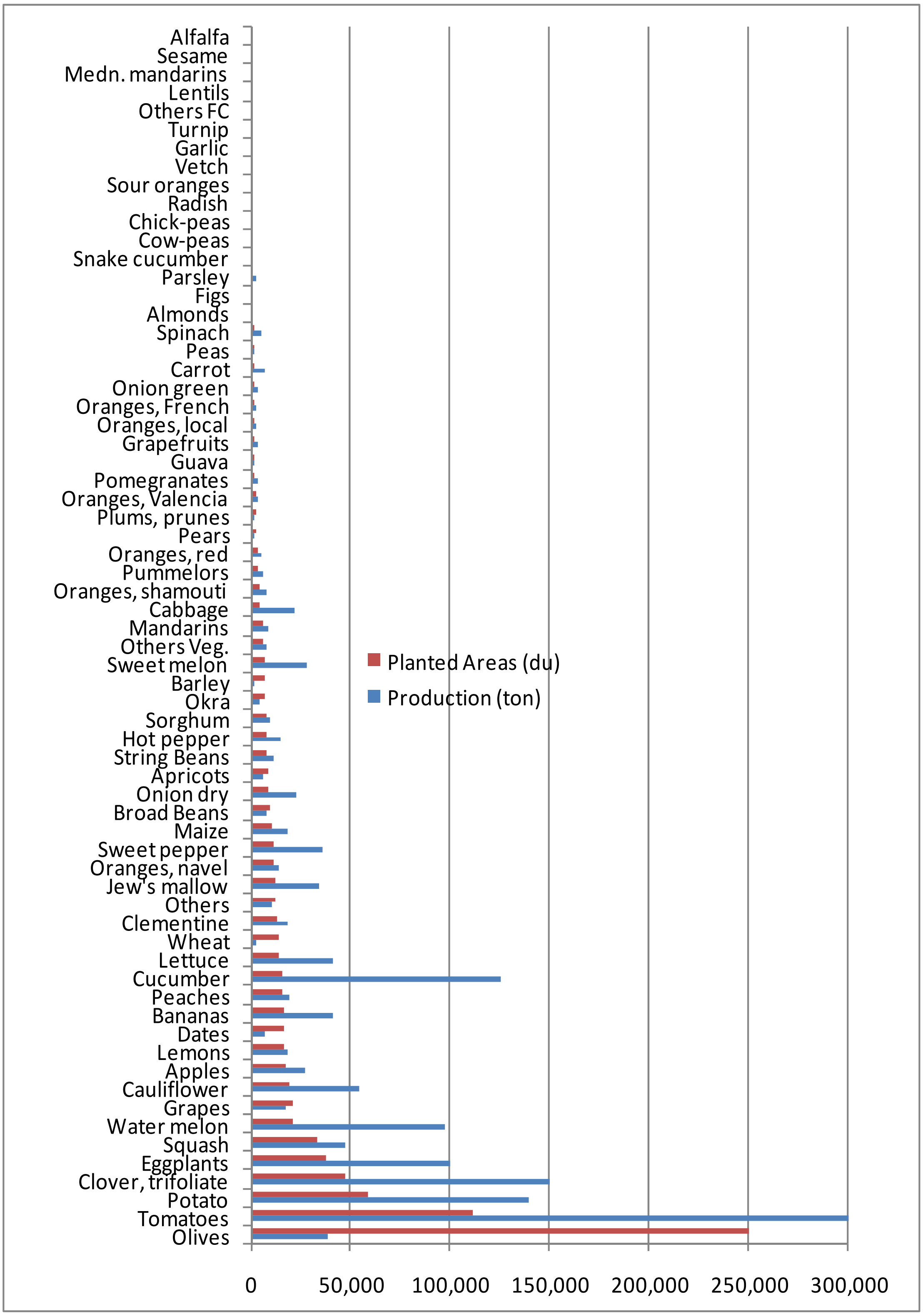



**Figure 4: Cultivated Areas, Production of field & horticultural crops in Jordan in 2008**

### 4.2.2 The crop coefficients

From the literature available in MWI and Faculty of Agriculture, the crop water requirement are gathered, more specifically, the data on net water requirements for crop cultivated in different agro-climatological zones in different season (Winter and Autumn) are collected an aggregated to represent whole Jordan for the purpose of this study. It is not possible to take into account the influence of aspects such as the varieties that could be used by the farmers. Differences in water qualities, and source of irrigation water. The net irrigation water requirements was used instead of crop water requirement to measure the value of irrigation water and to subtract the contribution of effective rainfall precipitation from irrigation requirements.

### 4.2.3 Crop Production

Data on 2009 crop production are fully available from DOS database for each crop considered in each of the 12 governorates and 4 sub-governorate in Jordan Valley. These data encompass cultivated area (planted area), area harvested (ha), yield (kg/du) by season

### 4.2.4 Cultivation Methods

Data on 2009 crop production are fully available from DOS database for each crop does not distinguishes between crop cultivated under irrigation or in rainfed condition. It is necessary to determine the crop cultivated using different irrigation technology, since the net irrigation requirement will be differ. We use the results of agricultural census conducted in 2007 to estimate the cultivated area under irrigation for different crops in the study.

### 4.2.5 Crop Water Requirements

Crop water use, consumptive use and evapo-transpiration (ET) are the terms that are used interchangeably to describe the water consumed by a crop. Water requirement depend mainly on the nature and stage of growth of the crop and environmental conditions. Different crops have different water-use requirements under the same weather conditions. Hence the crop coefficients appropriate to the specific crops are used along with the values of reference evapo-transpiration for computing the consumptive use at different growth stages of the crop by water-balance approach. Crops will transpire water at the maximum rate when soil water is at field capacity. When soil moisture decreases, crops have to exert energy to extract water from soil. Usually, the transpiration rate does not decrease significantly until the soil moisture falls below 50% of field capacity. The evapo-transpiration (Etc in mm) of a crop under irrigation is obtained by the following equation (Sharma, 2001)

$ETc = Kc \times Eto$;

where

Eto is the reference evapo-transpiration and Kc is the crop coefficient. Crop coefficient is dynamic in nature and varies according to crop characteristics, dates of (trans) planting, stage of growth and climatic conditions.

Various methods have been developed to determine the water requirements for specific plants. A comprehensive guide to the details of these methods is Doorenbos and Pruitt (1992). The calculation method is not explained here. For more details on the calculation method, consult an authoritative reference such as Critchley and Siegert (1991), Doorenbos and Pruitt (1992), or Allen et al., (1998).

Several studies were conducted in Jordan on crop water requirements and irrigation scheduling, mainly by researchers Shatanawi et. al. (1986), Shatanawi et al. (1987), Fardous (1983), Ghaw (1988) and Mazahreh (1993), Shatanawi et al. (1987) measured the water consumption of wheat and barley in the Jordan Valley. They found that the ET for wheat and Barley to be 326 and 304, respectively. Ghawi (1988) measures the actual crop evapotranspiration for fodder corn crop, and reported a value of 348 mm, compared to 517mm of the alfalfa crop. Under cover plastic houses, Suwwan et. al. (1985) studied the water consumption for tomatoes, and found that tomatoes plants consumed 490 mm of water inside the plastic house at the Jordan Valley. Mazahreh (1993) used several methods to determine the actual water consumption of mature bananas. She found actual water consumption of mature banana to be 1476 mm. Shatanawi et al. (1998) used the literature above to determine the net water requirements of crops planted in the Jordan Valley according to agroclimatic zones. The crop net water requirements stated below were adopted from Ministry of Water and Irrigation as shown in Table 2. The total crop-water requirements have been assigned to each crop from different agroclimatic zones in the Jordan Valley.

**Table 2: Annual Net Irrigation Requirements (m3/du.) in Jordan Valley**

| Group | North Irrigation Project | North East Irrigation Project | MJV Irrigation Project | South Irrigation Project | 14.5 km Extension Area |
|---|---|---|---|---|---|
| **Field Crops** | 304 | 304 | 528 | 527 | 527 |
| **Vegetables** | 276 | 276 | 453 | 337 | 337 |
| **Fruit Trees** | 786 | 786 | 1187 | 984 | 984 |
| **Banana** | 1295 | 1295 | 1992 | 1625 | 1625 |
| **Citrus** | 814 | 814 | 1334 | 1134 | 1134 |

The situation considered is such that there are no available data on quantity of water used in agriculture production for each crop. Since the actual water used by farmers for each crop require a field survey. Therefore, the first step of the method is a quantitative estimation of the water used by the crops. As there are available data on production per crop, the water use of each crop can be estimated. These data on crop water requirement are also obtained from The Ministry of Water and Irrigation and then filled in the models as shown in Table 3. In this case it is preferred to estimate the net irrigating crops water requirements for the crops not the gross water requirements. The average irrigation crop-water requirements for main crops produced in Jordan are shown in Table 3.

**Table 3: Annual Average net irrigation Requirements (m3/du) in Jordan**

| Field Crops | CWR | Vegetables | CWR | Fruit Trees | CWR |
|---|---|---|---|---|---|
| Wheat | 353 | Tomatoes | 400 | Citrus fruits | 950 |
| Barley | 236 | Squash | 351 | Lemons | 950 |
| Lentils | 350 | Eggplants | 293 | Oranges, local | 950 |
| Vetch | 250 | Cucumber | 320 | Oranges, navel | 950 |
| Chick-peas | 350 | Potato | 326 | Oranges, red | 950 |
| Maize | 723 | Cabbage | 326 | Oranges, Valencia | 950 |
| Sorghum | 600 | Cauliflower | 328 | Oranges, French | 950 |
| Broom millet | 600 | Hot pepper | 274 | Oranges, shamouti | 950 |
| Tobacco, local | 300 | Sweet pepper | 318 | Clementine | 950 |
| Tobacco, red | 523 | Broad beans | 231 | Mandarins | 950 |
| Garlic | 320 | String beans | 235 | Grapefruits | 950 |
| Vetch, common | 400 | Peas | 278 | Medn. mandarins | 950 |
| Sesame | 529 | Cow-peas | 242 | Pummelors | 784 |
| Clover, trifoliate | 529 | Jew's mallow | 379 | Sour oranges | 755 |
| Alfalfa | 300 | Okra | 207 | Olives | 600 |
| Others FC | 459 | Lettuce | 356 | Grapes | 750 |
| | | Sweet melon | 356 | Figs | 750 |
| | | Water melon | 208 | Almonds | 750 |
| | | Spinach | 532 | Peaches | 750 |
| | | Onion green | 823 | Plums, prunes | 1300 |
| | | Onion dry | 248 | Apricots | 750 |
| | | Snake cucumber | 248 | Apples | 750 |
| | | Turnip | 237 | Pomegranates | 750 |
| | | Carrot | 245 | Pears | 1395 |
| | | Parsley | 248 | Guava | 1400 |
| | | Radish | 250 | Dates | 600 |
| | | Others Veg. | 950 | Bananas | 1600 |

| | | | |
|---|---|---|---|
| | | Others Fruit trees | 600 |

### 4.2.6 Producer prices

The term "prices received by farmers" as a farm-gate price used in to be estimated the agricultural national account available from DOS Database, should in theory refer to the national average of individual crops comprising all grades, kinds, and varieties. These prices are determined by the farm gate or first-point-of-sale transactions when farmers participate in their capacity as sellers of their own products. Of course, data might not always refer to the same selling points depending on the prevailing institutional set-up in the country. In addition, different practices prevail in regard to individual crops.

### 4.2.7 Production Cost

The gross margins needed to be calculated for each cop grown in Jordan in order to analyze the value of water for these crops. The main components of the gross margin analysis are the total return, which is the field production in kg/du multiplied by the farm gate price JD/kg minus the variable cost and the cost of water in JD/du.

The general components of the variable cost are:

1. Water.
2. Fertilizers (trace elements, organic and compound or chemical fertilizer).
3. Pesticides and herbicides.
4. Containers and threads.
5. Plastic mulch used in vegetable production with drip irrigation, and under plastic houses.
6. Soil fumigants.
7. Plastic cover used in plastic tunnels crop enterprises.
8. Fuel and electricity.
9. The costs of hired machinery and seasonal hired labor expressed in hours/ labor, which include planting, spraying, tillage, land preparation, rearing, and crop harvesting , have been calculated for all these operations.

The gross margins were calculated, it was calculated without including irrigation water cost in the total variable cost.

### 4.2.8 Data for Optimization Model

This study is relied on secondary data that has been collected previously during the period 2006-2007 cropping season and updated according to the input and output prices for the year 2009. These data are the gross margins for all crops by season (winter and summer), including the farm gate prices, cost and level of intermediate consumption, water supply quantities which was obtained from the Jordan Valley Authority (JVA)– Ministry of Water and Irrigation (MWI) for the last 10 years (2000-2009). in addition to the cultivated crop areas in the study area which has been obtained from the Department of Statistics (DOS) for the last eight years (2000-2009), in addition to the farm-gate prices for the last four years 2000-2009 in order to avoid or minimize any possible deviations the could happen the input data of the linear programming model. All the data related to price and values were converted to constant price of 2008.

The study used only secondary data; the secondary data was obtained from different official sources they are; the Ministry of Water and Irrigation (MWI), Department of Statistics (DOS), Jordan Valley Authority (JVA), Ministry of Agriculture (MOA), and from PhD and MSc students. The data included the following:

1. Gross water requirement for all crops grown in MJV & SJV, taken from MWI
2. Water supply quantities, from JVA (2000 -2009)
3. Cultivated crop areas in both MJV & SJV from DOS 2000 -2009.
4. Farm gate prices of crops grown in both MJV & SJV from DOS 2000-2009.
5. Actual cropping patterns DOS 2000-2009.

Several factors affecting the production process were taken into consideration, such as the planting seasons (spring and autumn), different planting methods (plastic houses, plastic tunnels, and open field).

# 5 Results and Discussion

The value of water of each sector will be presented separately with a variety of approaches that used to estimate the value of water.

## 5.1 Value of Water for Domestic Sector

In order to determine, in monetary terms, the value of improved quantity of domestic water in the country and to provide an understanding of the factors that affect this monetary value. This attempt is essential to produce quantitative economic information on domestic water uses and value that policy-makers may find useful in implementing the national water policies.

### 5.1.1 Cost of Water Service

Cost of service is a methodical process by which revenue requirements are used to generate a system of fair and equitable costs in proportion to the service received for each user class

#### *5.1.1.1 Cost of Public Water Network*

The cost of water service through public water network is the cost accrued on WAJ and its water utilities to provide this service to Jordanian people. Table 4 summarizes the main revenue and cost items in the main regions in Jordan specified per the different water utilities; Mihayuna Company serving Amman Governorate, Yarmouk Water Company serving the northern governorates, Aqaba Water serving Aqaba governorate and rest of Jordan for 2009. The cost of water service varies between Jordan's governorates due to many reasons including the type of water resources, the distant and elevation difference between the water resources and customers, the density of customers, etc.

The cost items presented in Table 4 includes the cost of providing water and wastewater services. Therefore and based on the financial analyses carried out in the cost recovery program of WAJ from 2002 to 2004 (ECO Consult, 2004), it is assumed that 85% of O&M cost and 60% of capital cost is attributed to the water sector, while the remaining 15% of O&M cost and 40% of capital cost is attributed to the wastewater sector. Then, the full cost of water service is estimated at 179 million JD (see Table 4). As the total billed water in 2009 is 183 MCM and total water supply is 322 MCM, the average cost of water service for all Jordan can be estimated to be 0.89 JD/$m^3$ of billed water and 0.51 JD/$m^3$ of water supply.

**Table 4: Cost of water service provision in the main Jordan's regions for 2009 in 1000 JDs**

| Item | Amman | North region | Aqaba | Rest of Jordan | Adjust-ment | Total (Jordan) |
|---|---|---|---|---|---|---|
| **O&M Cost** | | | | | | |
| Operation and Maintenance | 38,980 | 16,099 | 3,957 | 21,558 | -3,975 | 76,619 |
| Wages | 11,689 | 7,669 | 2,796 | 20,669 | | 42,823 |
| Administration | 2,498 | 628 | 495 | 621 | 27 | 4,270 |
| Wastewater treatment | 10,471 | | | | | 10,471 |
| Water purchase from WAJ | 2,560 | | 3,091 | | -5,651 | 0 |
| Water purchase from other related parties | | | | 3,314 | -3,314 | 0 |
| Other expenses | 27 | | | | | 27 |
| **Total O&M cost** | **66,227** | **24,396** | **10,339** | **46,162** | **-12,913** | **134,210** |
| **Capital cost** | | | | | | **0** |
| Depreciation | 1,796 | 2,921 | 1,898 | 67,568 | | 74,183 |
| Revenues resulted from using assets | 9,269 | | | -9,269 | | 0 |
| Loan interests | | | | 21,637 | | 21,637 |
| Currency differences | | | | 9,336 | | 9,336 |
| debt doubtful to collect | 43 | | 54 | 2,920 | | 3,017 |
| Income tax for subsidiary company | 273 | | 137 | | | 410 |
| Training fund fee for subsidiary company | 0 | | 16 | | | |
| **Total capital cost** | **11,382** | **2,921** | **2,104** | **92,192** | **0** | **108,600** |
| **Full cost** | **77,609** | **27,317** | **12,443** | **138,354** | **-12,913** | **242,810** |
| **O&M cost – Water** | 56,293 | 20,737 | 8,788 | 39,238 | -10,976 | 114,079 |
| **Capital cost – Water** | 6,829 | 1,753 | 1,262 | 55,315 | - | 65,160 |
| **Full cost – Water** | **63,122** | **22,489** | **10,051** | **94,553** | **-10,976** | **179,239** |

*Source: WAJ's income statement for 2009*

In order to estimate the cost per region, the capital costs reported under the rest of WAJ were reallocated over Miyahuna, NGWA and rest of WAJ based on the water supply ratio, which allows estimating more accurately the actual capital cost of the different regions. Figure 5 presents the estimated average cost of water service provision based on the billed water and supply water.

It is important to address that the O&M cost of the rest of WAJ includes the administration, planning, and supervision of the capital investment executed overall the Kingdom. Thus, it is O&M cost does not actually reflect the actual cost of water service provision in the rest of Jordan.

In future, the cost of water service provision will definitely increase due to the more expensive water investment projects such as Disi water conveyance project, water network rehabilitation projects, Red Sea Dead Sea water cannel, etc. As an example, the cost of Disi water supply is estimated at about 0.8 JD/m$^3$, and by adding the distribution cost and accounting for the non-revenue for water (NRW), the estimated cost of delivering Disi water to customers would reach around 1.5 JD/$^3$. This is an increase of about 0.6 JD/m$^3$, which would contribute by increasing the domestic water value by the same amount.

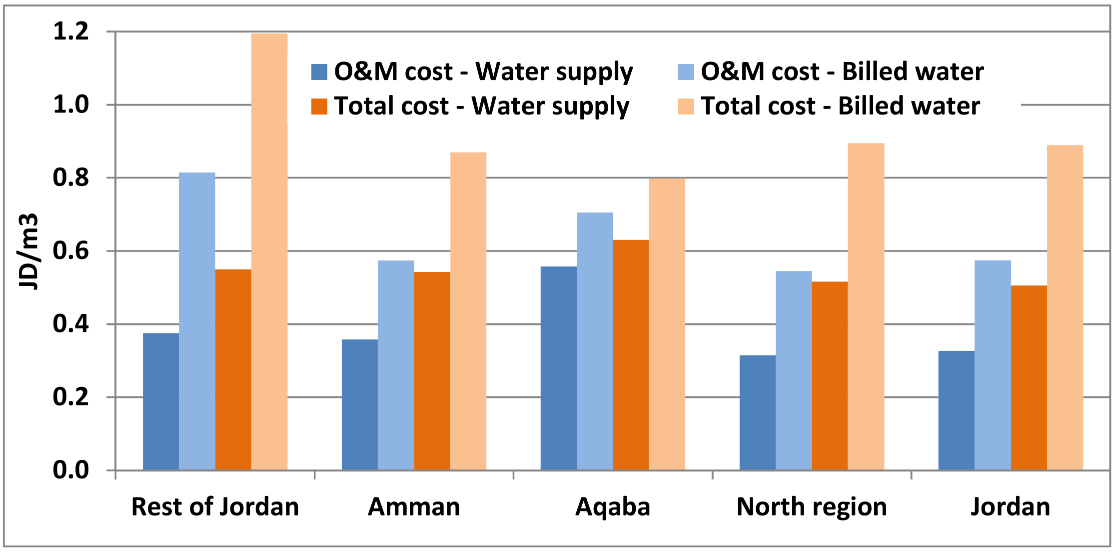



**Figure 5: Average cost of water service provision in main Jordan's region for 2009**

#### *5.1.1.2 Tariff of Public Water Network*

The previous section presents the cost of water supply accrued on the water service provider. This section presents the cost of obtaining the water supply accrued to the domestic water users both residential and non-residential.

***Residential water tariff***

Since 1975, Jordan adopted the increased volumetric tariff that was developed over the following years from a specific rate for each block of consumption into a complex tariff formula. Water tariff restructuring has witnessed several developments in the last 20 years, to cater for increases in the capital expenditure and operation and maintenance costs of the water systems. The Government also pursued tariff restructuring as a means to implement water conservation and demand management policies.

The 1997 Water Strategy of Jordan states the objectives of the water tariff policy as follows:

"Recovery of the cost of utilities and the provision of services shall be targeted. Recovery of operation and maintenance cost shall be a standard practice. Capital cost recovery shall be carefully approached. The role of water tariffs shall be considered as a tool to attract private investment in water projects."

The latest water and wastewater tariffs vary across two regions, Amman Governorate and the rest of Jordan (Abdalla et al., 2004). Figure 6 and Figure 7 respectively illustrate the currently applied water and wastewater tariff structures and bill values. The current municipal water and wastewater tariff structure is the same structure applied since 1997 with two increases done in 2003 and 2005 through adding the additional surcharge, in addition to the 12% increase on the wastewater tariff for Amman and Zarqa Governorates to compensate for the additional cost of building As-Samra Wastewater Treatment Plant on the BOT base. The imposed change in 1997 formed a major increase in water and wastewater tariff by almost doubling the rates. While, the two additional surcharges imposed in 2003 and 2005 only form an increase of around 20% of the tariff. From Figure 6 and Figure 7, it can be deduced that the maximum water tariff paid by residential customers is 0.85 JD/$m^3$, while the maximum wastewater tariff paid by residential customers is 0.39 JD/$m^3$ in Amman and Zarqa Governorates and 0.35 JD/$m^3$ in the other Governorates. It is important to address that at a quarterly consumption rate of 20 m3 or less, a minimum charge amount for water and wastewater services has to be paid which is JD 5.12, 4.42 and 4.35 for Amman, Zarqa and other governorates respectively.

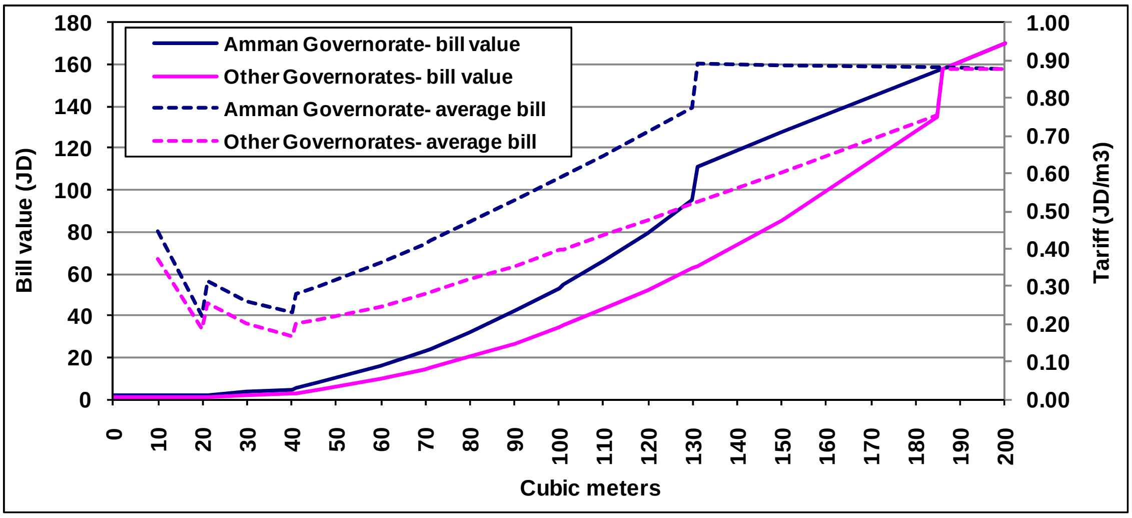



**Figure 6: Current residential water tariff structure and water bill value in Jordan**

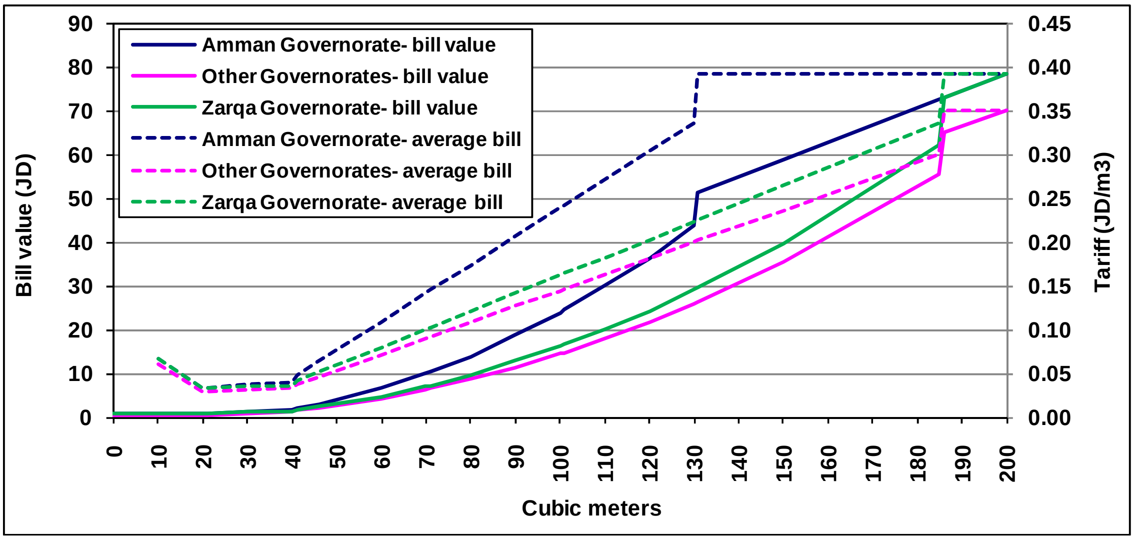



**Figure 7: Current residential wastewater tariff structure and wastewater bill value in Jordan**

***Non-residential water tariff***

The non-residential customers pay for water service 1 JD/m$^3$ in all Jordan's governorates and pay for wastewater service 0.56 JD/m$^3$ in Amman and Zarqa governorates and 0.5 JD/m$^3$ in the other governorates, with a minimum consumption of 5 m$^3$/quarter. In addition to the volumetric charge for water and wastewater, there are other non-volumetric charges levied by WAJ for all types of customers. These include 0.3 JD per bill as a meter charge and additional surcharges of 4.15 JD/bill for customers consuming less than 5 cubic meters in all regions and 4.65 JD/bill for customers consuming more than 20 cubic meters in all regions except for Amman, where the additional surcharge is 5.15 JD/bill.

Since the water tariff varies with the volumetric water consumption, then there is a need to use the average water rate through dividing the total quantity of the billed water by the water bill revenues as illustrated in Table 5. The table clearly shows the discrepancies in the average water tariff among the main Jordan's regions, which ranged from 0.33 JD/m$^3$ in most of Jordan's governorates to 0.48 and 0.63 JD/m$^3$ in Amman and Aqaba governorates respectively.

**Table 5: Average water bill in the main Jordan's regions for 2009**

| | **Amman** | **North region** | **Aqaba** | **Rest of Jordan** | **Total (Jordan)** |
|---|---|---|---|---|---|
| **Water bill revenues (JD)** | 40,165,553 | 12,508,932 | 8,217,784 | 16,025,780 | 76,918,049 |
| **Billed water (m$^3$)** | 83,233,190 | 38,061,280 | 13,112,317 | 48,790,104 | 183,196,891 |
| **Average revenue (JD/m$^3$)** | **0.48** | **0.33** | **0.63** | **0.33** | **0.42** |

### 5.1.2 Cost of Non-Public Water Network

Around 98% of residents in Jordan get drinking water through public water network. However and due to water system unreliability in some cases, residents use other more expensive sources including water tankers, water shops, and bottled water. Additionally, some households install water treatment system inside their houses to improve the quality of public water, which implies additional cost on them.

Other available sources of supply for residential uses include water sold by tankers, private wells water, and bottled water from private companies. The price of water supplied by private tankers ranges from 3 to 5 JD/m3 depending the region and customer location. The second alternative source is the water shop water purchased from private companies. The cost of cubic meter is the most expensive and is estimated to be of more than 25 JD per cubic meter and sometimes reaches 70 JD per cubic meters. The third source, which the least common to use is the bottled water, cost around 300 JD/m3. In many cases, there is additional cost in the case of water tankers associated with the need to have additional storage for water.

## 5.2 Domestic Water Value

The domestic water value is estimated by summing up the full water supply cost and the opportunity cost. The full water supply cost is the cost accrued on the service provider, which WAJ. The opportunity cost is the additional cost accrued on the water users from using an alternative water source. To estimate this additional cost, it is assumed that water users will buy water tankers, which is the cheapest alternative water source. The average cost of water tankers is around 4 JD/$m^3$, while the average cost of obtaining water through public network is presented in Table 5. Thereby, the opportunity cost can be estimated by subtracting average cost of obtaining water through public network (average revenue) by the water tanker price as presented in Table 6. The total cost of public water network is estimated previously in Table 4, thus the domestic water value is the sum up of the total cost of public network and the opportunity cost, which is 4.47 JD/$m^3$ and around 819 million JD for Jordan. The domestic water values for the different regions in Jordan are also presented in Table 6.

Improving the cost recovery levels by increasing water tariff would result in increasing the cost of public water network on customers and thereby reducing the opportunity cost and then the domestic water value. Additionally, reducing the NRW will reduce the cost of water service provision. Therefore, restructuring the water tariff and improving the operational performance of water utilities will result in reducing the domestic water value.

**Table 6: Domestic water value calculations**

| | Amman | North region | Aqaba | Rest of Jordan | Total (Jordan) |
|---|---|---|---|---|---|
| **Water bill revenues (Million JD)** | 40.17 | 12.51 | 8.22 | 16.02 | 76.92 |
| **Billed water (MCM)** | 83.23 | 38.06 | 13.11 | 48.79 | 183.2 |
| **Average revenue (JD/m$^3$)** | 0.48 | 0.33 | 0.63 | 0.33 | 0.42 |
| **Water tanker cost (JD/m$^3$)** | 4 | 4 | 4 | 4 | 4 |
| **Opportunity Cost (JD/m$^3$)** | 3.52 | 3.67 | 3.37 | 3.67 | 3.58 |
| **Total cost (JD/m$^3$ billed)** | 0.87 | 0.89 | 0.80 | 1.20 | 0.89 |
| **Water value (JD/m$^3$)** | 4.39 | 4.57 | 4.17 | 4.87 | 4.47 |
| **Total water value (JD)** | 365.18 | 173.78 | 54.70 | 237.44 | 818.79 |

## 5.3 Value of Water in Industry

Water has, like any good or service, simultaneously a number of values. This holds not only for the allocation to different sectors of water consumption but also with regard to the goals that decision makers pursue with the distribution of water. Amongst the multiple goals of a national economy, the following analysis of water values focuses on the economic value of water in different production processes only.

The available information on the sectors of industry and tourism allows for the assessment of water productivity, which is basically a technical parameter, but helps in decisions on the distribution of scarce resources between the economic sectors of a national economy. The preliminary work on water valuation by USAID in 2005 focused also on water productivity only, which supports the choice of this parameter for the requested update (*cf*. terms of reference, task 4).

However, partial productivities like water productivity neglect impacts on entrepreneurial income and returns to water use in the context of overall production factor inputs. The estimation of such suitable economic steering criteria for decision making on the reallocating of water between sectors would be desirable, but goes beyond the scope and capacities of this study.

The following assessment of water productivities in industry and tourism puts water consumption in relation two measures of national accounting:

a) *Water productivity based on the Gross Value Added (GVA)*: The GVA represents the difference between the gross output of an industrial sector minus the intermediate consumption. The resulting water productivity allows for the comparison with values from the previous studies of USAID and with water productivities in other countries.

b) *Water productivity based on the Operating Surplus (OS)*: The OS is the measure of the surplus accruing from production before deducting property income and thus a proxy for total pre-tax profit income. The resulting water productivity gives an indication about the economic efficiency of water consumption with regard to the profitability of specific industries in Jordan.

It has to be emphasized that both types of water productivity display only the outcome under an already given set of inputs in existing industrial production processes. The allocation of additional water to industry will yield comparable economic returns only under the assumptions of

- an adequate, simultaneous increase of all other production factors, i.e. goods, rights and services, for the specific industries and
- a similar market environment in terms of costs for inputs, prices and possibilities for sales of additional product amounts from these industries.

The available time series for this study differed between data on GVA and on OS. Data on water consumption and related GVA covered the 10-years period from 1999 until 2008, while data on OS where available only for the 6-years period from 2003 to 2008. Values from both time series where adjusted by the producer price index to the basis 2008 = 100 in order to achieve comparability between the results.

### 5.3.1 Water Values based on Gross Value Added

Jordan's industries consumed approximately 45.6 MCM of freshwater according to an estimation based on water bills and a tariff of 1JD/m³ in 2008, which constitutes the last year for which comprehensive data are currently available[1]. The gross value added (GVA) by industries, i.e. their monetary output minus intermediate consumption, during the same year amounted to about 4.1 billion JD. This yielded a ratio of about 89 JD in GVA per m³ of water consumed, which was considerably low annual water productivity in comparison with the ten-year average.

Figure 8 shows the average water productivity for the main industrial sectors over the period from 1998 to 2008 based on constant 2008 JD (adjusted by producer price index). The water value ranges from about 70 to 80 JD of GVA per m³ of water in the sectors of mining and chemicals up to 4600 JD/m³ in the sector of tobacco products and reaches even an average of nearly 7000 JD/m³ in oil & gas industries.

The high confidence intervals for the average water productivity for the sectors with high water productivities indicate significant variations between the considered years. The major

[1] This figure for consumption might be slightly underestimated, since water from own wells are charged with a lower tariff

reason for these fluctuations is the strongly varying contribution of the individual sectors to Jordan's GVA.

The comparatively low overall water productivity of 152 JD/m³ is due to the high contribution of industries with low water productivity to the GVA. Mining, chemical, food and non-metallic mineral product industries, i.e. the four sectors with the lowest water productivity, make up for about half of the total industrial GVA (*cf.* Figure 9)

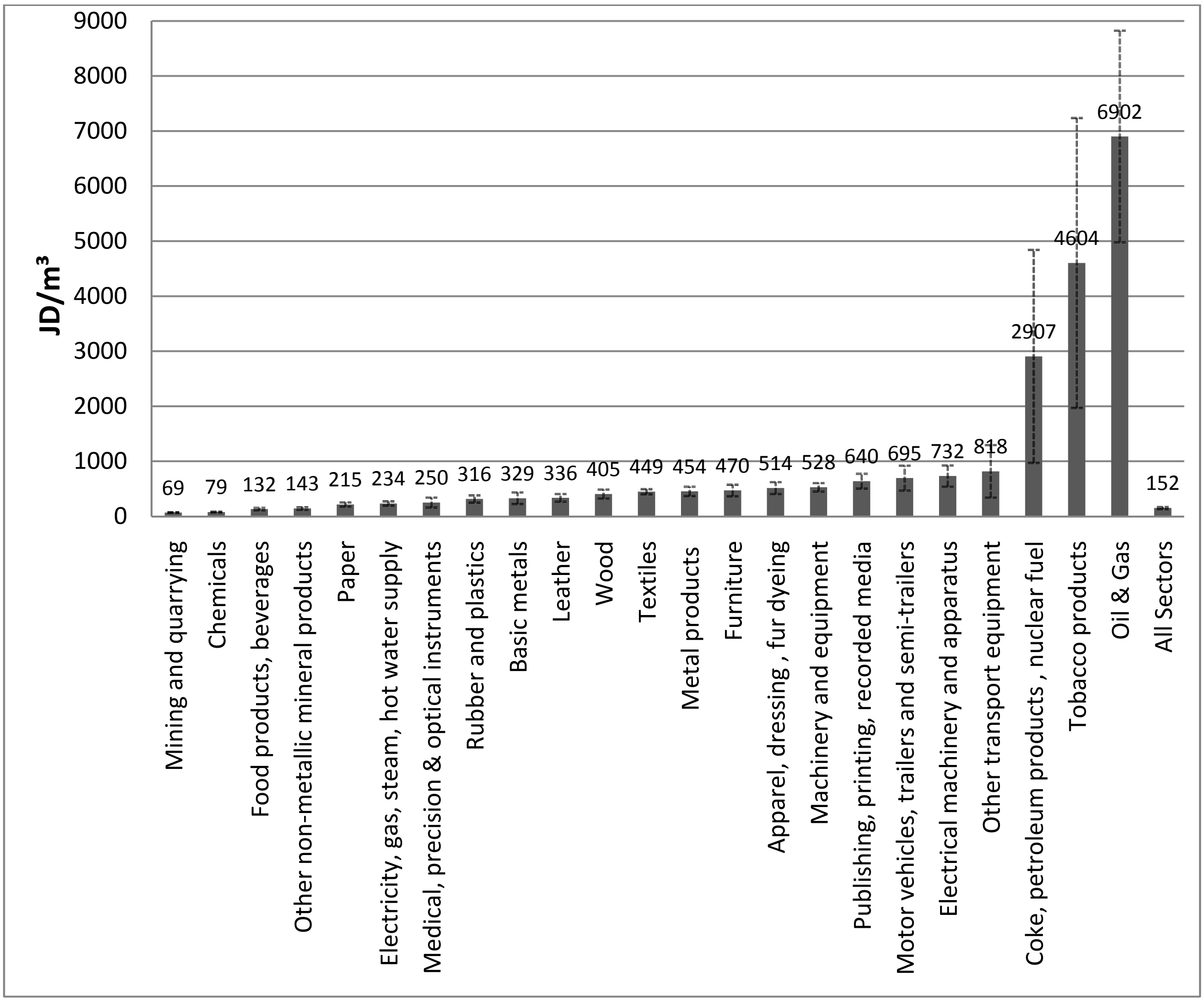
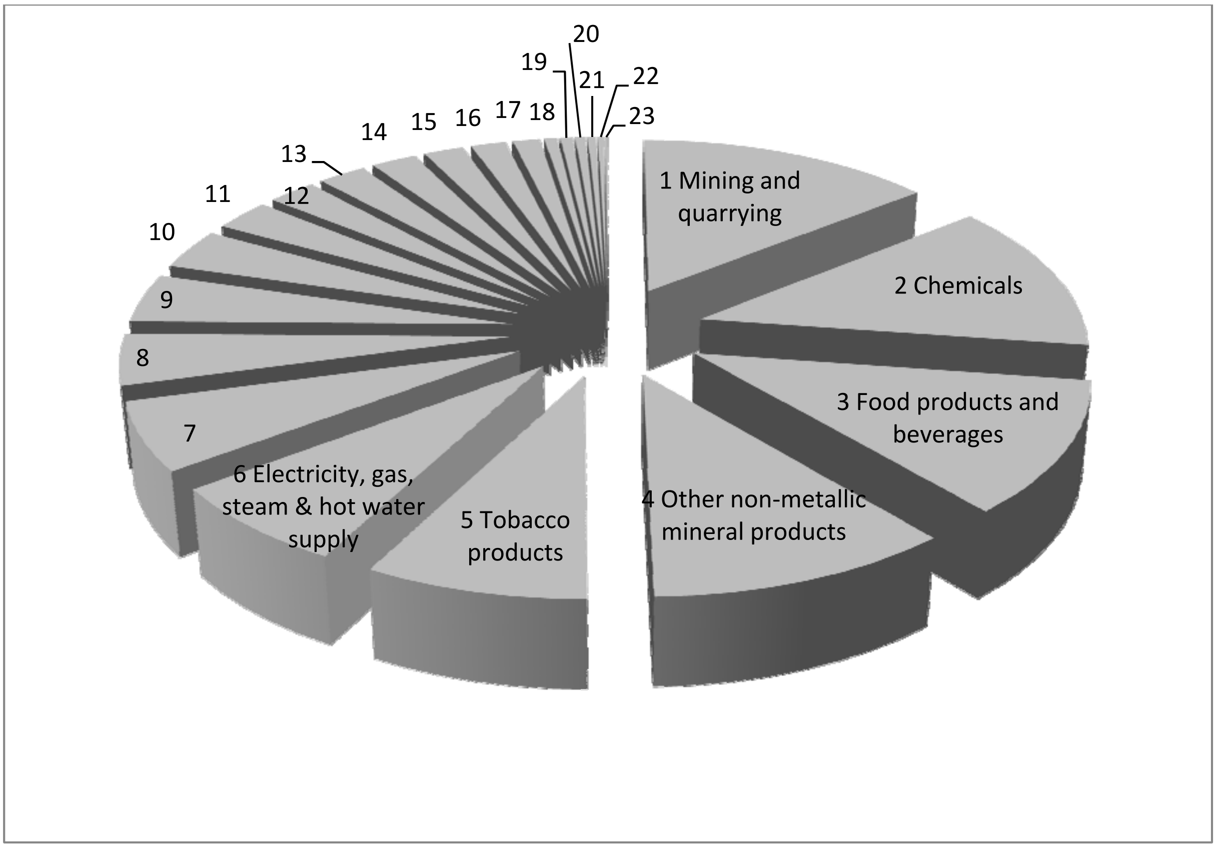



**Figure 8: Water Values in Jordan's industrial sector based on Gross Value Added: 10 year averages (1999-2008) and 95% confidence limits, based on constant 2008 JD (adjusted by producer price index)[2]**

[2] Source: own calculations based on data from the Jordanian Department of Statistics

┬, ┴ confidence limits at a probability of 95%




| | | | | | |
|---|---|---|---|---|---|
| 1 | **Mining and quarrying** | 9 | **Coke, petroleum products & nuclear fuel** | 17 | **Textiles** |
| 2 | **Chemicals** | 10 | **Metal products** | 18 | **Motor** |
| 3 | **Food products and beverages** | 11 | **Publishing, printing, recorded media** | 19 | **Oil & Gas** |
| 4 | **Other non-metallic mineral products** | 12 | **Furniture** | 20 | **Wood** |
| 5 | **Tobacco products** | 13 | **Rubber and plastics** | 21 | **Leather** |
| 6 | **Electricity, gas, steam & hot water supply** | 14 | **Paper** | 22 | **Medical,** |
| 7 | **Apparel, dressing & dyeing of fur** | 15 | **Electrical machinery and apparatus** | 23 | **Other** |
| 8 | **Basic metals** | 16 | **Machinery and equipment** | | |

**Figure 9: Industrial sectors' contribution to Jordan's Gross Value Added: 10 year averages (1999-2008) based on constant 2008**

### 5.3.2 Water Values based on Operation Surplus

The operation surplus (OS) of Jordan's industries, i.e. the approximate pre-tax profit income[3], amounted to about 2.48 billion JD in 2008, which corresponded to a related water productivity of about 55 JD/m³. This was well below the 6-year average of 78 JD/m³ (*cf.* Figure 10**Error! Reference source not found.**).

[3] The operation surplus represents the difference between the gross value added including producer subsidies minus *(1)* the consumption of fixed capital, *(2)* compensation for employees and *(3)* indirect taxes (definition according to the United Nations System of National Accounts, UNSNA)

Industrial sectors with the lowest profits per m³ in the inflation-adjusted 6-year average were, as in the case of water productivity based on GVA, mining and quarrying, chemicals and food products. Industries in the sector of "*other non-metallic mineral products*" fared better in their rank compared to "*electricity, gas, steam & hot water supply*" and "*medical, precision & optical instruments*", but stayed still below the overall average.

Major differences between the sectoral water productivities based on OS and on GVA apply to "*tobacco products*" and "*publishing and printing*". Both sectors rank considerably higher in their contribution to the GVA per m³ of water than they do with regard to the generated entrepreneurial profit, which holds in particular true for tobacco industries. The reverse applies to industries in the sectors "*wood*", "*metal products*" and "*apparel*", which contribute comparatively less to the GVA from Jordan's industries but allow for higher entrepreneurial profits per consumed m³ of water.

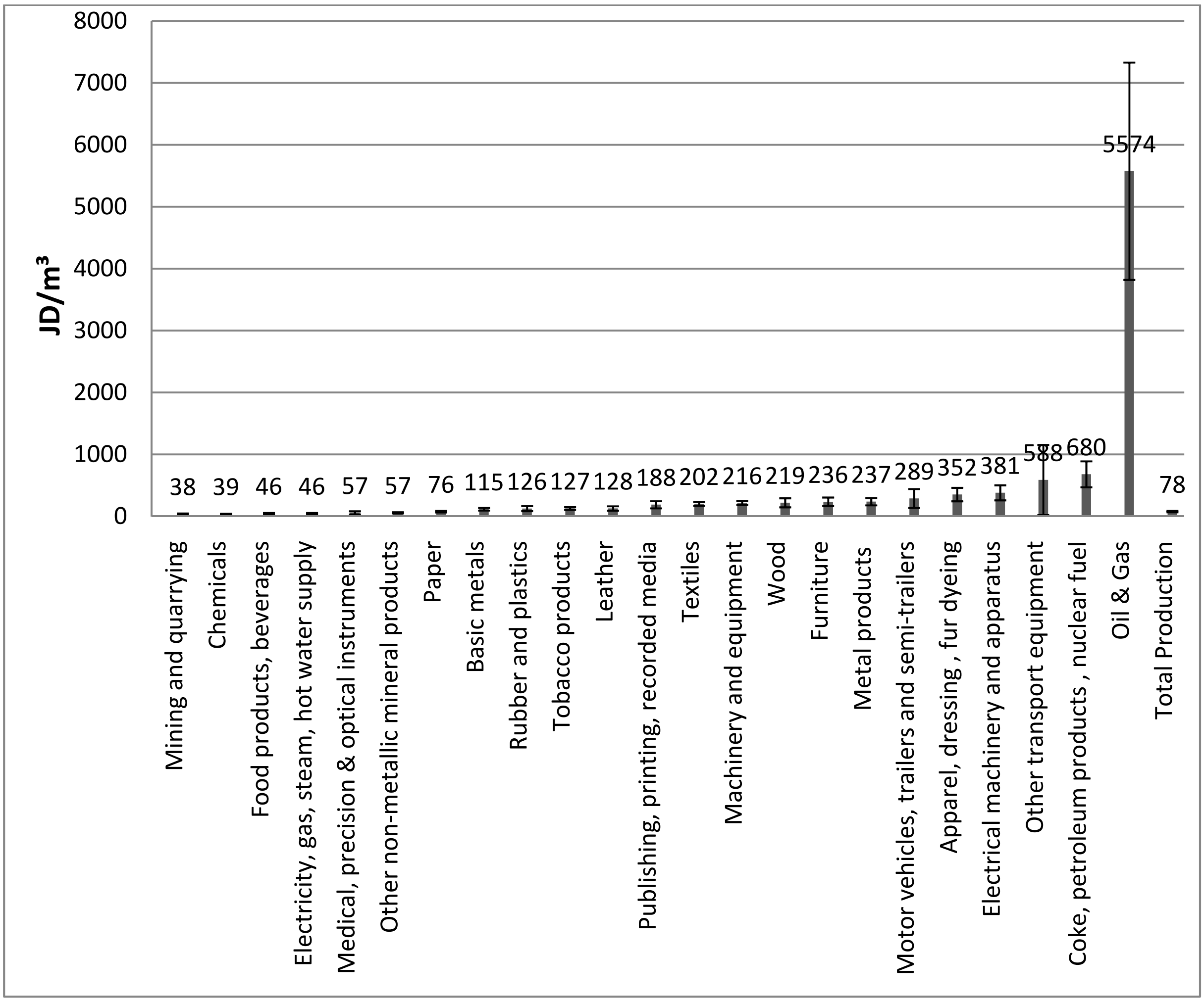



**Figure 10: Water Value in Jordan's industrial sector based on Operation Surplus: 10 year averages (2003-2008) and 95% confidence limits, based on constant 2008 JD (adjusted by producer price index)**[4]

[4] Source: own calculations based on data from the Jordanian Department of Statistics

Table 7 shows the value of water in industrial sector in relation to the gross output, (GO) the gross value added (GVA) and the operation surplus (OS). As an average over the period (2003-2008). The water values based on current prices range from about 29 to 64JD of GVA per m³ of water in the sectors of huge water consumers such mining and chemicals, food and beverage and manufacturing of non-metallic mineral up to 3,896 JD/m³ in the sector of Extraction of Petroleum and natural gas, tobacco products. The weighted average of water values in the industry, weighted by water consumption is 69 JD/m³.

Figure 11 sorted the Jordan's industry according to their gross output per cubic meter in a correlation with value added and operation surplus. .

**Table 7: Water Values in Jordan's industrial sector averages (2003-2008)**

| **Economic Activity** | **Water Consumption M3** | **Gross Output per M3** | **Gross value added Per M3** | **Operation surplus Per M3** |
|---|---|---|---|---|
| Ext. Petroleum and natural gas | 2,680 | 4,643 | 4,386 | 3,408 |
| Mining and quarrying | 8,004,420 | 59 | 34 | 17 |
| Man. of food & beverages | 3,671,000 | 254 | 71 | 26 |
| Man. tobacco products | 106,620 | 2,402 | 1,517 | 71 |
| Man. textiles | 113,720 | 523 | 228 | 111 |
| Man. wearing apparel | 599,420 | 504 | 278 | 200 |
| Tanning of leather | 44,420 | 518 | 176 | 71 |
| Man. Wood & Cork products | 58,120 | 598 | 219 | 121 |
| Man. Paper & Paper products | 412,760 | 339 | 114 | 40 |
| Publishing & printing | 229,360 | 595 | 295 | 102 |
| Man. Coke & refined petroleum | 801,040 | 3,121 | 298 | 388 |
| Man. Chemicals | 6,692,400 | 121 | 41 | 21 |
| Man. Rubber & Plastics | 292,380 | 533 | 176 | 70 |
| Man. non-metallic mineral | 3,656,340 | 146 | 71 | 32 |
| Man. basic metals | 775,140 | 413 | 143 | 67 |
| Man. fabricated metal products | 355,560 | 658 | 247 | 137 |
| Man. machinery and equipment | 140,120 | 784 | 272 | 122 |
| Man. electrical machinery | 126,340 | 1,738 | 437 | 211 |
| Man. Medical optical instruments | 115,020 | 260 | 109 | 33 |
| Man. motor vehicles | 40,260 | 1,084 | 369 | 160 |
| Man. transport equipment | 4,460 | 913 | 517 | 312 |
| Man. Furniture | 212,840 | 653 | 270 | 130 |
| Electricity, gas, & Steam | 1,169,620 | 298 | 123 | 25 |
| **Total industry** | **27,624,040** | **283** | **86** | **45** |

┬, ┴ confidence limits at a probability of 95%

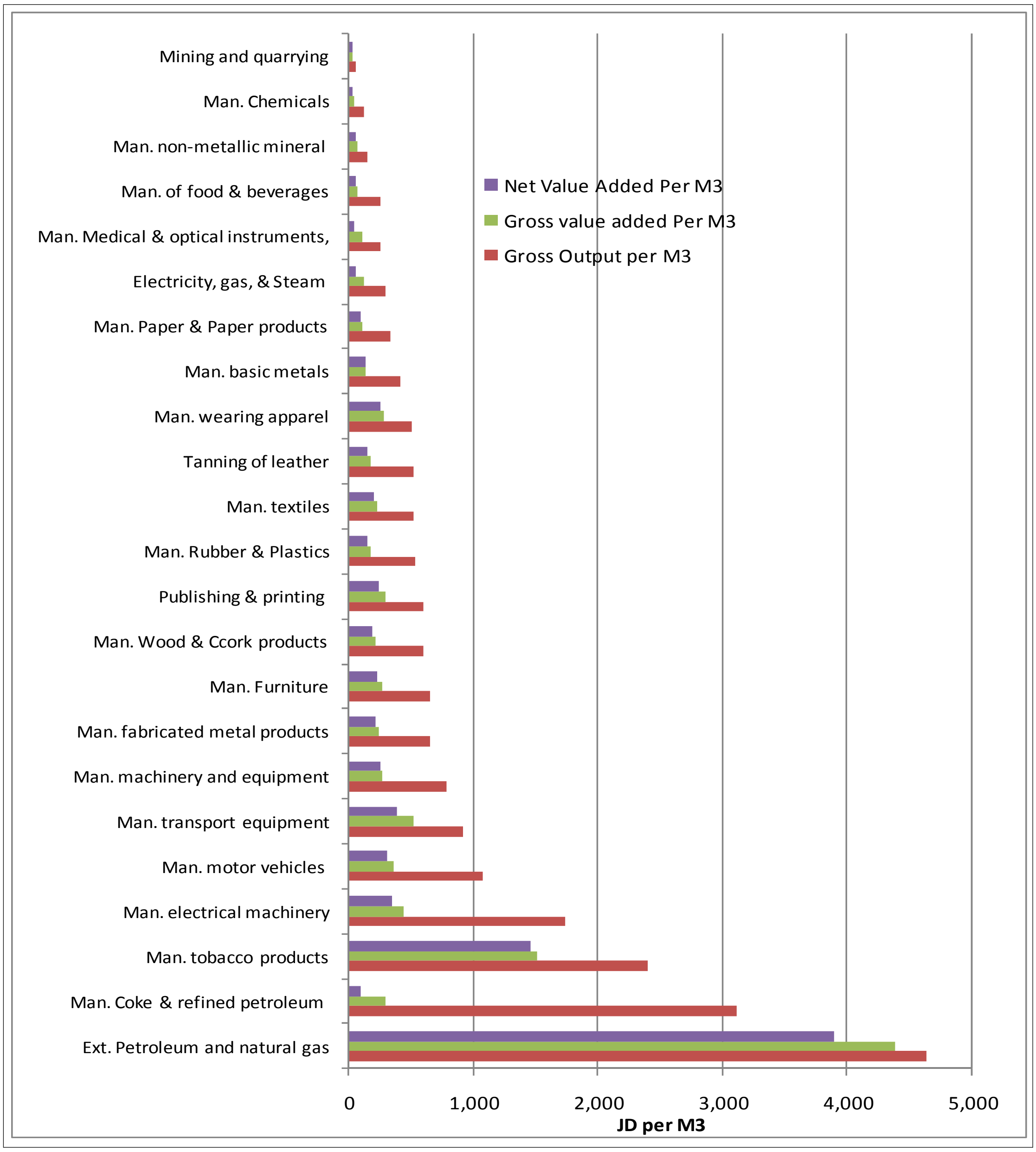



**Figure 11: Water Value in Jordan's industrial sector based on three indicators.**

## 5.4 Value of Water in Tourism and Services

The tourism sector remains an important element of the Jordanian economy, directly employing some 41,662 Jordanians and contributing 11.6% to the kingdom's GDP in 2009. Recent data show a rise in revenues generated by the tourism sector by 28% during the first six months of 2010, amounting to JD 1088.9 million compared to JD 850.7 million in 2009. The total tourism receipts JD2066.9 million in 2009. Tourists visiting the country continued to increase, with overall arrivals during the first six months of 2010 rising 24% compared to the same period of 2009. The total arrival in 2009 was 7,084,552 persons. The rising number of arrivals to the Kingdom increased the demand for accommodation and hotels. The number of hotels in Jordan increased from 177 in 1998 to 487 at the mid of 2010, increasing the number of rooms and beds to 23,867 rooms and 45,877 respectively as of June 2010. Therefore, the tourism sector contributes positively to the Jordanian economy composing 11.6% of the kingdom's GDP. Jordan is characterized by a rich heritage with a variety of natural, religious, historical and health interest represented by a large number of world-known sites such as Petra, Wadi Rum, Dead Sea, and the Baptism Site.

The tourism industry generates substantial economic benefits to both host countries and tourists' home countries. In a developing country such as Jordan, one of the primary motivations to promote itself as a tourism destination is the expected economic improvement. Amman has the highest number of nights spent since 2002 till 2010. Tourists usually take the capital as the base of their trip around Jordan. Amman provides better services and quality of accommodation compared to other cities that visitors are considering visiting, such as Madaba, Jerash or Irbid. Nights spent in Amman reached 3,491,162 nights compared to 715,496 nights at the second highest city of Aqaba. Amman is home to the majority of hotels at 321 hotels, followed by Aqaba with 45, Petra with 38 and the Dead Sea with 5 hotels. However, despite the fast increase in developing new hotels across the Kingdom, the uprise has been insufficient to cover the increasing demand.

In the year 2007 the hotels consumes about 5.3 mcm whereas restaurants consumes about 2.5 mcm. The water values in tourism sector about 38 JD/m3. Other services sectors such as wholesales and retailers have higher water vales ranged from 66 JD/m3 in food and beverages sales to 303 JD/m3 in the repair of personnel and household equipments. Table 8 shows the average water values in the services sector for the period (2003-2008)

The average water values for other sectors are range from 26 JD/m3 in Non-profit-Sporting activities to 2,298 JD/m3 in Post and telecommunications.

Main water consumers in other sectors are education, health care activities, supporting and auxiliary activity and construction. The value of water in education sector is amounted to 186 JD/m3, whereas 93 JD/m3 for health sector. The weighted average values of water in all other sector are estimated at 249 JD/m3 as shown in Table 9.

**Table 8: Water Values in Tourism and Services sector, averages (2003-2008)**

| ISIC-Code | Economic Activity | Water Consumption $m^3$ | Gross Output per $m^3$ | Gross value added Per $m^3$ | Net Value Added Per $m^3$ | Operation surplus Per $m^3$ |
|---|---|---|---|---|---|---|
| 55 | Hotels and restaurants | 4,773,080 | 74 | 38 | 28 | 7 |
| 522 | Retail sale of food & beverage | 901,360 | 99 | 66 | 63 | 45 |
| 50 | Sale, maintenance of vehicles | 1,883,480 | 138 | 107 | 103 | 55 |
| 523 | Other retail trade | 925,620 | 317 | 219 | 202 | 110 |
| 524 | Retail sale of second-hand | 34,760 | 382 | 259 | 230 | 168 |
| 526 | Repair of personal &household | 28,140 | 424 | 303 | 272 | 237 |
| 521 | Non-specialized retail trade | 386,460 | 435 | 320 | 255 | 185 |
| 51 | Wholesale trade | 739,700 | 671 | 535 | 471 | 138 |
| 525 | Retail trade not in stores | 4,980 | 3,349 | 2,302 | 329 | 1,650 |
| | **Total Services** | **9,677,580** | **176** | **123** | **107** | **49** |

**Table 9: Water Values in other sectors, averages (2003-2008)**

| ISIC-Code | Economic Activity | Water Consumption $m^3$ | Gross Output per $m^3$ | Gross value added Per $m^3$ | Net Value Added Per $m^3$ | Operation surplus Per $m^3$ |
|---|---|---|---|---|---|---|
| 45 | Total: Construction-Contractors | 2,668,560 | 303 | 73 | 65 | 24 |
| 60 | Land transport; transport | 199,900 | 3,516 | 2,232 | 1,871 | 1,514 |
| 61 | Water transport | 46,320 | 1,718 | 762 | 352 | 502 |
| 62 | Air transport | 85,820 | 5,270 | 1,278 | 1,030 | 318 |
| 63 | Supporting and auxiliary activities | 2,407,440 | 153 | 106 | 98 | 63 |
| 64 | Post and telecommunications | 258,500 | 3,306 | 2,298 | 1,799 | 977 |
| 65 | financial intermediation | 383,680 | 1,509 | 1,171 | 1,105 | 582 |
| 66 | Total Insurance | 77,300 | 792 | 461 | 434 | 140 |
| 67 | Administration of financial markets | 46,140 | 1,522 | 1,293 | 1,226 | 970 |
| 70 | Real estate activities | 308,220 | 121 | 91 | 74 | 49 |
| 71 | Renting of mach.& equipment | 50,940 | 339 | 216 | 138 | 52 |
| 72 | Computer & related activities | 50,600 | 574 | 390 | 258 | 155 |
| 74 | Other business activities | 348,360 | 461 | 313 | 294 | 114 |
| 80 | Education | 1,122,920 | 243 | 186 | 165 | 40 |
| 85 | Health activities | 1,199,200 | 164 | 93 | 75 | 27 |
| 85 | Non-profit : Social work activities | 147,320 | 142 | 84 | 59 | 0 |
| 91 | Non-profit : membership org. | 633,500 | 143 | 80 | 58 | 0 |
| 92 | Recreational, cultural & sporting | 394,900 | 123 | 62 | 33 | -10 |
| 92 | Non-profit : Sporting activities | 154,260 | 57 | 26 | 19 | 0 |
| 93 | Other service activities | 610,540 | 77 | 49 | 47 | 31 |
| | **Total** | **11,194,420** | **438** | **249** | **212** | **112** |

## 5.5 Value of Water in Agriculture

Analyses of water values in the agricultural sector resorted to more detailed data, which allowed for more specific calculations. For crops produced in Jordan, crop water requirements (m3 du-1) are quoted from different sources as shown in Table 3. Total water requirements for each locally produced crop was calculated using another set of DOS data on average land productivity (ton du-1) and total cultivated area (du) Total crop yield (ton) can, thus, be calculated and the respective total water requirements for each crop can be calculated

The revenue earned for each crop was calculated by multiplying their production by farm gate price drawn from DOS. The cost of production for a specific crop without irrigation cost was calculated. This cost of production was deducted from gross returns of that crop.

On the input side, costs of fertilizers, pesticides, herbicides, fuel and labor were taken into account. These were considered the relevant inputs in the production process. For fertilizers, pesticides and herbicides, the competitive market prices were used to determine costs. For these inputs and the output, market prices are thus considered to equal the shadow price. On the other hand, for the costs of family labor a shadow price was calculated based on previous studies conducted in Jordan and on the scarce data on wage labor in the dataset. A value of JD 7 per day was used. This minimum wage per day would be a correct reflection of the cost of family labor. This type of price corrections, as proposed by Lange & Hassan (2007), is necessary to fulfill the assumptions of the RIM. These net returns were further divided by the amount of water applied (M3) to get the price of water. The contribution of water in the production of each crop was represented by this value.

The residual method is used to determine the disaggregated economic value of irrigation water used in agriculture across crops, zones and seasons. This method relies on the belief that the value of a good (its price by its quantity) is equal to the summation of the quantity of each input multiplied by its average value. By applying this method to horticulture with a subdivision of the water basin in Jordan, it was found that the value of irrigation water use is not equated across the crops zones.

The use of residual imputation approach is a form of a budget analysis technique that seeks to find the maximum return attributable to the use of water by calculating the total returns to production and subtracting all non-water related expenses. The value of the product is allocated among the range of marketed inputs that go into its production. The residual value is assumed to equal the returns to water and represents the maximum amount the producer would be willing to pay for water and still cover input costs. The approach is sometimes categorized as a farm crop budget technique in applications to agriculture. A difficulty is that the residual return (after subtraction of the costs of all measured non-water inputs) is the return to water plus all unmeasured inputs, and hence will result in overstatement of the value of water. The approach is also extremely sensitive to small variations in assumptions concerning the nature of the production function or prices. Thus, it is most suitable for use in cases where the residual input contributes significantly to output. Calculation of residual values requires considerable information and accuracy in allocating contributions among the range of resource inputs.

In its application to irrigated agriculture, the yield comparison approach values irrigation water as the difference in per dunum returns between irrigated and non-irrigated land, using observed farm budget data. It is assumed that the additional net returns obtained from the use of irrigation in the production process represent the maximum amount that the producer would be willing to pay for use of irrigation water. However, the approach assumes homogeneity in land, crops, husbandry, quality of produce and price between irrigated and non-irrigated production. The heterogeneity that occurs in these factors in reality brings into question use of the difference in net returns as the net willingness to pay for irrigation water.

### 5.5.1 Results of Mathematical Programming

In constrained optimization in economics, the shadow price is the change in the objective value of the optimal solution of an optimization problem obtained by relaxing the constraint by one unit – it is the marginal utility of relaxing the constraint, or equivalently the marginal cost of strengthening the constraint.

More formally, the shadow price is the value of the Lagrange multiplier at the optimal solution, which means that it is the infinitesimal change in the objective function arising from an infinitesimal change in the constraint. This follows from the fact that at the optimal solution the gradient of the objective function is a linear combination of the constraint function gradients with the weights equal to the Lagrange multipliers. Each constraint in an optimization problem has a shadow price or dual variable.

The value of the shadow price can provide decision makers powerful insight into problems. For instance if you have a constraint that limits the amount of water available to one hundred cubic meter, the shadow price will tell you how much you would be willing to pay for an additional one cubic meter of water. If your shadow price is JD 0.5 for the water constraint, for instance, you should pay no more than JD 0.5/$m^3$ for an additional cubic meter. Water costs of less than JD 0.5/$m^3$ will increase the objective value; Water costs of more than JD 0.5 /$m^3$ will decrease the objective value. Water costs of exactly JD 0.5/ $m^3$ will cause the objective function value to remain the same.

In the linear programming (LP) model, we can use the optimal solution of the resources allocation and get shadow prices of the resources from the optimal solution of the dual problem according to the water resources constraint line in the linear programming. In nonlinear programming the shadow prices are equal to the Lagrange multipliers. In dynamic programming the shadow prices are equal to the vector in the Hamilton matrices.

Therefore, Shadow price reflect water resource value. The shadow price is a good index to scale water scarcity, which not only reflects the value of water resource but also reveals the demand and supply situation of water resource. Many scholars have tried to obtain the shadow price of water by solving a linear program (Huang, 1987; Jiang, 1998; Wang et al, 1999; Zhang, 1990; Jing He et al, 2006).

In addition to other factors, farmers rely on GM of crops to decide which crops are to be grown where farmers normally avoid growing risky crops with low GM's.

Demand price elasticity for water: Several price levels of irrigation water was applied to develop the water demand functions. Water demand function was used to estimate the elasticity of water demand in both basins 21 & 22 to determine the farmers' response to changes in irrigation water price. The general demand equation was: $Q = a - bp$ . Where *Q* = quantity demanded in cubic meters, *P* = water price in JD/$m^3$ and. *a, b* = equations parameters. The negative sign of *p* shows that the function has a negative slope which reflects the negative relationship between price and quantity demanded.

Table 10 shows a comparison between selected vegetables according to their GM's, productivity per dunum and profitability per cubic meter of irrigation water. Results show that in general there is an increase in the productivity of vegetable crops that are irrigated with fresh water from KAC compared to those irrigated with blended TWW from KTD during Autumn and spring seasons. Consequently, the GM's of crops irrigated from KAC were higher than those irrigated from blended water, this has been reflected on the profitability of one cubic meter of water. The average GM value and the profitability of one cubic meter for vegetable crops irrigated from KAC during autumn were 355 JD/du, and 1.18 JD/m3, respectively. While it was 199 JD/du and 0.66 JD/m3 for those vegetables irrigated from KTD. During the spring season the situation has not changed where the Gross Margin and the profitability of crops irrigated with fresh water was higher than those irrigated with blended TWW. However, it can be noticed that the productivity and the GM of vegetables during the spring season are in general greater than those during Autumn season, this can be attributed to high temperatures during spring season.

Demand price elasticity for water: Several price levels of irrigation water was applied to develop the water demand functions. Water demand function was used to estimate the elasticity of water demand in both basins 21 & 22 to determine the farmers' response to changes in irrigation water price. The general demand equation was: $Q = a - bp$ . Where *Q* = quantity demanded in cubic meters, *P* = water price in JD/m$^3$ and. *a, b* = equations parameters. The negative sign of *p* shows that the function has a negative slope which reflects the negative relationship between price and quantity demanded.

**Table 10: Water Values and gross margin per unit area for selected crops irrigated with the blended and fresh water.**

| Crop | Cultivation method | CWR m3/du | Autumn Season Fresh water (KAC) Yield kg/du | GM JD/du | Profit (JD/m3) | Blended Treated WW (KTD) Yield kg/du | GM JD/du | Profit (JD/m3) |
|---|---|---|---|---|---|---|---|---|
| Cucumber | Plastic house | 336 | 9,871 | 470.7 | 1.401 | 8,581 | 439.4 | 1.308 |
| Tomato | Plastic house | 344 | 10,500 | 783.0 | 2.276 | 8,647 | 462.6 | 1.345 |
| Cabbage | Open field | 197 | 3,800 | 97.9 | 0.497 | 3,000 | 100.3 | 0.509 |
| Potato | Open field | 384 | 3,400 | 201.6 | 0.525 | 2,500 | 137.9 | 0.359 |
| Sweet pepper | Open field | 924 | 5,600 | 288.7 | 0.312 | 3,599 | 223.3 | 0.242 |
| Hot pepper | Open field | 462 | 2,200 | 107.9 | 0.234 | 2,342 | 59.0 | 0.128 |
| Squash | Open field | 197 | 3,000 | 227.7 | 1.156 | 3,245 | 166.8 | 0.847 |
| Bean | Plastic house | 241 | 2,950 | 976.1 | 4.050 | 860 | 129.8 | 0.539 |
| Eggplant | Plastic house | 1000 | 10,901 | 294.8 | 0.295 | 7,500 | 203.0 | 0.203 |
| Eggplant | Open field | 500 | 5,051 | 105.1 | 0.210 | 4,053 | 70.3 | 0.141 |
| **Average** | | | | **355.3** | **1.096** | | **199.2** | **0.562** |
| | | | **Spring Season** | | | | | |
| Tomato | Open field | 398 | 7,950 | 574.2 | 1.443 | 5,300 | 313.2 | 0.787 |
| Sweet pepper | Open field | 536 | 3,000 | 174.3 | 0.325 | 1,680 | 97.6 | 0.182 |
| Hot Pepper | Plastic house | 1072 | 4,400 | 448.1 | 0.418 | 4,400 | 406.0 | 0.379 |
| Onion | Open field | 471 | 3,000 | 343.7 | 0.730 | 2,500 | 185.6 | 0.394 |
| Potato | Open field | 350 | 5,000 | 719.2 | 2.055 | 4,500 | 546.7 | 1.562 |
| Beans | Open field | 213 | 1,300 | 556.8 | 2.614 | 784 | 146.5 | 0.688 |
| **Average** | | | | **469.4** | **1.264** | | **282.6** | **0.665** |

*Source: Estimated from collected Primary data.*

The elasticity of demand is the relative change in quantity demanded resulting from a relative change in price, and the price elasticity of demand was calculated at two points; the current price that has been calculated 0.012-0.015 JD/m3 and the average prices used for parametric LP model.

Table 11 demonstrates that the results of linear programming model where the average GM of all vegetables along the year (for Autumn and Spring seasons together), that are irrigated by fresh water (450 JD/du) are higher that GM of vegetables irrigated by blended TWW (342.8 JD/du), on other hand, it can be noticed that crop water requirements are higher in the case of vegetables that are irrigated with blended TWW. **The shadow prices of water show clearly the impact of water quality on the productivity of vegetable crops. The shadow price of water was 0.240 JD/m3 for each additional cubic meter of blended TWW, while it was 0.389 JD/m3 for fresh water form KAC..**

Therefore, the shadow price will tell you how much you would be willing to pay for an additional one cubic meter of water. The shadow price of KAC water is JD 0.389 for the water constraint. This means for instance, farmers should pay no more than JD 0.389/$m^3$ for an additional cubic meter. Water costs of less than JD 0.389/$m^3$ will increase the objective of farmers to maximize profit; Water costs of more than JD 0.389/$m^3$ will decrease the farmer net profit.

**Table 11: Average GM, water consumption per dunum and shadow prices of water according to irrigation water qualities along the year.**

| Area irrigated from | Gross Margin JD/du | Water quantity m3/du | Water cost JD/du | Shadow price JD/m3 | Profitability JD/m3 |
|---|---|---|---|---|---|
| KTD | 342.8 | 591 | 11.82 | 0.240 | 0.596 |
| KAC | 450.3 | 482 | 9.64 | 0.389 | 0.944 |

*Source: Estimated from the linear programming model.*

Table 12 shows the water demand elasticities were inelastic at the current water prices and also at middle point in both catchments areas with a correct sign (negative). However it can be noticed that the elasticity in the area irrigated from KAC is greater than the elasticity in the area irrigated from KTD at the current and middle points. This shows that the responsiveness of farmers in basin 21 to changes in water prices is higher than those in basin 22. The price elasticities of demand of Blended TWW and fresh water, derived from equations in Table 12, are estimated at –0.024 and -0.011, at the actual water prices of JD 0.03 per cubic meter, respectively. The price elasticities of demand of Blended TWW and fresh water, at the respective midpoint prices that were applied to the parametric linear programming model are -0.41 and -0.68, respectively, so that demand is inelastic for both water qualities (Table 12).

**Table 12: Price elasticity of irrigation water in both catchments areas:**

| Source of Irrigation | Demand equation | Price Elasticity | |
|---|---|---|---|
| | | Current price (0.02 JD/m3) | Average price |
| Irrigated from KTD | Qd=6042477-6912512 P | - 0.024 | - 0.41 |
| Irrigated from KAC | Qd=4323188-2642166 P | - 0.011 | - 0.68 |

The result shows a difference in crop yield according to water quality. Fresh surface water has a salinity of less than 1000 ppm. Fresh water is used in Northern Jordan Valley and uplands. The treated wastewater, which appears to be overall of acceptable quality, but create an important problems of salinity and bacteriological contamination of a localized nature . The increasing proportion of the poor quality KTR and KTR/KAC waters has been postulated to cause a corresponding deterioration in quality of irrigated soils, especially in the Middle Jordan Valley. That was due to the little supply of the surface water where farmers have been forced to seek additional quantities by over pumping ground water. This ongoing practice has resulted in a continuous salinization of the groundwater and a subsequent salinity problem in the irrigated soils due to continuous accumulation of salt in the root zones. Treated Wastewater & mixed with fresh water: treated wastewater is becoming more and more as a major water source for irrigation particularly in Middle Jordan Valley, where it is mixed with fresh water coming through King Abdulla Cannel. However, Jordan has worked to manage irrigation with wastewater for several decades. Since the early 1980s the general approach has been to treat the wastewater and either discharge it to the environment where it mixes with freshwater flows and is indirectly reused downstream, or to use the resulting effluent to irrigate restricted, relatively low-value crops. Given the diminishing per capita freshwater supply, the increasing dominance of effluent in the water balance and the overloading of wastewater treatment plants. Poor water quality can limit the crops a farmer is able to grow. Low water quality also reduces water use efficiency and thus may reduce yield but increase water use.

Therefore, water quality is multi-dimensional. It includes concentration of certain chemicals, level of salinity, concentration of bacteria and organic matter, as well as temperature. The choice of which water quality indicators are meaningful depends on the activities the water is used for. For example, production of certain crops depends on salinity levels. So, if one switches from high quality to more saline water, it may imply a necessary transition between crops. In cases where the quality of water as an input of a production process one can measure it values using markets, several methods have been developed to estimate these values.

Since KAC water undergoes mixing with KTR water in Sawalha town, the quality of KAC water. The available data show salinity and major soluble ions in water samples collected from key sites along the pathway of KAC starting from the Tunnel point (intake point from the River Yarmouk) to Zahrit Er-Raml location to the south of the KAC/KTR mixing point of Mu'addi town..

The abstraction of water from KAC to the Zai treatment plant decreases the quantity of good quality water used to dilute the KTR lower quality waters. Water quality at different locations. The salinity of water is dependent upon the mixing ratio of KTR and KAC..Table 13 show the chemical prosperities of irrigation water in Jordan Valley. Figure 12 and Figure 13 present the average and the range of total dissolved solids (TDS) and electrical conductivity (EC) for samples from different locations along the flow path of the irrigation water. TDS and EC are aggregate measures of the concentration of dissolved constituents in the water and will reflect changes in salinity.

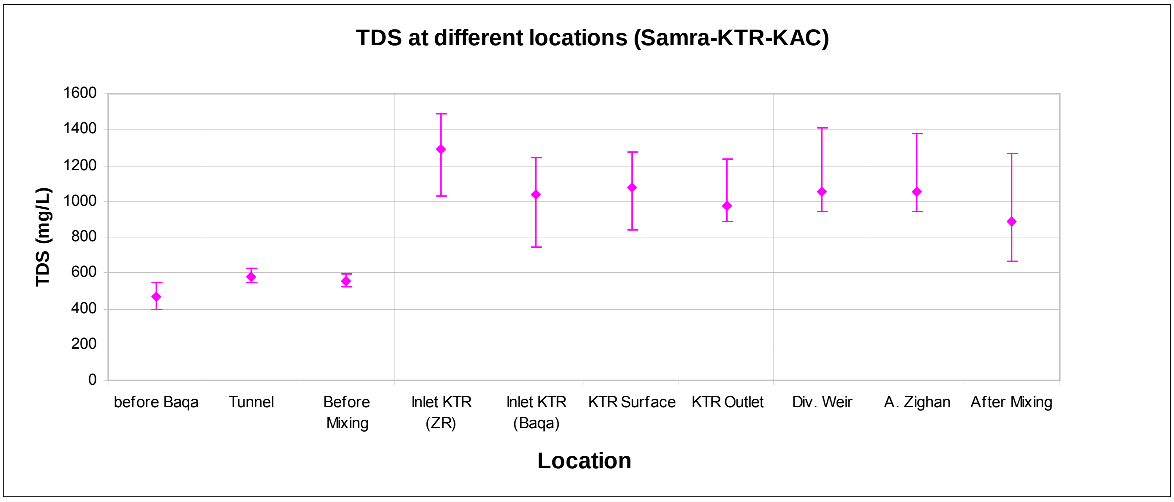



**Figure 12: TDS at different sites of KAC**

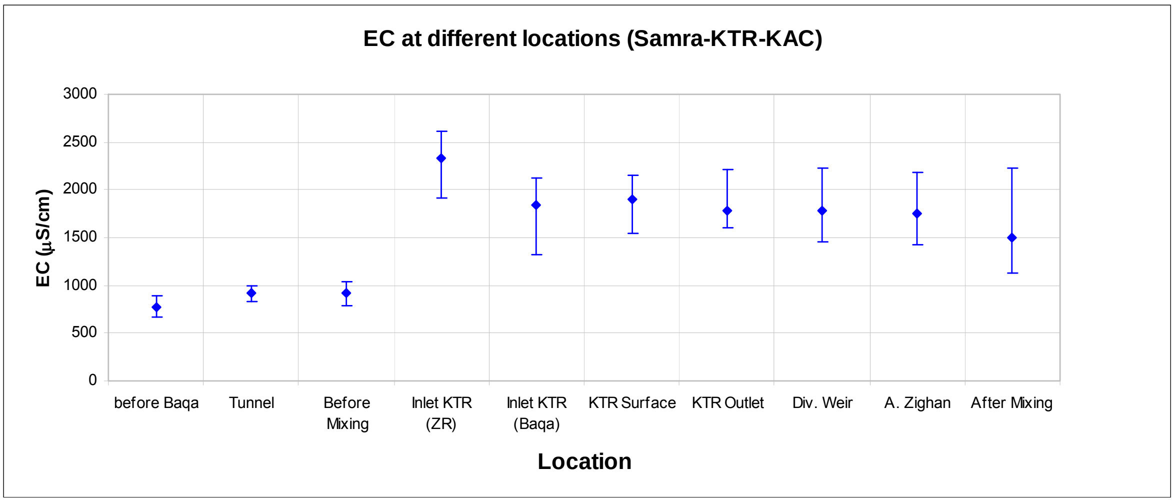



**Figure 13: EC at different sites along KAC**

**Table 13: Long Term average of Chemical Properties of Irrigation Water in JV**

| Source | **KAC** | **KTR** |
|---|---|---|
| EC (dS/m) | 0.91 | 1.85 |
| pH | 8.28 | 8.09 |
| Na (meq/l) | 3.33 | 7.28 |
| K ppm | 0.16 | |
| Ca (meq/l) | 2.89 | 5.41 |
| Mg (meq/l) | 2.38 | 4.14 |
| Ca + Mg (meq/l) | 5.44 | 10.96 |
| Ca/Mg | 1.21 | 1.31 |
| Cl (meq/l) | 2.87 | 8.1 |
| $SO_4$ (meq/l) | 1.45 | 3.37 |
| HCO3 (meq/l) | 4.68 | 6.75 |
| $NO_3$ ppm | 4.53 | 13.1 |
| B ppm | 0.19 | 0.46 |
| SAR | 2.01 | 3.2 |

long term average (1990-2008)

The damages to agricultural resources resulted from additional wastewater effluents causing a further deterioration in irrigation water quality associated with using of drip irrigation technologies without leaching the salt accumulation in the soil due to water shortages. The additional salts from the WWTP effluents and in particular, Boron have resulted in additional accumulations in the soils. There are two components to caused lower yield and crop productivity in the areas used blended wastewater, These are:

1. lost productive capacity of soils resulting in lower yields and;
2. lost assimilative capacity of soils, such that salts have accumulated but not to the threshold level where yields are affected (however, the threshold level is expected to be reached in the near future.

Soil damage by salt and toxic element accumulation was estimated using the soil and water data (from two sources, KTR and KTR+KAC mixture). Since salinity is a very dynamic parameter and easily fluctuate with time of sampling and other field conditions. Therefore, assessment of soil damage by salinity using more reliable approach is needed

On the other hand, SAWAS model as an optimizing linear model for analyzing agriculture given various water qualities in different months was used in this study. The objective function that is maximized in SAWAS is the total annual net income of agriculture in the Jordan Valley. Net income is considered in two parts. The first of these is what was referred to above as "water-related contribution" (WRC). WRCj, the water-related contribution of activity j, is defined as the gross income generated by activity j per unit area less all direct expenses (machinery, labor, materials, fertilizers) associated with doing so except for direct payments for water. WRCj thus measures the maximal ability of the jth activity to pay for water. WRC enters the

Table 14 shows the optimal allocation of water quantities (surface and groundwater abstraction) compared to the actual use over twelve months. It also shows that water has been allocated at a high rate during winter compared to summer where the peak of production takes place. Moreover Figure 14 show the dynamics of optimal water allocation compared to actual one in the Jordan Valley.

The result of the optimal cropping pattern obtained by SAWAS will be discussed in the subsequent chapter related to intra-sectoral water allocation

**Table 14: Optimal Monthly Water Allocation and Actual Supply in the Jordan Valley**

| Month | Actual Monthly Water allocation (MCM) | Optimal Water Allocation (MCM)y |
|---|---|---|
| Oct | 13.921 | 19.174 |
| Nov | 12.582 | 15.666 |

| | | |
|---|---|---|
| Dec | 16.482 | 10.483 |
| Jan | 20.949 | 12.222 |
| Feb | 22.911 | 14.460 |
| Mar | 20.868 | 18.589 |
| Apr | 21.082 | 23.569 |
| May | 21.609 | 16.805 |
| June | 22.151 | 14.234 |
| July | 23.289 | 14.815 |
| Aug | 18.621 | 17.628 |
| Sep | 14.496 | 19.628 |
| Total | **228.961** | **197.273** |

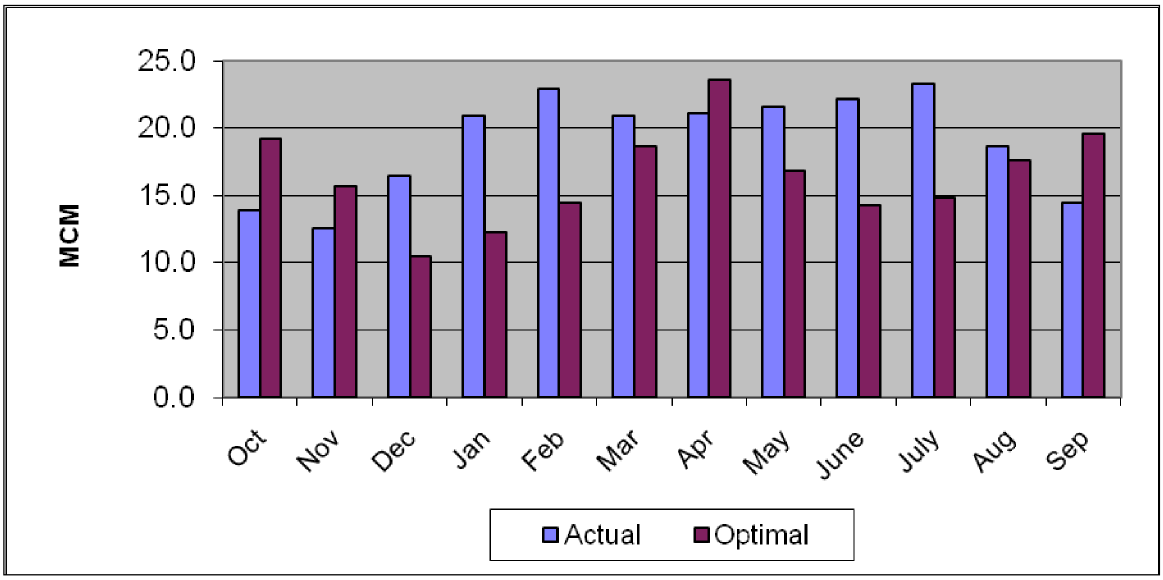



**Figure 14: Optimal Monthly Water Allocation and Actual Supply in the Jordan Valley**

### 5.5.2 Value of Water in Agriculture Using Residual Imputation Method (RIM)

Crop production is then a dynamic process in which decisions about inputs are made sequentially as crops are planted, grown and harvested. Linking water supply and agricultural production is a complex research issue, as it integrates different dimensions of water supply and several decisions taken by farmers at different periods of time (planning of farming activities, water scheduling, water use, etc.). Farm level decisions use field level information on the soil-water-plant relationship, and watercourse level information regarding potential access to (or sharing of) water resources. Irrigation management activities are usually individual decisions but often include interactions with other water users [Strosser & Rieu 1997]. Each farmer's decision in this process is contingent upon results of past decisions, past events, and information regarding future events. Thus, the character of his decisions could be either *extensive* (as for land devoted to a crop) or *intensive* (as for application of fertilisers, water, etc.).

#### *5.5.2.1 Value of Water in Field Crops*

The estimated quantities of water consumed by crop are shown in Table 15. Clover for livestock feed consume about 25 mcm or about 60% of water used in field crops followed by corn with about 5.4 mcm (12.8%), followed by wheat and barley with a percent of 10% and 9% of total water used in field crop production, respectively.

The results of the calculation of value added per cubic meter of water, presented in Table 16, show that the value of water range from the highest of 3.44 JD/$m^3$ for Garlic to the lowest of less than 0.08 JD/$m^3$ for irrigated Vetch, Lentils, Sesame, Tobacco, Broom millet and other field crops. The cost of water used to produce these crops in Jordan Valley is 0.012 JD/$m^3$. Therefore, it is still profitable for farmers to produce these crops under irrigation. However, the weighted average for water value in field crop production is 0.44 JD/$m^3$. However, it is worth mentioning that Garlic is classified as field crop according to DOS database, it might be that historically garlic is cultivated in an open field in highland areas.

**Table 15: Production, Irrigated Areas, Water Use and Economic Return of Field Crops in 2008 in Jordan**

| No. | Crops | Production (ton) | Planted Areas (du) | Water Consumption (M3) in 2008 | Gross Output (JD) | Value Added (JD) | Operation Surplus (JD) |
|---|---|---|---|---|---|---|---|
| 1 | Wheat | 2,597 | 12,146 | 4,299,986 | 1,122,077 | 785,454 | 561,039 |
| 2 | Barley | 1,748 | 9,728 | 2,391,391 | 555,826 | 400,195 | 300,146 |
| 3 | Lentils | 4 | 48 | 16,800 | 1,764 | 1,058 | 582 |
| 4 | Vetch | 6 | 58 | 15,135 | 1,816 | 1,090 | 599 |
| 5 | Chick-peas | 77 | 520 | 182,189 | 46,200 | 27,720 | 15,246 |
| 6 | Maize | 18,544 | 7,965 | 5,417,580 | 3,209,997 | 1,540,799 | 898,799 |
| 7 | Sorghum | 9,607 | 6,939 | 4,091,083 | 1,152,900 | 599,508 | 368,928 |
| 8 | Broom millet | 9 | 71 | 42,300 | 1,385 | 762 | 485 |
| 9 | Tobacco | 0 | 4 | 2,092 | 128 | 72 | 36 |
| 10 | Garlic | 228 | 61 | 17,681 | 104,804 | 60,786 | 35,633 |
| 11 | Sesame | 1 | 22 | 9,011 | 709 | 361 | 191 |
| 12 | Clover | 150,083 | 45,693 | 25,561,269 | 21,762,012 | 15,233,408 | 10,010,525 |
| 13 | Alfalfa | 1 | 52 | 29,968 | 176 | 121 | 79 |
| 14 | Others FC | 4 | 704 | 212,908 | 1,079 | 550 | 291 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Field Crops** | **182,911** | **84,009** | **42,289,392** | **27,960,873** | **18,651,884** | **12,192,580** |

**Table 16: Computed water values (JD/m3) for Field Crops in 2008**

| No. | Crops | Gross Output (JD/ M3) | Value Added (JD/M3) | Operation Surplus (JD/M3) |
|---|---|---|---|---|
| 1 | Wheat | 0.261 | 0.183 | 0.130 |
| 2 | Barley | 0.232 | 0.167 | 0.126 |
| 3 | Lentils | 0.105 | 0.063 | 0.035 |
| 4 | Vetch | 0.120 | 0.072 | 0.040 |
| 5 | Chick-peas | 0.254 | 0.152 | 0.084 |
| 6 | Maize | 0.593 | 0.284 | 0.166 |
| 7 | Sorghum | 0.282 | 0.147 | 0.090 |
| 8 | Broom millet | 0.033 | 0.018 | 0.011 |
| 9 | Tobacco | 0.061 | 0.034 | 0.017 |
| 10 | Garlic | 5.928 | 3.438 | 2.015 |
| 11 | Sesame | 0.079 | 0.040 | 0.021 |
| 12 | Clover | 0.851 | 0.596 | 0.392 |
| 13 | Alfalfa | 0.006 | 0.004 | 0.003 |
| 14 | Others FC | 0.005 | 0.003 | 0.001 |
| | **Field Crops** | **0.661** | **0.441** | **0.288** |

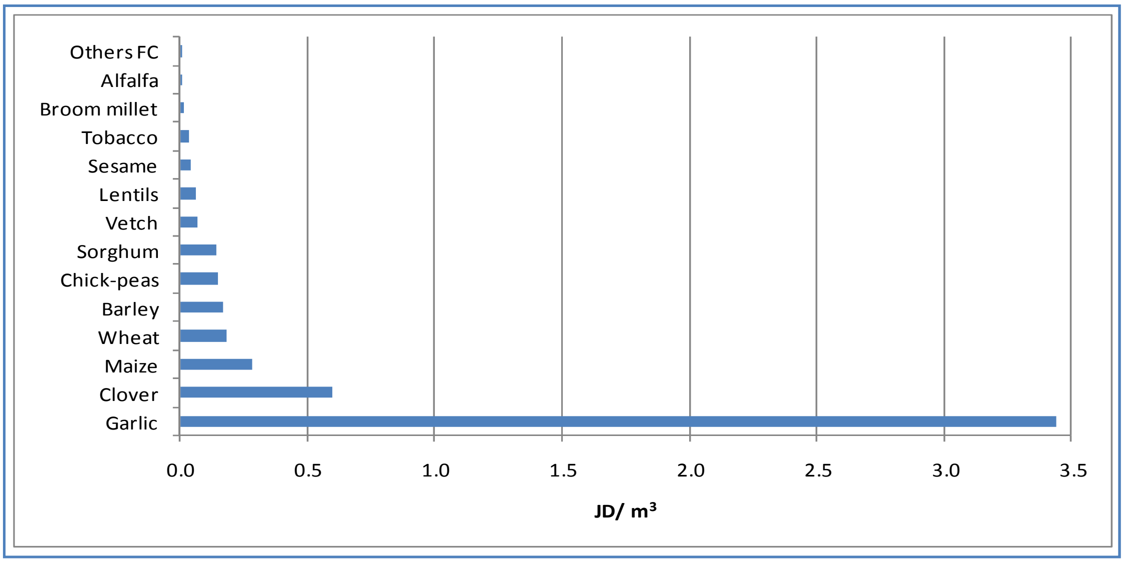



**Figure 15: Water Values in field crop production in Jordan for the year 2008.**

### *5.5.2.2 Value of Water in Vegetables*

The quantities of water consumed by vegetables crops are shown in Table 17. It is clearly shows that tomatoes consume 48 MCM or about 38% of water used in vegetable production followed by potatoes with about 16 MCM (12.7%), followed by eggplants (7.3%), squash (6.5%), cauliflower (4%), and water melon (3.5%)

Irrigation water values (VMPw) are calculated per crop for vegetables in Jordan. Results of the RIM calculations of water value per crop are presented in Table 18.

Cucumber has the highest water values (6.05 JD/m3), followed by Sting Bean (2.64 JD/m3), and sweet pepper (2.54 JD/m3). The lowest return to one cubic meter was found for Squash (0.67 JD/m3), Radish (0.66 JD/m3) and Hot pepper with the lowest value of (0.38 JD/m3).

Using the operation surplus as an indicator for net profit, again cucumber has the heist net profit of (3.95 JD/m3). Followed by String beans (2.24 JD/m3), Sweet pepper of (1.36 JD/m3), and Cow-peas (1.25 JD/m3) then Okra with about (1.0 JD/m3).

The vegetables crop are ascending sorted as shown in Figure 16, whereas Figure 17 shows the scatter plot correlation between water uses and water values for vegetable crops. One crop (tomatoes) consume about 50 MCM of water with an gross value added of about 1 JD/$m^3$, whereas cucumber consume about 3 MCM and has the highest value added per cubic meter.

**Table 17: Production, Irrigated Areas, Water Use and Economic Return of Vegetables grown in 2008**

| No. | Crops | Production (ton) | Planted Areas (du) | Water Consumption (M3) in 2008 | Gross Output (JD) | Value Added (JD) | Operation Surplus (JD) |
|---|---|---|---|---|---|---|---|
| 1 | Tomatoes | 598,200 | 124,000 | 48,357,950 | 80,278,499 | 56,632,832 | 37,161,647 |
| 2 | Squash | 47,470 | 30,716 | 8,375,069 | 11,136,562 | 5,679,646 | 3,786,431 |
| 3 | Eggplants | 99,818 | 29,912 | 9,366,229 | 15,691,327 | 9,854,153 | 5,852,865 |
| 4 | Cucumber | 125,478 | 13,855 | 3,379,942 | 29,236,435 | 20,465,504 | 13,374,340 |
| 5 | Potato | 139,787 | 50,735 | 16,240,028 | 30,068,141 | 15,936,115 | 9,020,442 |
| 6 | Cabbage | 22,263 | 5,273 | 1,604,944 | 2,680,477 | 1,688,701 | 1,206,215 |
| 7 | Cauliflower | 54,535 | 19,583 | 6,024,688 | 10,225,305 | 6,441,942 | 4,601,387 |
| 8 | Hot pepper | 15,049 | 8,280 | 2,295,914 | 1,354,419 | 886,091 | 568,856 |
| 9 | Sweet pepper | 36,365 | 8,646 | 2,253,241 | 8,974,947 | 5,743,966 | 3,083,393 |
| 10 | Broad beans | 8,176 | 8,307 | 2,098,632 | 3,482,335 | 2,263,518 | 1,775,991 |
| 11 | String beans | 11,063 | 8,462 | 1,815,341 | 6,224,218 | 4,790,158 | 4,068,149 |
| 12 | Peas | 1,319 | 1,353 | 330,397 | 622,789 | 404,813 | 317,622 |
| 13 | Cow-peas | 477 | 456 | 120,882 | 308,035 | 197,142 | 150,937 |
| 14 | Jew's mallow | 33,955 | 9,453 | 2,175,827 | 3,796,203 | 2,163,835 | 1,670,329 |
| 15 | Okra | 3,954 | 6,282 | 2,106,038 | 5,652,610 | 3,699,068 | 2,134,426 |
| 16 | Lettuce | 41,570 | 11,994 | 3,458,312 | 5,749,152 | 3,762,245 | 2,731,997 |
| 17 | Sweet melon | 28,174 | 6,894 | 2,270,603 | 6,074,382 | 3,069,588 | 1,648,182 |
| 18 | Water melon | 97,527 | 21,851 | 4,583,496 | 13,253,892 | 7,554,719 | 3,976,168 |
| 19 | Spinach | 4,850 | 1,143 | 509,797 | 664,477 | 434,834 | 275,891 |
| 20 | Onion green | 3,426 | 1,286 | 878,882 | 1,248,158 | 723,931 | 474,300 |
| 21 | Onion dry | 22,885 | 9,266 | 4,344,118 | 5,323,105 | 2,980,939 | 1,650,163 |
| 22 | Snake cucumb | 540 | 619 | 146,798 | 183,189 | 119,879 | 69,172 |
| 23 | Turnip | 312 | 94 | 21,102 | 34,632 | 22,663 | 13,077 |
| 24 | Carrot | 7,391 | 1,887 | 464,938 | 948,291 | 620,562 | 358,075 |
| 25 | Parsley | 2,689 | 716 | 173,525 | 322,687 | 211,167 | 121,847 |
| 26 | Radish | 665 | 395 | 99,298 | 100,743 | 65,926 | 38,041 |
| 27 | Others Veg. | 8,279 | 6,082 | 3,955,877 | 1,200,426 | 785,559 | 453,281 |
| | Vegetables | 1,416,219 | 387,540 | 127,451,868 | 244,835,435 | 157,199,496 | 100,583,222 |

**Table 18: Computed water values (JD/m3) for vegetables in 2008**

| No. | Crops | Gross Output (JD/ M3) | Gross Value added (JD/M3) | Operation Surplus (JD/M3) |
|---|---|---|---|---|
| 1 | Tomatoes | 1.660 | 1.171 | 0.768 |
| 2 | Squash | 1.330 | 0.678 | 0.452 |
| 3 | Eggplants | 1.675 | 1.052 | 0.625 |
| 4 | Cucumber | 8.650 | 6.055 | 3.957 |
| 5 | Potato | 1.851 | 0.981 | 0.555 |
| 6 | Cabbage | 1.670 | 1.052 | 0.752 |
| 7 | Cauliflower | 1.697 | 1.069 | 0.764 |
| 8 | Hot pepper | 0.590 | 0.386 | 0.248 |
| 9 | Sweet pepper | 3.983 | 2.549 | 1.368 |
| 10 | Broad beans | 1.659 | 1.079 | 0.846 |
| 11 | String beans | 3.429 | 2.639 | 2.241 |
| 12 | Peas | 1.885 | 1.225 | 0.961 |
| 13 | Cow-peas | 2.548 | 1.631 | 1.249 |
| 14 | Jew's mallow | 1.745 | 0.994 | 0.768 |
| 15 | Okra | 2.684 | 1.756 | 1.013 |
| 16 | Lettuce | 1.662 | 1.088 | 0.790 |
| 17 | Sweet melon | 2.675 | 1.352 | 0.726 |
| 18 | Water melon | 2.892 | 1.648 | 0.867 |
| 19 | Spinach | 1.303 | 0.853 | 0.541 |
| 20 | Onion green | 1.420 | 0.824 | 0.540 |
| 21 | Onion dry | 1.225 | 0.686 | 0.380 |
| 22 | Snake cucumber | 1.248 | 0.817 | 0.471 |
| 23 | Turnip | 1.641 | 1.074 | 0.620 |
| 24 | Carrot | 2.040 | 1.335 | 0.770 |
| 25 | Parsley | 1.860 | 1.217 | 0.702 |
| 26 | Radish | 1.015 | 0.664 | 0.383 |
| 27 | Others Veg | 0.303 | 0.199 | 0.115 |
|  | Vegetables | **1.921** | **1.233** | **0.789** |

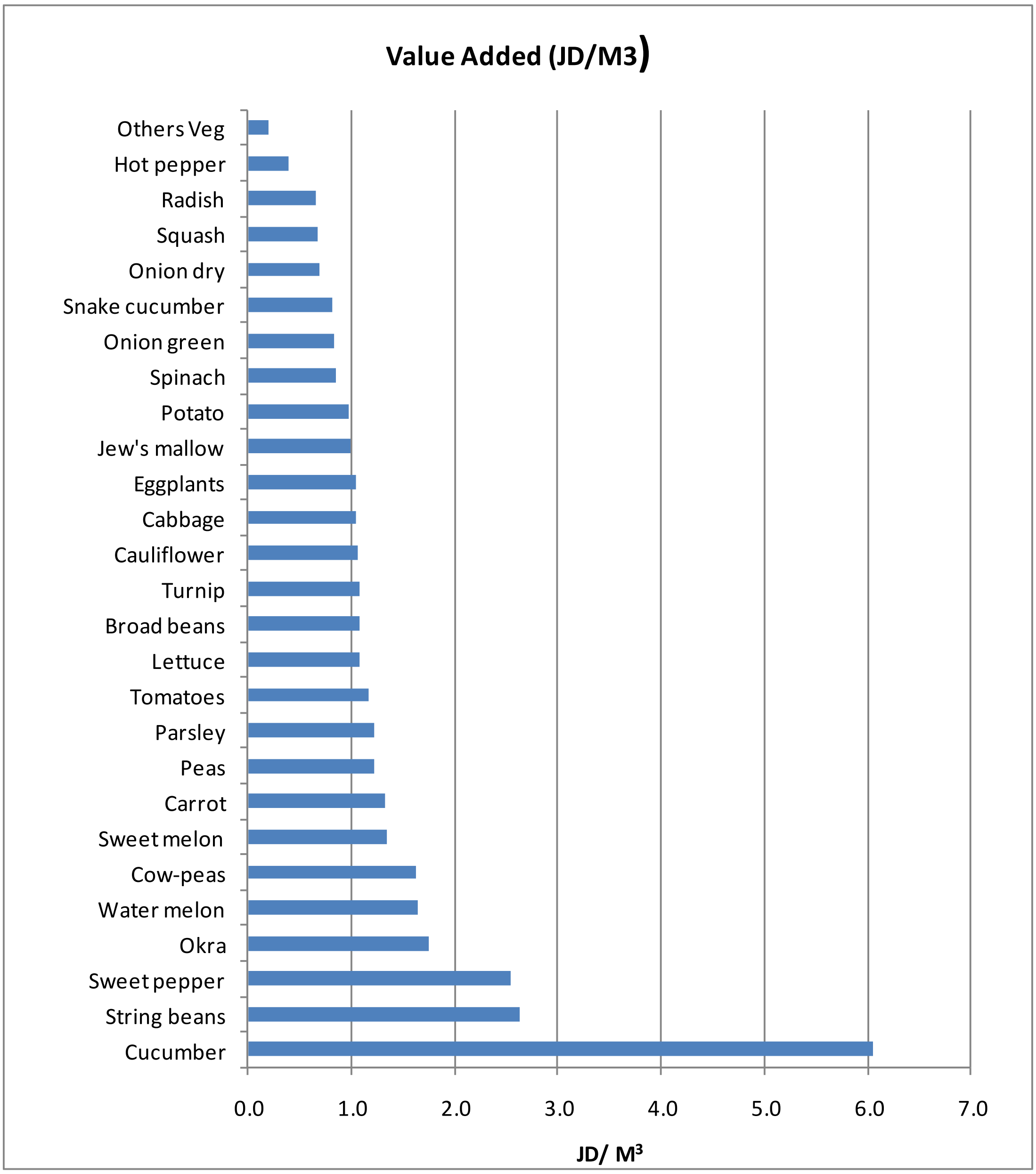



**Figure 16: The Value of Water used in Vegetable Production in Jordan for the year 2008.**

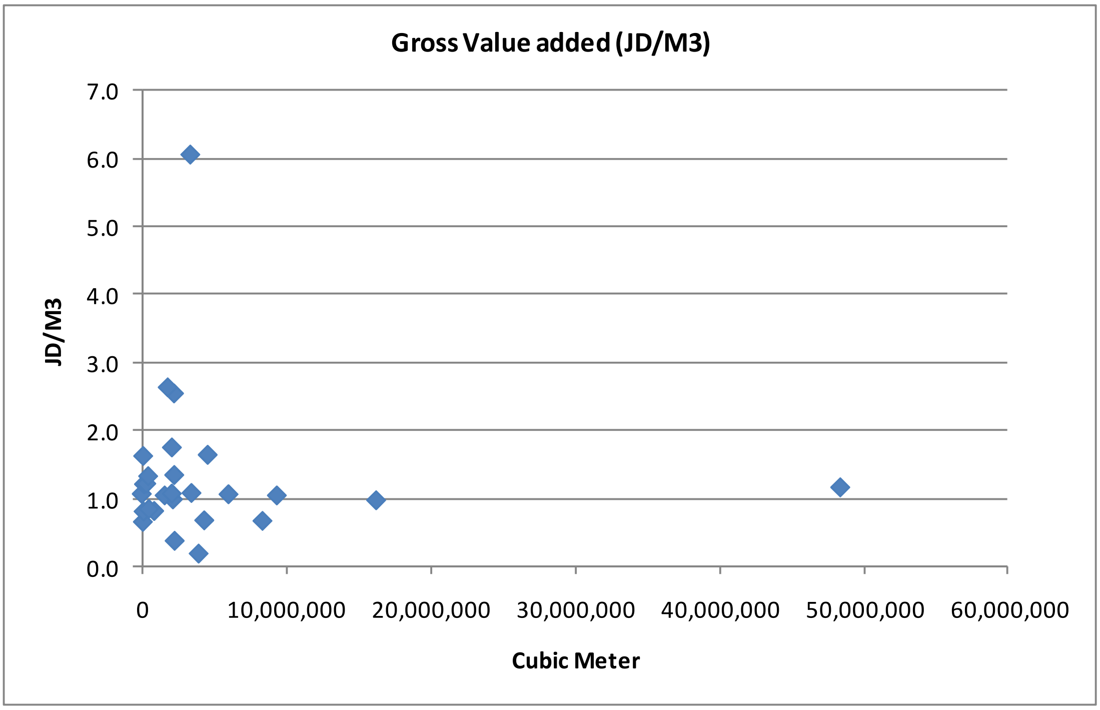



**Figure 17: Correlation between Water Value and Water consumption in vegetable in Jordan for the year 2008.**

### *5.5.2.3 Value of Water Fruit Trees*

The quantities of water consumed by fruit trees are shown in Table 19. It show that olive trees consume about 145 MCM or about 46% of water consumption in fruit trees followed by banana with about 21.2 MCM (6.7%), then Lemons (5.1%), Dates (5%), and Grape (5%). Banana has the highest total value added to national economy with about JD 20 million generated from 15.42 thousand dunum compared with Olives with JD 16.7 million generated from 248 thousand dunum as shown in Table 19.

The aggregate average water value for the fruit trees is 0.226 JD/m3 as shown in Table 20. From the perspective of improving water allocation, farmers should prefer the crops with higher water value.

Banana has the highest water value added (0.79 JD/m3), followed by Orange of Shamouti variety (0.58 JD/$m^3$), Mandarins (0.54 JD/$m^3$) followed by Apricot (0.53 JD/$m^3$) and Apples (0.5 JD/$m^3$). One reason for this could be the higher intensity in terms of labor and inputs, which generally leads to higher gross margins and consequently higher irrigation water values

The lowest return to one cubic meter was found for Olive trees with only (0.069 JD/$m^3$). Looking to the net profit to one cubic meter, it was found it is about 0.51 JD/$m^3$ for Banana crop. Therefore, it is economically rational for banana producers to install RO unit to irrigate banana, since the cost of desalination of one cubic meter is about the half of net profit from one cubic meter Table 20.

**Table 19: Production, Irrigated Areas, and Water Use for Fruit Trees in 2008**

| No. | Crops | Production (ton) | Planted Areas (du) | Water Consumption ($m^3$) in 2008 | Gross Output (JD) | Value Added (JD) | Operation Surplus (JD) |
|---|---|---|---|---|---|---|---|
| 1 | Lemons | 18,027 | 16,953 | 16,080,275 | 7,764,219 | 4,736,174 | 3,028,045 |
| 2 | Oranges, local | 2,672 | 1,938 | 1,833,996 | 963,931 | 655,473 | 424,130 |
| 3 | Oranges, navel | 14,216 | 11,762 | 11,254,125 | 5,401,942 | 3,673,321 | 2,376,854 |
| 4 | Oranges, red | 5,032 | 3,174 | 3,026,105 | 2,128,425 | 1,447,329 | 936,507 |
| 5 | Oranges, Valencia | 3,676 | 2,842 | 2,708,555 | 1,554,834 | 1,057,287 | 684,127 |
| 6 | Oranges, French | 2,316 | 1,767 | 1,693,499 | 979,768 | 666,242 | 431,098 |
| 7 | Oranges, Shamouti | 8,267 | 4,287 | 4,084,161 | 3,496,933 | 2,377,915 | 1,538,651 |
| 8 | Clementine | 18,569 | 13,077 | 12,458,557 | 3,567,186 | 2,425,686 | 1,569,562 |
| 9 | Mandarins | 8,515 | 6,318 | 6,019,478 | 714,384 | 414,343 | 257,178 |
| 10 | Grapefruits | 3,681 | 1,958 | 1,866,047 | 573,501 | 344,101 | 217,930 |
| 11 | Medn. mandarins | 155 | 60 | 57,150 | 52,034 | 31,220 | 19,773 |
| 12 | Pummelors | 6,186 | 3,367 | 3,198,833 | 1,312,674 | 787,604 | 498,816 |
| 13 | Olives | 38,588 | 248,291 | 145,878,424 | 16,746,989 | 10,048,193 | 6,363,856 |
| 14 | Grapes | 17,857 | 20,920 | 15,616,930 | 8,782,238 | 4,303,297 | 3,161,606 |
| 15 | Figs | 352 | 1,025 | 767,817 | 147,830 | 103,481 | 82,785 |
| 16 | Almonds | 541 | 1,260 | 911,242 | 421,666 | 282,516 | 223,483 |
| 17 | Peaches | 18,871 | 15,982 | 11,831,678 | 6,225,503 | 3,984,322 | 2,614,711 |
| 18 | Plums, prunes | 1,748 | 2,863 | 3,473,284 | 1,604,554 | 722,049 | 320,911 |
| 19 | Apricots | 6,086 | 8,376 | 6,141,558 | 5,124,590 | 3,279,738 | 2,152,328 |
| 20 | Apples | 27,165 | 17,826 | 12,491,605 | 8,206,547 | 6,319,042 | 4,595,667 |
| 21 | Pomegranates | 3,305 | 2,074 | 1,578,295 | 1,477,475 | 753,512 | 561,441 |
| 22 | Pears | 2,015 | 2,978 | 3,992,595 | 1,335,954 | 855,011 | 561,101 |
| 23 | Guava | 1,843 | 1,970 | 1,713,849 | 831,218 | 531,979 | 349,112 |
| 24 | Dates | 7,437 | 15,727 | 15,948,099 | 4,461,900 | 3,480,282 | 2,364,807 |
| 25 | Bananas | 41,540 | 15,418 | 21,213,045 | 20,944,569 | 16,755,655 | 10,891,176 |
| 26 | Others FT | 10,913 | 12,492 | 7,311,637 | 1,036,773 | 622,064 | 393,974 |
| | **Fruit trees** | **269,573** | **434,705** | **313,150,837** | **105,857,637** | **70,657,835** | **46,619,626** |

The Fruit crops are ascending sorted as shown in Figure 18, Figure 19 shows the value added of all horticultural crops in Jordan. All shows the scatter plot correlation between water uses and water values for fruit tree crops

The higher values for the food gardens can be attributed to a more intensive production and could be also explain the higher water values for farmers irrigating on private land.

**Table 20: Computed water values (JD/$m^3$) for Fruit Trees in 2008**

| No. | Crops | Gross Output (JD/ M3) | Gross Value added (JD/M3) | Operation Surplus (JD/M3) |
|---|---|---|---|---|
| 1 | Lemons | 0.483 | 0.295 | 0.188 |
| 2 | Oranges, local | 0.526 | 0.357 | 0.231 |
| 3 | Oranges, navel | 0.480 | 0.326 | 0.211 |
| 4 | Oranges, red | 0.703 | 0.478 | 0.309 |
| 5 | Oranges, Valencia | 0.574 | 0.390 | 0.253 |
| 6 | Oranges, French | 0.579 | 0.393 | 0.255 |
| 7 | Oranges, Shamouti | 0.856 | 0.582 | 0.377 |
| 8 | Clementine | 0.286 | 0.195 | 0.126 |
| 9 | Mandarins | 0.119 | 0.069 | 0.043 |
| 10 | Grapefruits | 0.307 | 0.184 | 0.117 |
| 11 | Medn. mandarins | 0.910 | 0.546 | 0.346 |
| 12 | Pummelors | 0.410 | 0.246 | 0.156 |
| 13 | Olives | 0.115 | 0.069 | 0.044 |
| 14 | Grapes | 0.562 | 0.276 | 0.202 |
| 15 | Figs | 0.193 | 0.135 | 0.108 |
| 16 | Almonds | 0.463 | 0.310 | 0.245 |
| 17 | Peaches | 0.526 | 0.337 | 0.221 |
| 18 | Plums, prunes | 0.462 | 0.208 | 0.092 |
| 19 | Apricots | 0.834 | 0.534 | 0.350 |
| 20 | Apples | 0.657 | 0.506 | 0.368 |
| 21 | Pomegranates | 0.936 | 0.477 | 0.356 |
| 22 | Pears | 0.335 | 0.214 | 0.141 |
| 23 | Guava | 0.485 | 0.310 | 0.204 |
| 24 | Dates | 0.280 | 0.218 | 0.148 |
| 25 | Bananas | 0.987 | 0.790 | 0.513 |
| 26 | Others FT | 0.142 | 0.085 | 0.054 |
| | **Fruit trees** | **0.338** | **0.226** | **0.149** |

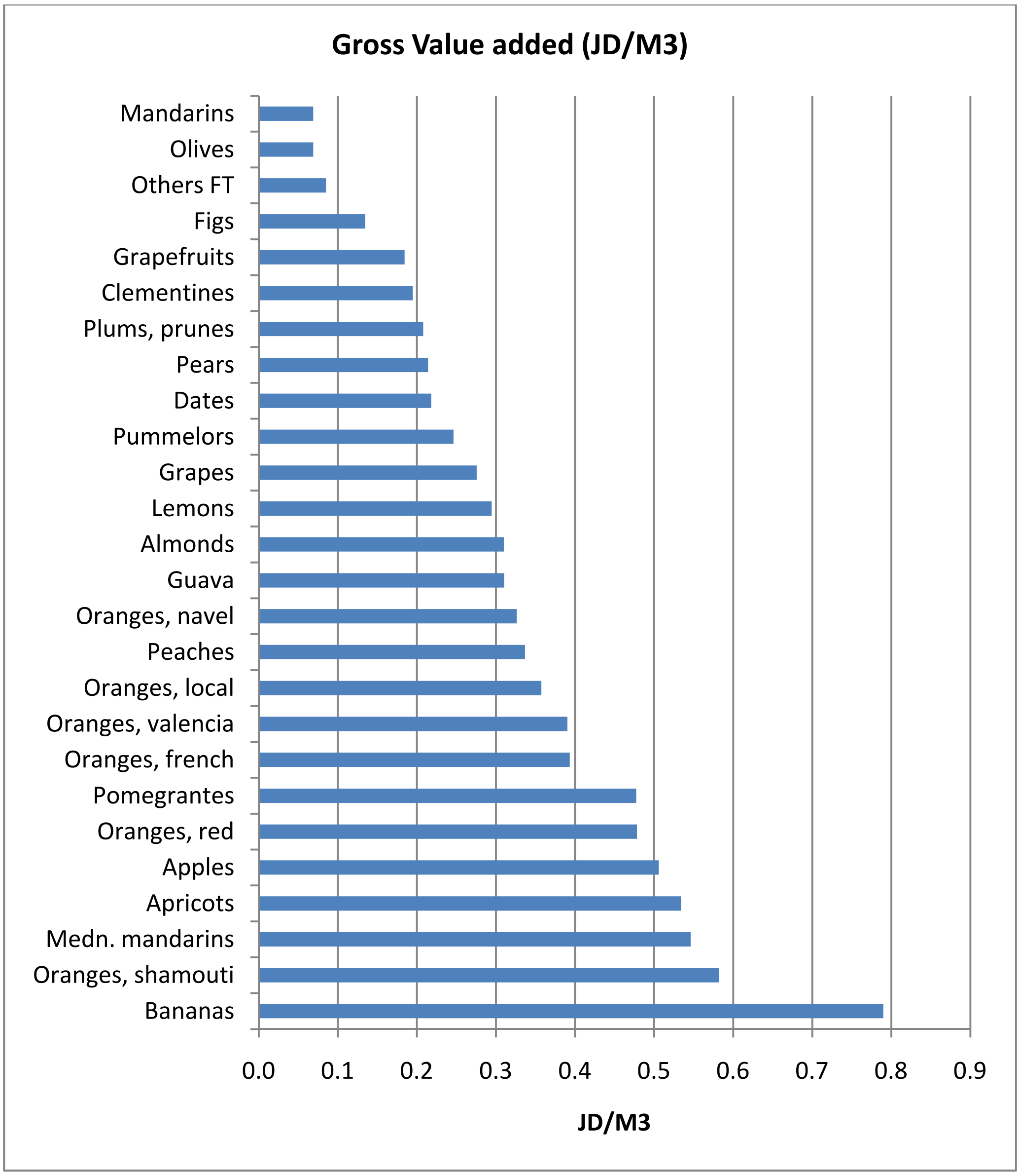



**Figure 18: The Value of Water in Fruit Trees in Jordan for the year 2008.**

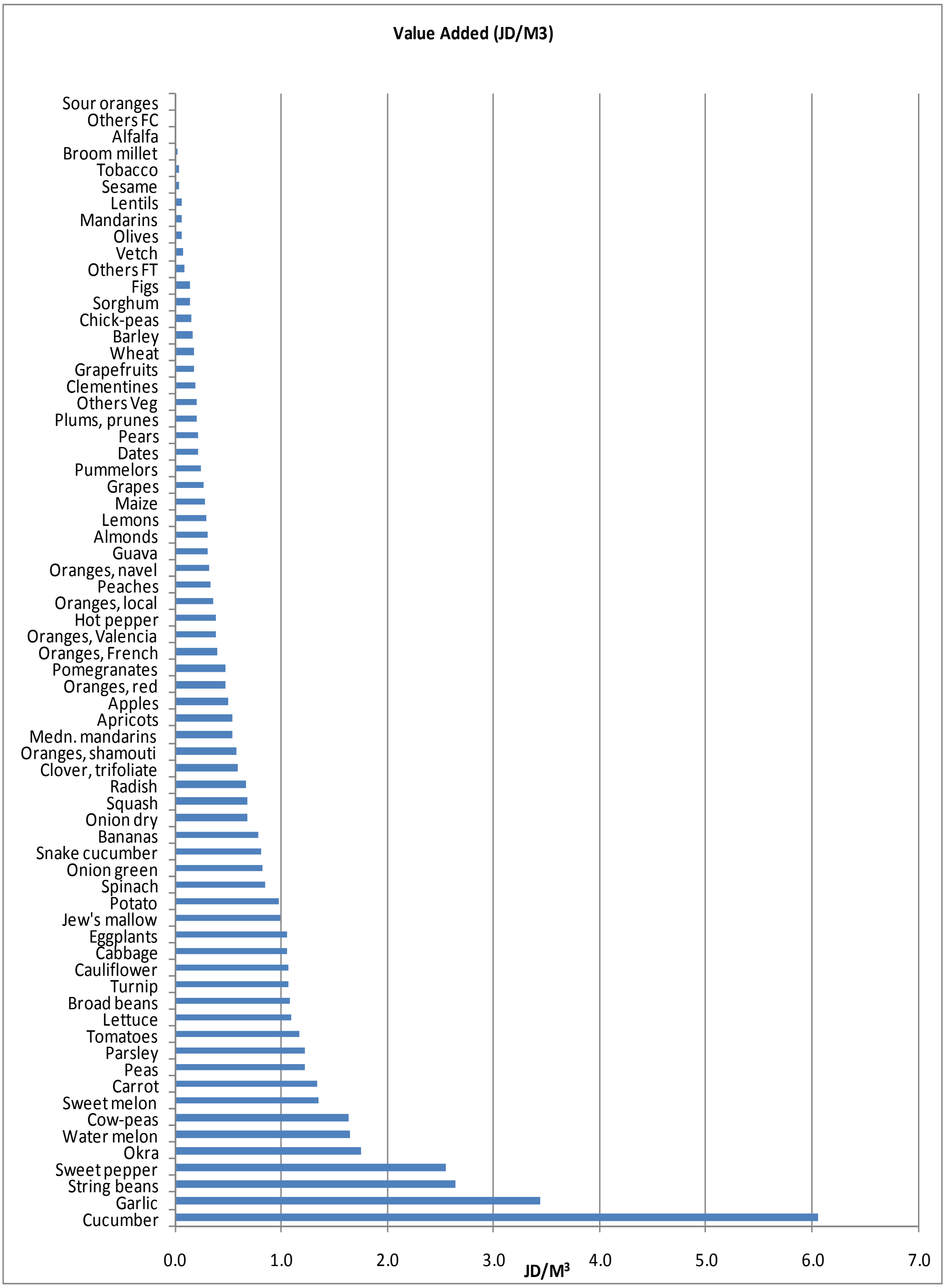



**Figure 19: Sorted Water Value in Horticultural crops in Jordan for the year 2008.**

## 5.6 Value of Water in Livestock

Young [1996] recommends that returns from livestock and poultry operations should not be included in the analysis for the estimation of the value of water for agriculture. Some planners include livestock activities into their analysis because addition or augmentation of irrigation water produces more forages and feeds, which may fold a better outlet through farm livestock and poultry feeding operations than on the open market. Water value in livestock is often neglected in water productivity studies.

However, the increment in water supply directly augments only feed and forage production, not livestock production (this could be augmented, but as a consequence). As markets usually exist for feeds and forage, it could be simpler and more accurate to directly price the incremental forage than to impute a price through the livestock enterprises. Feed grains used in livestock production can be valued at cost of acquisition. Fresh forages used for livestock grazing could be priced by rental markets for grazing.

The livestock enterprise can be best regarded as a form of secondary processing for the feeds and forages rather than a primary enterprise directly impacted by the irrigation water supply. Introducing another intermediate good enterprise in the analysis opens the way for additional errors in imputing benefits to incremental water supplies. Table 21 shows the computed water values in the livestock sector in Jordan. The highest value added was in the Hatcheries, since their water consumption is the lowest and does not exceed 200,000 $m^3$ annually. The lowest value added was in Layers. Sheep and goat shows a significant contribution in the value of water in the livestock sector. The value added was 21.6 JD/$m^3$ compared to Dairy Cattle of 10.3 JD/$m^3$. The value added in broiler farm is higher than the values in Layer. This can be attributed to higher profitability in broiler production compared to Layer.

**Table 21: Computed water values (JD/$m^3$) for Livestock sub-sector in 2009**

| | Gross Output | Intermediate Consumption | Value Added | Water Consumption | Gross Output Per M3 | Value Added M3 | Percent Cost of Water |
|---|---|---|---|---|---|---|---|
| Sheep & Goat | 270.49 | 158.16 | 112.32 | 5.21 | 51.95 | 21.57 | 2.47 |
| Cattle | 104.47 | 89.46 | 15.02 | 1.46 | 71.41 | 10.26 | 1.23 |
| Broilers | 241.14 | 220.44 | 20.70 | 1.42 | 170.04 | 14.59 | 0.48 |
| Layers | 65.80 | 59.94 | 5.85 | 0.65 | 101.32 | 9.01 | 0.81 |
| Parent Stock | 45.62 | 36.20 | 9.41 | 0.71 | 63.89 | 13.18 | 1.48 |
| Hatchery | 43.15 | 32.26 | 10.89 | 0.19 | 221.91 | 56.00 | 0.45 |
| **Livestock** | **770.66** | **596.49** | **174.17** | **9.65** | **79.89** | **18.06** | **1.21** |

# 6 Conclusions and Policy Implications

Insight into the value of water is essential to support policy making about water pricing and the efficient allocation of water among different water users this study use the Residual Imputation Method (RIM). The domestic water value is the sum up of the total cost of public network and the opportunity cost, which is 4.47 JD/$m^3$ and around 819 million JD for Jordan. The domestic water values for the different regions in Jordan range from 4.17 to 4.87 JD/$m^3$.

Using constant price of 2008, the water value ranges from about 70 to 80 JD/$m^3$ of water in the sectors of mining and chemicals up to 4600 JD/$m^3$ in the sector of tobacco products and reaches even an average of nearly 7000 JD/$m^3$ in oil & gas industries.

Using the current prices the water values are ranges from about 29 to 64JD of GVA per $m^3$ of water in the sectors of huge water consumers such mining and chemicals, food and beverage and manufacturing of non-metallic mineral up to 3,896 JD/$m^3$ in the sector of Extraction of Petroleum and natural gas, tobacco products. The weighted average of water values in the industry, weighted by water consumption is 69 JD/$m^3$.

The water values in tourism sector about 38 JD/$m^3$. Other services sectors such as wholesales and retailers have higher water vales ranged from 66 JD/$m^3$ in food and beverages sales to 2,302 in retail trade not in stores.

The value of water in education sector is amounted to 186 JD/$m^3$, whereas 93 JD/$m^3$ for health sector. The weighted average values of water in all other services sector is estimated at 249 JD/$m^3$

In this study values are calculated for irrigation Jordan, using the residual imputation method. The average value of irrigation water is JD 0.51/$m^3$ at the country level. Using linear programming approach the average water values in Jordan Valley range from 0.24 JD/$m^3$ for Blended water to 0.39 JD/$m^3$ for fresh surface water.

The water Values was calculated to all horticultural sector in Jordan. The observed values of water were in the range of those found in other studies for irrigated vegetables (Haddadin et al., 2006). He reports that the value of water is 0.48 JD/$m^3$ for vegetables under plastic houses and 0.35 JD/$m^3$ for citrus crops and 0.37 JD/$m^3$ for fruit trees. The study revealed a high level of variability in irrigation water values. It was shown that the differences in water values can be mainly attributed to two factors that can be relevant for policy makers and extension services: (1) the characteristics of irrigation system and (2) the type of crop grown.

The aggregate average water value for field crops is 0.44 JD/$m^3$, for the vegetable crops in this study is 1.23 JD/$m^3$ and for Fruit trees is 0.23 JD/$m^3$. The aggregate average water value for horticulture is 0.51 JD/$m^3$. These values are comparable to results of other recent studies. In a review paper on water values, Hussain et al. (2007) report values up to

US$0.37/m$^3$ for high value crops in some African countries, concluding that for vegetable production, water values are usually higher than US$0.2/m$^3$.

The reasons why there is no single value of irrigation water use are: (1) farmers do not have perfect knowledge about products and inputs market, (2) do not all possess the same resource base, (3) plant different crops variety in different seasons, (4) possess different crop rotation practices and are possibly risk adverse, Therefore, they all value water differently.

However, the results need to be interpreted with care as the crop with the lowest return to water is probably not the one to be sacrificed if water is restricted, since farmers plant crops for a variety of reasons (and sometimes not for the highest return to water that they can achieve) and shortage of supply from lowest return crop in next season lead to raise the market price of that crop and become more profitable and have a high value of return per cubic meter

To investigate the policy relevance of the computed or estimated marginal values, there is the need to ascertain the policy option for which the estimated figures are more appropriate: either for inter-sectoral water pricing policy or intra-sectoral water reallocation using different approaches.

# 7 Recommendations for Future Studies

It is suggested to conduct a further detail study in value of water in horticultural sector taken into consideration agricultural the crop performance in term of prices according to production season (winter versus Summer), growing season (Winter versus Summer) and irrigation technology (irrigated versus Rainfed) and irrigation methods such as open field drip irrigation, furrow, sprinklers and plastic cover. In addition to the source of waster such as fresh versus blended wastewater, surface versus groundwater. Therefore, it is necessary to conduct a further detail study on the value of agricultural products according to above mentioned source of water, agro-climatological zones and production technology.

Because there are relatively large climatic differences between Highland and Jordan Valley and within Jordan Valley (North, Middle, south and Safi, detailed agricultural census data can be used for the subdivisions as defined by the regional districts. If such data base on the crop water requirements are available by region and cropping season. This database can now be used to compare the water values and crop water efficiency for different crops in different regions. Depending on the prevailing climatic, soil and management conditions water demand for the same crop differs greatly between regions

The data on crop production should be disaggregated in space (regional level) and time (winter, summer an annual basis), in addition to data on production costs and data on quantity of water used by or applied to the crops

The expected results from the above approach can match crops to appropriate prevailing climatic conditions and can result in substantial gains in water saving. What this suggests is that some region can produce crops in a much more water efficient manner than others. When that crop is exported with low economic value, the water used to produce that crop cannot be used for other purposes with the country.

With regard to the domestic water value, it is recommended to consider the indirect subsidy provided to the domestic water sector through subsidizing the electricity price and through the historical fuel subsidy that reduced the capital investment value before fuel liberalization in 2008. These indirect subsidy elements are part of the economic externalities component of water value in use.

# 8 References


Abu-Zeid, M. (2001) Water pricing in irrigated agriculture. *International Journal of Water Resources Development*. 17 , pp. 527-538

Agudelo, J. I. (2001). The Economic Valuation of Water: Principles and Methods. IHE Delft , Delft. Value of Water Research Report Series 5

Agudelo. J. I. and Arjen Y. Hoekstra (2001). Valuing water for agriculture: Application to the Zamvezi Basin Countries. Globalization and Water Resource Management: The changing Value of Water. August 6-8 AWRA/IWLRI- University of Dundee International Specialty Conference.

Al Weshah, R. 2000, Optimal Use of Irrigation Water in the Jordan Valley. *Water Resource Management* . 14: 5 pp.327-338.

Al-Assaf Amani Amer Z. Salman , Franklin M. Fisher, Emad Al-Karablieh (2007)A Trade –off Analysis for the Use of Different Water Sources for Irrigation (The Case of Southern Shounah in the Jordan Valley).*Water International*.32, (2):224-253

Al-Karablieh Emad and Amer Salman (2006)Measuring the Profitability of Different Irrigation Water Qualities in the Down Stream of Amman Zarqa Basin in Jordan International Conference: Integrated Water Resource Management and Challenges of the Sustainable Development. Marrakech 23-25 May 2006

Al-Karablieh, Emad, Amer Salman, and Abbas Al-Omari, Mohammad E. Osman(2006)Water Allocation Model in Ghor Al-Safi in Jordan . The 3rd International Conference on the "Water Resources in the Mediterranean Basin" WATMED 3,Tripoli-Lebanon, 1-3 November 2006.

Allen R., L. Pereira, D. Raes, and M. Smith. 1998. *Crop Evapo-transpiration: Guidelines for Computing Crop Water Requirements.* FAO Irrigation and Drainage Paper 56. Rome, Italy: Food and Agriculture Organization.

Ashfaq Muhammad, Saima Jabeen and Ifran Ahmad Baig (2005) Estimation of the Economic Value of Irrigation Water. *Journal of Agriculture and Social Sciences*. Vol. 1, No. 3, 2005, 270–272

CBJ (2010). Monthly Statistical Bulletin. Central Bank of Jordan. Volume 46, No. 4, p 66.

Chambers, R. G. (1988). Applied Production Analysis-A dual Approach. Cambridge University Press.

CIA World Fact Book, 2010, accessed Dec 2010, https://www.cia.gov/library/publications/the-world-factbook/geos/jo.html

Critchley, W., and K. Siegert. 1991. *Water Harvesting: A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production.* Rome, Italy: Food and Agriculture Organization

Doorenbos, J., and W. Pruitt. 1992. *Crop Water Requirements.* FAO Drainage and Irrigation Paper 24. Rome, Italy: Food and Agriculture Organization.

DOS (2010). Agricultural Statistics 2009. Department of Statistics, Amman, Jordan

DOS, (2010), Department of Statistics website, www.dos.gov.jo, accessed in Dec 2010.

ECO Consult, 2004, Pricing of Water and Wastewater Services for the Water Authority of Jordan, Amman, Jordan

Fardous, A. A. (1983). Determination of crop coefficients for some direct and indirect methods of estimating evapotranspiration in Jordan Valley. M. Sc. Thesis, University of Jordan, Amman-Jordan.

Ghawi, I. O. and M. R. Shatanawi. (1986). Water Consumption of Broad Beans and Beans in the Central Jordan Valley. Damascus University Journal, 10: 11-23.

Haddadin , M. J., Salman, A. and Al-Karablieh, E. (2006) . The Role of Trade in Alleviating Water Shortage, in “Water Resources in Jordan (Evolving polices for development, the environment and conflict resolution)”, Editor: Munther J. Haddadin, Resources for The Future, Washington DC

Heathfield, D. F. and Wibe, S. (1987). An Introduction to Cost and Production Function. MacMillan Education Ltd. London.

Hellegers, P. J. and Perry, C. J. (2006) Can irrigation water use be guided by market forces? Theory and practice. *International Journal of Water Resources Development.* 22 , pp. 79-86

Hellegers, Petra and Brian Davidson (2010). Determining the disaggregated economic value of irrigation water in the Musi sub-basin in India. *Agricultural Water Management*. Volume 97, Issue 6, June 2010, Pages 933-938.

Hellegers, Petra and Brian Davidson (2010). Determining the disaggregated economic value of irrigation water in the Musi sub-basin in India. *Agricultural Water Management*. Volume 97, Issue 6, June 2010, Pages 933-938.

Huang, Y. X. (1987) Expense-Benefit Analysis. Shanghai: Tongji University Press.

Hussain, I. , Turral, H. , Molden, D. and Ahmad, M. (2007) Measuring and enhancing the value of agricultural water in irrigated river basins. *Irrigation Science.* 25 , pp. 263-282

Jabarin, A. S. 1997. Some of the expected impacts of the peace treaty on vegetable production in the Jordan Rift Valley. Journal of Economic Cooperation Among Islamic Countries. 18 (4), 143-153.

Jiang, W. L. (1998). Theory of Water Value. Beijing: Science Publishing House.

Jing He, Xikang Chen and Yong Shi (2006). A Dynamic Approach to Calculate Shadow Prices of Water Resources for Nine Major Rivers in China Journal of Systems Science and Complexity . Volume 19, Number 1, 76-87/

Jitan, M. A (2005). Evaporation of Major crops in the Jordan Valley using Remore Sensing Techniques compared with Estimated field Measurements using Eddy-Correlation. Ph.D thesis. Department of Agricultural Resources and Environment, The university of Jordan, Amman, Jordan.

Lange, G. M. and Hassan, R. (eds) (2007) Case studies of water valuation in Namibia's commercial farming areas. The Economics of Water Management in Southern Africa: An Environmental Accounting Approach Edward Elgar Publishing , Cheltenham

Lange, G. M. and Hassan, R. (eds) (2007). Case studies of water valuation in Namibia's commercial farming areas. The Economics of Water Management in Southern Africa: An Environmental Accounting Approach Edward Elgar Publishing , Cheltenham

Littlefair, K. (1998). Willingness to Pay for Water at the Household Level: individual financial responsibility for water consumption, MEWEREW Occasional paper No. 26, Water Issues study Group, School of Oriental and African Studies (SOAS), University of London, UK.

Mazahreh, N. Th. (1993). Determination of actual water consumption and crop coefficient of mature banana in central Jordan Valley. M.Sc. Thesis, University of Jordan, Amman, Jordan.

Mazahreh, N. Th. (2001). Evapotranspiration measurement and modeling for Bermuda Grass, Alfalfa, Cucumber, and Tomato grown under protected cultivation in the central Jordan valley. Ph.D. Thesis, University of Jordan, Amman, Jordan.

Perret, S. and Geyser, M. (2007). The cost of irrigation: adapting existing guidelines to assess the full financial costs of irrigation services. The case of smallholder schemes in South Africa. *Water.* SA 33 , pp. 67-78.

Rogers, P., Bhatia, R., and Huber, A., 1998, Water as a Social and Economic Good: How to Put the Principle into Practice, Global Water Partnership/ Swedish International Development Cooperation Agency, Technical Advisory Committee, Sweden

Salman Amer, Emad Al-Karablieh , Hans-Jochen Regner, Heinz-Peter Wolff, and Munther Haddadin (2008)Participatory Irrigation Water Management in the Jordan Valley. *Water Policy*.10.(4):305-322

Salman Amer, Emad AL-Karablieh and Munther Haddadin (2008). Limits of Pricing Policy in Curtailing Household Water Consumption. *Water Policy*.10, (3):295-307

Salman Amer, Emad K. Al-Karablieh, Franklin M. Fisher.(2001).An Inter-Seasonal Agricultural Water Allocation System (SAWAS).*Agricultural Systems*. 68(3)  233-252

Salman, A. and Emad Al-Karablieh. (2004).Measuring the Willingness of Farmers to Pay for Groundwater in the Highland Area of Jordan. *Agricultural Water Management*. 68, (1): 61-76

Sharma B. R. (2001). Crop Water Requirements and Water Productivity: Concepts and Practices. College of Agricultural, Engineering, Punjab Agricultural University, Ludhiana

Shatanawi, M. R. (1986). Efficiency of the Jordan Valley irrigation system. Dirasat. Vol XIII, No. 5, p 121-142.

Shatanawi, M. R., I. Ghawi, and R. Sharaiha (1986). Actual consumptive use of wheat and Barley in the Jordan Valley. DIRASAT, 14(2): 49-67.

Shatanawi, M. R., I. Ghawi, M. Fayyad, M. Habbab, A. Taimeh, A. Abu Awwad, J. Wolf, J. Gleason, S. Salti, M. Ababneh, M. Jitan, and M. Hamdan (1994). Irrigation management and water quality in the central Jordan valley. A 149 baseline report prepared for the USAID mission to Jordan. Prepared by the water and environment research and study center, University of Jordan. Amman - Jordan.

Shatanawi, M. Y. Al-Zu'bi, and O. Al-Jayoussi (2003). Irrigation Management Dynamics in the Jordan Valley under Drought Conditions. Tools for Drought Mitigation in Mediterranean Regions, 243-258. Kluwer Academic Publishers, Netherlands.

Shatanawi, M., G. Nakshabandi, A. Ferdous, M. Shaeban, and M. Rahbeh. 1998. *Crop Water Requirement Models for Crops Grown in Jordan.* Technical Report no. 21. Amman, Jordan: University of Jordan, Water and Environmental Research and Study Center.

Speelman, S. ,Farolfi, S. ,Perret, S. ,D'haese, L. and D'haese, M. (2008). Irrigation Water Value at Small-scale Schemes: Evidence from the North West Province, South Africa', International Journal of Water Resources Development. 24:4, 621 - 633 .



Speelman, S. ,Farolfi, S. ,Perret, S. ,D'haese, L. and D'haese, M. (2008). Irrigation Water Value at Small-scale Schemes: Evidence from the North West Province, South Africa', International Journal of Water Resources Development. 24:4, 621 - 633 .

Suwwan, M., A.M. Battikhi and O. M. Judah (1985). Influence of plastic mulching on growth, yield and soil moisture conservation in plastic house tomatoes. Dirasat, 7(4):21-32.

Turner, K., Georgiou, S., Clark, R., Brouwer, R., 2004. Economic value of water resources in agriculture. From the sectoral to a functional perspective of natural resource management. FAO Water Reports 27, Rome. (http://www.fao.org/docrep/007/y5582e/y5582e00.htm#Contents,(accessed December, 2010).

Wang, D. X., Wang, H. & Yin, M. W. (1999). Water resource, water resource value, water resource shadow price. Water Resource Evolution, 10, pp.195-200.

Werner Doppler, Amer Z. Salman, Emad K. Al-Karablieh and Heinz-Peter Wolff (2002).The impact of water price strategies on irrigation water allocation under risk: the case of Jordan Valley. *Agricultural Water Management*. 55, (3). 171-182

World Bank 2010, Country Brief – Jordan, http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/MENAEXT/JORDANEXTN/0,,menuPK:315140~pagePK:141132~piPK:141107~theSitePK:315130,00.html

Young, R. (2005). Determining the Economic Value of Water: Concepts and Methods, Resource for the Future, Washington D.C.

Young, R. (2005). Determining the Economic Value of Water: Concepts and Methods, Resource for the Future, Washington D.C.

Zhang, Q. SH. (1990). The economic meaning of shadow price and its application. Jilin University Social Science Transaction, 10, pp.14–18.

# 9 Appendixes

## 9.1 Appendix I: Methodology of Valuation of Water Used in Domestic Sector

### 9.1.1 Stated Preference Approach: Contingent Valuation Method

This method is based on the use of survey techniques to directly estimate benefits based on the willingness to pay for an improved water supply as stated by water users in a questionnaire. The stated preference approaches, including contingent valuation and conjoint analysis. Contingent valuation is based on discrete choice responses that reflect estimated willingness to pay. Conjoint analysis is based on survey responses to pick the most desirable alternative out of a set of alternatives that have a variety of characteristics.

Willingness to pay is the price (JD amount) that a buyer is willing to give up (opportunity cost) to acquire a good or service. The willingness of consumers to pay for a reliable, good quality water supply depends on the satisfaction or utility they obtain from the service as well as the utility consumers obtain from all other goods and services, constrained by available income. Therefore, willingness to pay takes preferences and income constraints into account. Willingness to pay is reflected through the demand curve for that good or service. The supply curve for a good or service reflects the marginal cost of providing that service and represents the minimum price required to bring an additional unit of output into the market.

Using willingness to pay as a measure of benefit presents some potential equity issues. First, willingness to pay is constrained by ability to pay, so households with high incomes will appear to place a higher value on water service than those with low incomes. This may conflict with some ideas of fairness or justice (Pearce, 1994).

In addition to the equity issues presented above, there are also practical problems in measuring the willingness to pay of water users for a water supply. Due to limited information available on how much water users will pay for water supplies with differing levels of quality and reliability along with the non-competitive nature of some water supply markets, it may not be possible to derive a demand curve from actual market data.

The Value of water can be approximated by consumer surplus and producer surplus. Consumer surplus is the difference between what consumers are willing to pay for water (as reflected by the demand curve) and what that consumer actually has to pay (as reflected by the market price). Consumer surplus is represented as the area under the demand curve and above market price in the supply and demand curve

The stated preference approach can be used to directly estimate M&I water supply benefits based on preferences reflected through responses to water user surveys. There are two methods that can be used to estimate natural resource values in terms of stated preferences, the contingent valuation method (CVM) and conjoint analysis (CA). The two methods are similar in that they are based on the use of surveys to estimate willingness to pay. However, the two methods are different in the way the water being valued are presented in the survey questionnaires .The differences in the two methods can lead to a divergence in the estimates of willingness to pay using CVM and CA.

The benefits from a water supply improvement can be measured using either CVM or CA by 1) asking water users their willingness to pay for increased water supplies, improved reliability of service or improved water quality by presenting a range of scenarios that include different characteristics and asking for a ranking of scenarios (CA

There is disagreement among economists regarding the accuracy of value estimates derived from contingent valuation based analyses. Potential biases exist in the presentation of information in a survey, the hypothetical nature of contingent valuation questions, and the sampling methods used. However, CVM has been applied to a wide variety of resource valuation situations.

### 9.1.2 Revealed preference approach: Contingent Valuation Method

This methodology is based on actual observed behavior in market situations. The basic idea is that markets reveal the preferences of an individual through the price paid and the quantity purchased for a good or service. Market prices can be used to estimate willingness to pay functions from which benefits can be estimated. A revealed preference approach is used when the domestic water supply and demand relationships are estimated using observed market behavior and these relationships are then used to estimate changes in welfare from water supply changes.

The revealed preference approach is based on observed market behavior or behavior in "market like" conditions. These observations of how consumers react to changes in price can be used to estimate a demand curve from which benefits can be estimated. Observed price-quantity combinations in municipal water markets reveal consumer preferences and will reflect willingness to pay for various quantities of water

In order to estimate a household demand curve, data are needed for water price, the quantity of water purchased, income, household size, climate variables, and any other variables that would be expected to influence the quantity of water demanded. A demand curve for commercial water supplies would include price and quantity variables, along with a type of good or service variable that would indicate the importance of water as a production input, number of employees as a measure of business size, revenues, climate variables, and any other variables that would be expected to influence the quantity of water demanded.

It should be recognized that there are potential difficulties involved in estimating generalized demand curves using cross-sectional data. First, water price and quantity information obtained from each water provider represent averages actually observed for each provider. Therefore, an aggregated demand curve based on averages from each provider will portray a representative demand relationship but will not portray a precise relationship for the specific site being studied. Second, it must be assumed that each price-quantity combination represents a market clearing equilibrium. If the price of water is administratively set at a level that is lower than the equilibrium market price, then that price-quantity observation would not represent a point on the demand curve and will introduce bias in the estimated demand curve.

### 9.1.3 Demand Curve Estimation

An estimate of the price elasticity of demand and supply for municipal can be quantified water along with current quantities and prices in the market. This demand relationship can then be used to estimate benefits. Using price elasticity of demand estimates applicable to the study area along with current quantities and prices for water in the study area to derive a demand curve from which water values can be estimated

In many cases it may not be possible to estimate demand curves from which water supply can be estimated due to the time and costs associated with gathering the amount of data needed to estimate these curves. However, in many cases estimates are available on a regional basis for the price elasticity of demand for municipal water supplies.

If the price elasticity of demand for a good is known, along with the current quantity exchanged in the market, then the effect of relatively small changes in the quantity supplied on prices can be predicted

Price elasticity of demand is a measure of the change in the quantity of a good or service obtained as a result of a change in the price of the good or service. A related measure is income elasticity of demand, which can be defined as the change in the quantity of a good or service obtained as a result of a change in the income of the individual obtaining the good

For a normal good price elasticity is negative (a higher price results in less purchased) and income elasticity is positive (a higher income results in more purchased). Demand for a good with an absolute value of elasticity greater than 1 is said to be elastic, meaning that the quantity demanded is very responsive to a change in price. An absolute value of elasticity less than 1 is inelastic demand, where a change in price results in a relatively small change in the quantity of a good demanded. Given that water does not have any good substitutes and generally represents a small percentage of total household expenditures and business operating costs, demand would be expected to be price inelastic

Price elasticity of demand is a useful measure because it can be used to estimate demand curves when sufficient price and quantity data are not available to estimate a demand curve. If the price elasticity of demand for water is known, along with the current quantity exchanged, then the effect of relatively small changes in the quantity supplied on prices can be predicted

### 9.1.4 Benefits Transfer Approach

Using the results from previously completed studies is used to estimate benefits at the study site under consideration. The application of the benefit transfer method assumes that a general relationship exists between various socio-economic variables and the value of a resource. It is further assumed that this relationship can be estimated and applied to another geographic area. Potential benefit transfer problems that must be considered include differences in water supply problems between sites and differences in socio-economic characteristics

### 9.1.5 The opportunity cost of the most likely alternative

Using the resource cost of the water supply alternative that would be implemented in the absence of any an estimate of benefits. Estimates of benefit should be based on the cost of the most likely alternative only if there is evidence that the alternative would be implemented. In other words, the procedure should only be used in cases where preferences for an alternative that would provide a service are revealed to support the alternative.

## 9.2 Appendix II: Methodology of Valuation of Water Used in Agriculture and Industry

### 9.2.1 Estimating the Producers Water Demand Function

In this approach, water demand function can be deduced from historical water use statistics or calculated from the analysis of optimum water consumption patterns, by mathematical programming to determine the schedule of increases or decreases in net income accruing from changes in the level of water use (Agudelo, 2001). From the estimated demand curve, the quantity of water demanded can be determined. If there are any changes in the level of water consumption, the area below the curve for the specified increase in the quantity of water demanded represents the maximum amount the producer is willing to pay to obtain the resource input. Where no information about the entire demand function exists, the price of water is used as the best estimate of the maximum willingness to pay for unit increase in the level of water use. The slope of the demand curve shows how the producer adjusts to changes in water price and this price indicates the marginal benefits of water use to the producer.

In estimating the producers' demands function, other variables such as the prices and quantities of other inputs are included. These variables generally cause the demand curve for water to shift over time, because the demand for water depends on the degree of variability in the demand for other inputs. The various methods that can be used to estimate the producer's demand function include the production function, assumed price elasticity, econometric modeling and mathematical programming.

### 9.2.2 The Production Function Approach

In this approach the functional relationship between output and all the inputs including water is estimated.

$$\boldsymbol{Y = f(K, L, N, I, \dots W)} \qquad \textbf{\textit{9}}$$

Where Y is output in a physical unit, K is capital, L is land, N is labor, I is any other intermediate input except water and W is water. In an attempt to maximize profits, the producers select inputs such that the value of the marginal product is equal to the price of the product. That is;

$$\boldsymbol{P_k = P_y.\frac{\partial y}{\partial k},\ P_l = P_y.\frac{\partial y}{\partial l}, \dots,\ P_w = P_y.\frac{\partial y}{\partial w}} \qquad \textbf{10}$$

The above implies that the level of water W is increased until the value of the additional unit of water used ( $P_w$=$P_y$. $\partial y/\partial w$) just equals the cost of using an additional unit of water ($P_w$). Optimum condition requires that this must hold for all the inputs used and that the ratios of the marginal value to the marginal cost of an input must be the same for all inputs. As on of the main empirical estimation methods used in the study, this method will be fully discussed in chapter three.

### 9.2.3 Optimization Methods using Mathematical Programming Approach

The mathematical programming approach follows the linear programming model, which is an optimization model that combines unit processes of water utilization systems in the form of linear inequalities. The variables are the levels of the systems' operations and the inequalities express constraints of the overall system (Salman, et al. 2001; Doppler et al. 2002; Salman and Al-Karablieh, 2004; A-Karablieh et al., 2006). These models are developed to represent the optimum allocation of water and other inputs so as to maximize profits, subject to constraints on resource availability and institutional capabilities. The procedure usually follows the construction of a flow diagram of sectoral activities, linking up the components of the flow diagram, algebraically formulating linear inequalities and constraints, and estimating the coefficients of the decision variables. This approach articulates the links between water input alternatives, their prices, other input choices and output, and identifies the best or optimal input strategies or the profit maximizing production path that could be followed by firms. In effect, it identifies the most efficient water utilizing options by the production sectors in terms of cost effectiveness and output maximization. The objective function for a mathematical programming model is usually written as;

**Max *f*(π,, X)**

**Subject to A'X ≤B)**

Where 'π' represents the net return per activity, 'X' is a vector of production activities, the elements of the 'A' matrix are the production coefficients and 'B' is the vector of production inputs such as labor, capital, natural resources including water, intermediate inputs and so on (Al Weshah, 2000; Salman, et al. 2001; Doppler et al. 2002; Salman and Al-Karablieh, 2004; Al-Assaf, et al., 2007; Al-Karablieh and Salman 2006; A-Karablieh et al., 2006; Young, 2005). The parameter 'π' is a measure of the marginal return to water in activity 'X'. The use of mathematical programming is quite advantageous in a situation where a wide range of technological options is to be studied. In such a situation, it is important that the marginal productivity, which is represented by the net profit coefficients, is accurately calculated. However, this valuation method requires detailed data at the farm/firm/industry level and is most suitable for the individual sector or country level inter-sectoral water use analysis; but it is expensive and time consuming.

**Disadvantages**

Mathematical programming models tend to be static one-period models. They model economic problems in which the economic agent (consumer, central planner, or firm) seeks to optimize (maximize or minimize) a single objective function (e.g. surplus, costs, profit or revenue) over a specific time period, while facing constraints that restrict choice to certain levels of inputs or outputs. The models can determine marginal or non-marginal values for use of water as an input. Water enters mathematical programming models as an input constraint, such that its marginal value is found by relaxing the water constraint by adding a unit to the water available for production and calculating the difference between the optimal value before and after relaxing the constraint. This marginal value of water is also known as the 'shadow value' of water. Non-marginal changes can be evaluated similarly, and also changes in the shadow value of water can be calculated for exogenous changes in output prices, input prices, or constraints. Mathematical programming models are often used to determine the value of irrigation water and groundwater in situations where detailed data are available for a few representative agents (Turner et al . 2004)

### 9.2.4 Residual Imputation Method (RIM)

This is a very frequently used approach to estimate the value of water for irrigation. By this method, the total value of output is allocated among each of the resources (inputs) used in the production process. If appropriate prices can be assigned (presumably by market forces) to all resources but one, the remainder of total value of product is imputed to the remaining (or "residual") input. This residual imputation method is most suitable where the residual claimant (water in our case) contributes the largest fraction of the value of output.

The total value of product can be divided into shares, such that each resource is paid according to its marginal productivity and the total product is completely exhausted. (This is satisfied when the total value function is a *linear homogeneous production function'.* There is a standard mathematical result, called *Ruler's theorem,* which shows that if a production function involves constant returns to scale, the sum of the marginal products will actually add up to the total product [Baumol 1977]).

If it is considered a production function Y=*f*(X's) in which four factors of production, namely capital *(K),* labour *(L),* other intermediate inputs (M) such as fertilizer, seed, pesticides et*.,* and water *(W),* are used to produce a single output *Y,* then the production function can be written as [Young & Gray 1985]:

$$Y=f(K,L,M,W) \qquad 11$$

Assume production and prices are known (no uncertainty and the production function is not stochastic) Py is the price of output, Px price of input under perfect information (Heathfield & Wibe ,1987). Assume we have an producer whose objective is to maximize profits with single input X. Then the profit equation is:

$$\pi = Py.Y - Px.X - FC \qquad 12$$

$$\pi = Py\, f(X) - Px.X - FC$$

$$\pi = TVPy - Px.X - FC$$

where FC is the fixed cost of the predetermined inputs. To find the conditions for optimal profits, take the first derivative of π with respect to x and set that equal to zero

$$d\,\pi/dx = Py.df(X)/\,dx - Px = 0\,, \qquad 13$$

*Therefore Py. dy/dx = Px, or Py. MPx = Px which means*

$$WMPx = Px \qquad 14$$

Which is the value of the marginal product (VMP) inputs, the value of marginal product is defined as output price multiplied by the marginal physical productivity of the input. Notice that as the price of the input (Px) decreases, more input will be used and more output will be produced. The same will occur if the output price increases. If competitive product and factor markets are assumed to exist, then prices may be treated as constants. By the second postulate, it can be written (Chambers, 1988):

This method requires the subtraction of the economic cost of all the other production inputs except water from the sales revenue. The difference becomes the value of water in the production of commodity. In the case where just one commodity is produced, the use of the residual imputation method is based on the theory that the sales revenue exactly equals the total cost of production. This implies that the sales revenue (TV= price multiplied by the quantity sold) exactly equals the sum of the inputs used, multiplied by their respective prices. This relationship is expressed below as:

$$\boldsymbol{P_y . Y = \sum_{i=1}^{n} Px_i . X_i + P_w . Q_w} \qquad \mathbf{15}$$

Where 'P' is the competitively determined commodity prices, 'Y' represents the quantity of the commodity produced and sold, while '$Px_i$' is a vector of competitively determined prices (equal to the marginal value product) of non-water factors, and '$X_i$' is a vector of non-water inputs employed in the production process and '$Q_W$ and '$P_w$' are the quantity and price of water respectively. If all the inputs, including water are exchanged in a competitive market and employed in the production process, the value of water (price multiplied by its volume used) will be;

$$\boldsymbol{P_w . Q_w = P_y . Y - \sum_{i=1}^{n} Px_i . X_i} \qquad \mathbf{16}$$

The RIM determines the incremental contribution of each input in a production process. If appropriate prices can be assigned to all inputs but one, the remainder of total value of product is attributed to the remaining or residual input, which in this specific case is water (Young, 2005; Ashfaq et al. 2005, Lange and Hassan, 2007, Speelman et al., 2008, Hellegers and Davidson, 2010). Residual valuation thus assumes that if all markets are competitive, except the one for water, the total value of production (TV= $P_y . Y$) equals exactly the opportunity costs of all the inputs

$$\boldsymbol{TV = \sum_{i=1}^{n} VMP_i \, X_i + VMP_w \, X_w} \qquad \mathbf{17}$$

Where:

TV =total value of the commodity produced;

VMPi = value of marginal product of input i;

Qi = quantity of input i used in production, w for water.

It is assumed that the opportunity costs of non-water inputs are given by their market prices (or their estimated shadow prices). Therefore, the shadow price of water can be calculated as the difference (the residual) between the total value of output (TVP) and the costs of all non-water inputs to production. The residual, obtained by subtracting the non-water input costs from total annual crop revenue equals the gross margin (Water Related Contribution equal gross margin minus the water costs) and can be interpreted as the maximum amount the farmer could pay for water and still cover costs of production. It represents the at-site value of water:

$$\boldsymbol{GM = TV - \sum_{i=1}^{n} P_i \, X_i} \qquad \textbf{18}$$

Where:

GM =gross margin;

Pi = price of input *i*.

This monetary amount, divided by the total quantity of water used on the crop, determines the marginal value for water (VMPw), corresponding to the irrigator's maximum willingness to pay per unit of water for that crop (Agudelo, 2001). Average values were used in this study as a proxy of the marginal ones.

$$\boldsymbol{VMP_w = (TV - \sum_{i=1}^{n} P_i \, X_i)/Q_w} \qquad \textbf{19}$$

This method can be extended to a multi-input and multi-product situation, in which different sectors compete for the use of the scarce resources (production inputs) and sell their products in a non-differentiated market. This implies that the firms are in perfect competition. The residual value of water in the $i^{th}$ sector producing the $j^{th}$ commodity is;

$$\boldsymbol{P_{wj} \, . \, Q_{wj} = \sum_{i=1}^{n} Py_{ij} \, . \, Y_{ij} \; - \; \sum_{i=1}^{n} Px_{ij} . X_{ij}} \qquad \textbf{20}$$

For a sector with *n* inputs and *m* outputs, using a different nomenclature the residual calculation can be expressed as follows:

$$Pw^* = \frac{(\sum_{j=1}^{m} Y_j * P_j - \sum_{i=1}^{n} X_i * P_i)}{\sum Q_w} \qquad \textbf{21}$$

where:

*Xi* stands for quantity of input I, i=l,2,...,n;

*Yj* refers to quantity of product *j, j=1,2,...,m;*

*Py,* and *Pxi* are the prices of products and inputs respectively;

*Qw* denotes the quantity of water input.

This Pw* will represent is the shadow price of water, i.e., the net benefit imputed as the value per unit of water input.

To estimate the water value in specific commodity group such as field crop we use the following formula to get an weighted average water value in the entire sector as:

$$Pwj = \frac{(P_{w_i} * Q_{w_i})}{\sum Q_w} \quad \textbf{22}$$

Where Pwi is the estimated water value in crop i, Qwi is the quantity of water use to produce crop I, and Qw is the total amount of water used in the group j

Renwick (2001) used the concept expressed in above to estimate both the implicit and explicit costs of securing water and the scarcity value of the resource use. Thus equation [12] can be broken into:

$$(\boldsymbol{P^*_{wj}} + \boldsymbol{\lambda}\ ) \,.\, \boldsymbol{Q_{wj}} = \sum_{i=1}^{n} \boldsymbol{Px_{ij}}.\boldsymbol{X_{ij}} \ - \sum_{i=1}^{n} \boldsymbol{Px_{ij}}.\boldsymbol{X_{ij}} \quad \textbf{23}$$

Where 'P*' reflects both the implicit and explicit costs of securing water and 'λ' reflects the scarcity value of the resource use, hence:

$$(\boldsymbol{P^*_{wj}} + \boldsymbol{\lambda}\ ) = (\sum_{i=1}^{n} \boldsymbol{Px_{ij}}.\boldsymbol{X_{ij}} \ - \sum_{i=1}^{n} \boldsymbol{Px_{ij}}.\boldsymbol{X_{ij}}\ )/\boldsymbol{Q_{wj}} \quad \textbf{24}$$

Using the residual imputation method, Renwick, (2001) calculated the shadow price of water and by using discounting method, estimated the present value of water in irrigated agriculture and reservoir fisheries in Sri Lanka.

However, the assumptions of the RIM are not overly restrictive, but care is required to assure that conditions of production under study are reasonable approximations of the conceptual model. The main issues can be divided into two types (Young, 2005; Lange & Hassan, 2007): (1) those relating to the specification of the production function and (2) those relating to the market and policy environment (i.e. the pricing of outputs and non-residual inputs). If inputs to production are omitted or underestimated (incorrect production function) or if there are inputs that are unpriced or not competitively priced, then the RIM will generate inaccurate estimates. To overcome the first problem, all relevant inputs should be included in the model. The second problem can be solved by determining shadow prices for the inputs that are not correctly priced. Because of this sensitivity to the specification of the production function and the assumptions about market and policy environment, the residual imputation method is only suitable when the residual input contributes a large fraction of the output value. However, this is the case for irrigated agriculture in water scarce regions.

However, this method is simple and, under certain specified conditions, is applicable for estimating the value of resources used in production. If appropriate prices can be assigned to all inputs but one, and certain other assumptions are met, then the residual of the total value of product is imputed to remaining resource

While residual imputation appears to be a very simple technique for estimating shadow prices of resource values, it is faced with certain limitations, which should be recognized by the user. The limitations are:

(i) The problem of exact exhaustion of the total product (Are the conditions for Euler's Theorem satisfied?). This means is the total value function is a linear homogeneous production function'. There is a standard mathematical result, called Ruler's theorem, which shows that if a production function involves constant returns to scale, the sum of the marginal products will actually add up to the total product [Chambers,1988; Heathfield and Wibe 1987)

(ii) The question whether prices equal marginal value product except for the one whose value is being estimated (Does the production process exhibit optimal factor input levels?).

(iii) The problem of omitted variables (Are all inputs with positive MVP properly accounted for?

(iv) Problems of estimation when price supports, subsidies, or other exogenous influences are exerted on production (Do factor and product prices properly reflect scarcity values?).

All of the above shortcomings impose constraints on value estimated by residual imputation (Ashfaq et al., 2005). Some authors use the term *'farm budget approach'.* However, It was found that this is just a name given to the residual valuation technique when it is specifically applied to agriculture by using a farm budget analysis. The name arises from the fact that representative farm crop budgets developed for a region are used to estimate the maximum revenue share of the water input. The total annual crop revenue less non-water input costs is a *residual,* the maximum amount the farmer could pay for water and still cover costs of production. It thus represents the *on-site* value of water.

### 9.2.5 The value added method

This approach could be used in any situation that requires the estimation of economic benefits derived from the use of water as an intermediate input in sectoral production activities. Value added refers to net payments to the primary factors of production such as wages and salaries, rents and other natural resources, interest or depreciation on capital. Value added is measured on a sector-by-sector basis through an input-output model representing the economic structure of a country, region or water management area. The framework of the input-output model, which is a static model, is used to estimate the direct and indirect impacts. This framework based on the linear structure of inter-industry production linkages. The input-output coefficient matrix is used to calculate the direct and indirect intermediate inputs requirements per extra unit of output or value added in a specific sector. This coefficient matrix, which is also referred to as the Leontief inter - industry transactions matrix, defines the amount of the output from each production sector which is required as an intermediate input used to produce a unit of an output in a specific sector. The model illustrates the interdependence nature of the production sectors in an economy, hence the inter-sectoral forward and backward linkages. With the incorporation of water into the inter-sectoral production framework, the input-output model can be used to investigate the economy-wide contribution of water to inter-sectoral production activities and the impact of investment in water infrastructure on output growth and value added. It can also be used to evaluate the economy-wide impact of inter-sectoral water pricing, re-allocation and other managerial policies.

### 9.2.6 Financial and Economic Returns

Farm costs have three components, namely fixed costs, variable costs, and total costs. The fixed cost (FC) portion includes rent of land, and farm machinery etc; variable cost (VC) includes labor, both family and hired, seed, fertilizer, farm manure pesticides, draught power, and irrigation service etc. The FC and VC are added up to arrive at the total cost (TC). All costs are estimated on a per dunum or hectare basis. The financial returns (FR) are estimated by taking the average yield from each crop times the farm gate prices (FGP), and adding up the by-product times the prices received by the farmers. The financial net returns are obtained by subtracting the total cost from the gross returns. The financial returns FR are estimated on a per dunum basis.

The economic returns (ER) are obtained by valuating the main product of the crop at economic prices (EP). Economic prices are also referred to as social prices or efficiency prices. By-product prices are the same as used for estimating gross returns. The input costs are also estimated at world prices. World prices of inputs and outputs are the cornerstone for estimating the efficiency prices. The costs of production are separated into tradable and non-tradable components. World prices are the prices for tradable commodities, which can be traded in the world market. To obtain economic prices, the market prices of the tradable inputs and outputs have been adjusted by applying a standard conversion factor (SCF) i.e. 0.80. The SCF has been derived by taking into account, CIF (cost insurance freight) value of imports and FOB (free on board) value of exports, net value of taxes on imports and on exports. Shadow pricing is used to convert financial prices into economics prices. Shadow pricing aims to ensure that values applied to inputs and outputs reflect their real scarcity in society (i.e. the cost to society of their being used or produced in the specific activities). Seeds, fertilizers, and materials for plant protection (pesticides, insecticides, sprays, herbicides etc.) can be traded internationally, so prices of these inputs also have been adjusted by applying SCF to arrive at economic prices. For hired labor, actual wage rate is the private price. To estimate the economic price of the hired labor, wage rate is multiplied by SCF. (Ashfaq et al. 2005)

This approach is appropriate when estimates of direct demand schedules or functions are difficult to be computed because of data unavailability or other reasons. This approach is based on the assumption that the maximum willingness to pay for a publicly supplied good or service is not greater than the cost of providing it. That is, if a given project, with a specified output costs is less than the next best project with the same output level, then the former is preferred to the alternative. The present value of the total costs of each alternative is calculated on the basis of commensurate planning period, price level, and discount rate (Agudelo, 2001). The analysis must verify that the highest-cost alternative would actually be constructed in the absence of the project under consideration. The alternative cost approach is very useful when the demand for water is price inelastic and when the objective of a public project is to reduce the cost of producing an output which could otherwise be provided at a higher cost to the consumer. The approach has the advantage of permitting benefits evaluation without actual estimation of the demand curve.

### 9.2.7 Alternative Cost Approach

The alternative cost approach is appropriate when estimates of direct demand schedules or functions are difficult to be computed because of data unavailability or other reasons. This approach is based on the assumption that the maximum willingness to pay for a publicly supplied good or service is not greater than the cost of providing it. That is, if a given project, with a specified output costs is less than the next best project with the same output level, then the former is preferred to the alternative. The present value of the total costs of each alternative is calculated on the basis of commensurate planning period, price level, and discount rate (Agudelo, 2001). The analysis must verify that the highest-cost alternative would actually be constructed in the absence of the project under consideration. The alternative cost approach is very useful when the demand for water is price inelastic and when the objective of a public project is to reduce the cost of producing an output which could otherwise be provided at a higher cost to the consumer. The approach has the advantage of permitting benefits evaluation without actual estimation of the demand curve