

# Chapter 22

## Economic Efficiency of Production Systems in the Gharb Irrigated Area (Morocco) Affected by Access to Water Resources

R. Harbouze, Ph. Le Grusse, A. Bouaziz, J. C. Mailhol,  
P. Ruelle and M. Raki

**Abstract** The aim of this work is to calculate and compare the economic efficiency indices of irrigated farms and the level of optimisation of irrigation water used for the main crops of the Gharb area. To this end, a Data Envelopment Analysis (DEA) model was used to calculate efficiency indices. The survey covered 49 farms with different crop systems (vegetables, citrus crops, cereals, forage, sugar beet and sugar cane) and different irrigation systems (drip, sprinkler and gravity-fed). The results show that the most efficient farms are both those affected by water stress and those with “unlimited” access to water resources (private pumping). On the other hand, 73 % of the farms are inefficient, indicating that the majority of farmers do not have a good grasp of the available technology.

### 22.1 Introduction

The major work undertaken by Farrell (1957) for estimating production efficiency was initiated by the evaluation of technical efficiency suggested by Debreu (1951) and Koopmans’ definition of efficiency: ‘A feasible input-output vector is said to be technically efficient if it is technologically impossible to increase any output and/or reduce any input without simultaneously reducing another output and/or

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R. Harbouze (✉)  
Montpellier 1 University, Montpellier, France  
e-mail: harbouze@iamm.fr

R. Harbouze · Ph. Le Grusse  
CIHEAM-IAM, Mediterranean Agronomic Institute of Montpellier, Montpellier, France

R. Harbouze · A. Bouaziz · M. Raki  
Hassan II Agronomy and Veterinary Medicine Institute, Rabat, Morocco

J. C. Mailhol · P. Ruelle  
Joint Research Unit G-Eau, Cemagref, Montpellier, France

*one other input* (Koopmans 1951)'. Koopmans enabled the first significant step towards border econometrics. Farrell's innovation lies in the application of the efficiency calculated by Debreu '*with the resource load factor which calculates the maximum equiproportional reduction of all the factors of production, making it possible to maintain the existing level of production within each manufacturing unit of a sector*'.

The concept of efficiency is often used to characterise resource use; one can say that efficiency is a ratio representing the performance of a process which transforms a set of inputs into a set of outputs. It corresponds to the difference between the maximum possible production, taking into account the inputs consumed and the actual production (Boussemart 1994).

In terms of comparative analysis, the limit of production refers to best practices. The variation of each observation compared to this limit represents its degree of inefficiency. The variation may be due to a lack of competition, which means that farms may operate below their capacity if they are protected on the market (Bachta and Chebil 2002). Other explanations point to the effects of non-physical inputs (information, creative knowledge, etc.) on the efficiency of the farms (Muller 1974).

Today, in the new context of water scarcity and climate change, governments limit the over-exploitation of water resources and encourage the use of alternative resources (reuse of sewage, desalination, etc.). Groundwater merits peculiar attention due to its relative importance, especially in the coastal zone of the Gharb. Indeed, due to the many different uses to which they are put, groundwater resources and aquifers in different parts of the world are increasingly over-exploited.

It is consequently important to consider another system of resource management and to move away from supply management to demand management. In this way it will be possible to reduce total water demand by diversifying crops and sources of income and by introducing crops and activities with a higher added value, lower water requirements, higher income potential and more significant financial capacities (Bouaziz and Belabbes 2002). Farmers thus need to be encouraged to make more efficient use of irrigation water in growing crops. Demand management, particularly of large irrigation areas, represents considerable potential for water saving and conservation in the context of limited water resources and increasing mobilisation costs.

In Morocco, irrigated areas (1.454.000 ha) account for about 11 % of the total agricultural area. In the past, these areas profited as they had been declared a priority for investment. They thus contribute to approximately 45 % of the agricultural-added value, accounting for 75 % of agricultural exports and generating more than a third of the employment in rural areas (Belghiti 2008). The irrigated sector consumes nearly 92 % of the water used. Water therefore needs to be used wisely to ensure technical, economic and social optimisation and especially to preserve it for future generations.

This study was conducted in the Gharb irrigated area and was based on a survey of a sample of 49 farms, with the aim of:

- assessing the economic efficiency indices of the farms;
- identifying farms that could be used as management models for economically inefficient farms;
- understanding how farming systems affect the level of efficiency of these farms.

## 22.2 Materials and Methods

### 22.2.1 *The Gharb Area*

The Gharb area is located in north-western Morocco. It is bounded to the west by the Atlantic Ocean and the dunes of the Sahel, to the north by the hills of pre-Rif, to the east by the Sais plateau and to the South by the Maamora Forest. Its elevation ranges from 4 to 25 m. It is a coastal area with sandy soils, sharing borders with the alluvial plains, and the central Sebou region (the main river) with clay and loamy soils.<sup>1</sup> It covers a total area of 616,000 ha. The uncultivated area (infrastructure, rangeland and arid uncultivated land) comprises about 228,000 ha, of which 122,000 ha consists of forest. The 388,000 ha of agricultural land are divided into:

- 250,000 ha of irrigable land, of which 107,000 ha are equipped with large hydraulic systems and 12,000 ha with small and medium hydraulic systems, and
- 138,000 ha of rain-fed cultivated land.

The area includes three irrigation sectors:

- *The first section (PTI)* a net area of 35,858 ha was fully equipped between 1972 and 1978. Most of the area is located on the left bank of the Sebou river and part of it is on the right bank of Oued Beht (sectors P7 and P8). The areas along the Sebou river are supplied by lift stations that serve networks of canals. Sectors P7 and P8 are supplied by the pumping station and the Boumaiz canal (between Sebou and Beht). Only sector P7 is irrigated by sprinklers (2,558 ha), while the remaining 33,300 ha are irrigated by gravity.
- *The second section (STI)* covers an area of 37,000 ha. It includes sectors C1 to C4, N1-N5 and N9. These sectors are irrigated by gravity, while other sectors are equipped with sprinklers.
- *The third section (TTI)* is irrigable land but most of it has not yet been equipped. The net area to be equipped by the end of the project will exceed 110,000 ha. It includes areas Z1 to Z6, E1 to E5 and N10. Areas Z1, Z2 and N10 are part of the coastal area called **Mnasra**.

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<sup>1</sup> Gharb Regional Agricultural Development Agency.

This region is characterised by a range of different crops: sugar, cereals, vegetables, forage crops, grain legumes, oil crops and fruits (citrus, etc.).

### 22.2.1.1 The Survey and Farm Sample

The survey covered 49 farms in three areas of Gharb (Fig. 22.1):

- 18 farms in the central area, mainly in sectors S9, N4, N5, P7 and P8. The main crops in this area are cereals, sugar (sugar beet and sugar cane) and forage crops. The two main irrigation systems are surface and sprinkler systems.
- 18 farms in the Beht zone. The main crops in this area are citrus fruits, cereals and forage crops. Surface irrigation systems are mainly used in the area.
- 13 farms<sup>2</sup> in the coastal zone, where the main crops are bananas, strawberries and vegetables under drip irrigation.

The farms were chosen to reflect the diversity of the three areas, particularly in terms of farm size (<5 ha, 5–10 ha and >10 ha), land tenure systems (private property, collective, estates, agrarian reform and *Guich*) and irrigation systems (drip, surface and sprinkler or pump<sup>3</sup>).

In terms of size, 38 % of the farms sampled in the coastal zone had less than 5 ha, and 38 % had more than 10 ha. Farms of between 5 and 10 ha account for only 23 % of the sample. In the central and Beht areas, more than half of the farms surveyed had less than 5 ha (Fig. 22.2).

Direct land tenure was observed in 94 % of our survey in the central area, 67 % in the Beht area and 61 % in the coastal zone. The remaining land was under indirect tenure: land rent or run by associations for part of the production.

### 22.2.1.2 Production Systems and Access to Water

In the coastal zone, the main crops are vegetables and fruit (bananas and strawberries), followed by cereals and oil crops. The central area is more oriented to the production of sugar beet and sugar cane, cereals and fodder (corn fodder and Berseem clover). The **Beht** area is mostly used for citrus cultivation in addition to the same main crops as in the central area. Livestock is the main source of cash income for most farmers. Meat production plays a very important role in the production systems of the farms we surveyed in the central zone and the Beht zone. Cattle farming occupies 72–61 % in these two areas, respectively.

<sup>2</sup> Six of the 13 farms were surveyed by Mamounata SEMDE, Rural Engineer, Hassan II Agronomy and the Veterinary Medicine Institute.

<sup>3</sup> In this irrigation method, a worker brings water to the plot with a plastic hose and tries to cover the whole acreage. This practice is very common in groundnut cultivation in the sandy coastal area.

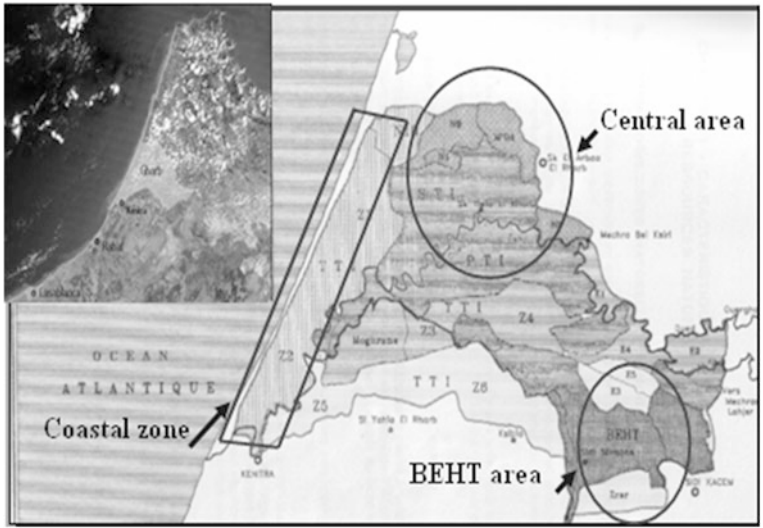


Fig. 22.1 Gharb area (source GRAAD 2007)

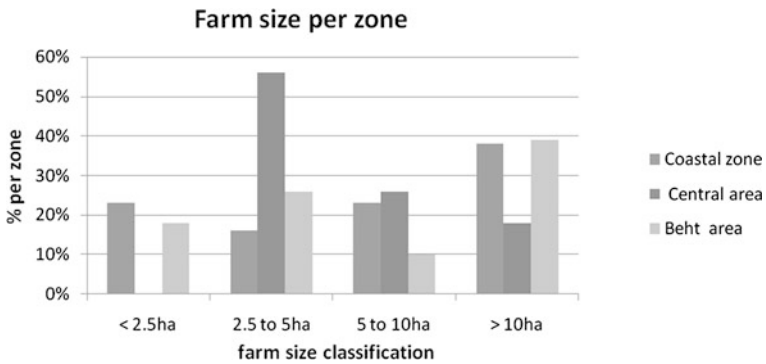


Fig. 22.2 Farm size in the 3 zones

In terms of water access, the farmers only use groundwater in the coastal zone, where private pumping is very widespread. Most farmers use drip irrigation. Less fortunate farmers use the ‘pumpman’ technique. In the central area, they use the state water supply for irrigation: 56 % by gravity feed; 39 % by sprinklers and 5 % use both gravity and drip irrigation through a pool supplied by the public network.

In the Beht area, which is facing a serious water shortage, all the farms use the state water supply, 83 % irrigate by gravity feed, 11 % use both gravity feed and sprinklers, and one farm uses gravity and drip irrigation. The latter is generally supplied from a well (which in theory is not allowed in an equipped area) in order to cope with water shortage problems, the irregular supply from the state water

supply network and delays in water turns. Other farmers in this region would like to use drip irrigation but the groundwater salinity prevents them from doing so. In the Beht area, we also observed that many farmers irrigate from the drainage network because of a lack of water.

### ***22.2.2 The Olympe Platform***

To evaluate the levels of access to water resources for the 49 farms in different agro-economic situations, techno-economic investigations were modelled on the Olympe platform<sup>4</sup> (Penot and Dehevels 2007). This enabled an evaluation of the techno-economic performance of different production systems with different means of access to water resources. These data enabled us to produce conventional indicators:

- Gross income per crop and per cultivated hectare;
- Net margin per crop per cultivated hectare;
- Water efficiency of the main crops grown and volume of water provided (in m<sup>3</sup>);
- Production expenditure, structural expenditure per crop per hectare and the proportion of the water cost in relation to the overall expenditure.

### ***22.2.3 Efficiency Measurement***

#### **22.2.3.1 Parametric Methods**

##### Pragmatic Approach

The simplest way of measuring economic efficiency is by means of the partial productivity index, usually that of the labour force. This approach ignores the presence of other factors which affect the average and marginal productivity (Lau and Yotopoulos 1971).

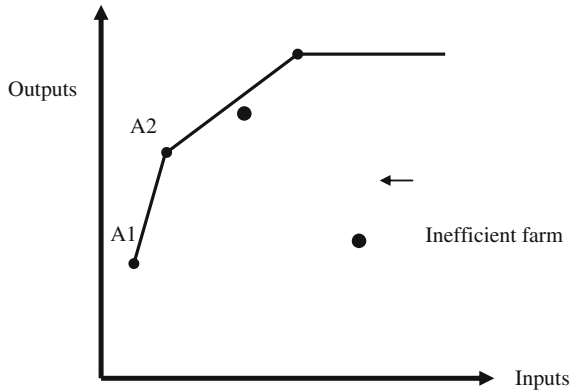
##### Econometric Approach

Farrell also put forward a measure related to the outputs, implemented by Timmer (1971). This measurement corresponds to the ratio of the observed output to the optimal output for a given level of inputs. It coincides with input measurement when technology enables a constant yield of scale (Afriat 1972).

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<sup>4</sup> <http://www.olympe-project.net/>

**Fig. 22.3** Linear envelope per item



**22.2.3.2 Non-parametric Methods: Data Envelopment Analysis as a Means of Measuring Efficiency**

The approach developed from an original proposal by Farrell (1957) is described as non-parametric because it was built by mathematically programming an envelope of observations, but with no vector of the parameters being estimated. Charnes et al. (1978, 1981) generalised Farrell’s proposal and implemented it as an operational tool while allowing for estimation of the production function by an envelope curve formed of the segments of the right-hand side joining the effective entities (A1, A2..) (Fig. 22.3).

The DEA method is based on linear programming to identify empirical production functions. It determines the limit of efficiency from the point of view of best practices and compares all similar units in a given population. Each unit is regarded as a decision-making unit (DMU) that transforms inputs into outputs.

The efficiency formula for the DEA method for a given decision-making unit *k* is as follows:

$$E_k = \frac{\text{summon balanced outputs}}{\text{summon balanced inputs}}$$

$$E_k = W_1 * \text{Out1} + W_2 * \text{Out2} + \dots \dots / V_1 * \text{Inp1} + V_2 * \text{Inp2} + \dots \dots$$

With: *W* (weights of outputs) and *V* (weights of inputs).

The DEA method calculates the separated weighting for each unit, assuming that the weightings give the best result for the unit concerned. The basic ideas of this method for each DMU *k* are as follows:

- To maximise  $E_k$ , under the constraint  $E_k \leq 1$  for all the DMU of the population concerned.
- All weightings are positive.

In this work, we used the form ratio of the Charnes, Cooper and Rhodes (CCR) model (Liu et al. 2013). This model makes it possible to measure the unused

factors available to the farm and the potential production not achieved by the farm during the production process.

Specifically, DMU 1 consumes amounts  $X_j = (x_{ij})$  of inputs ( $i = 1, m$ ) and produces amounts  $Y_j = (y_{rj})$  of outputs ( $r = 1, \dots, s$ ). For these constants, which generally take the form of observations, we assume that  $x_{ij} > 0$  and  $y_{rj} > 0$ . The matrix (sxn) of output measurements is indicated by  $Y$ , and the matrix (mxn) of input measurements is indicated by  $X$  (Badillo and Paradi 1999).

The form ratio of the model is as follows:

For  $DMU_0$

$$\text{Max}_{u,v} h_0(u, v) = \sum_{r=1}^s u_r y_{r0}$$

Under the constraint

$$\begin{aligned} \sum_{i=1}^m v_i x_{i0} &= 1 \\ \sum_{r=1}^s u_r y_{rj} - \sum_{i=1}^m v_i x_{ij} &\leq 0 \\ u_r, v_i &\geq \varepsilon \end{aligned}$$

where:

- $h_0$  represents the technical efficiency of the farm according to the definition of Farrell (1957)
- $X, Y$  are matrices of the observed outputs and inputs, respectively;
- $y_0$  is the vector of the observed outputs of the farm used for efficiency evaluation;
- $x_0$  is the vector of the observed inputs of the farm used for efficiency evaluation
- $v_i$  and  $u_i$  are the weights determined by the solution of the problem (Vermersch et al. 1995), i.e. by the data on all the DMU used, e.g. unit of reference,  $x_{i0}$  and  $y_{r0}$  observed values of  $DMU_0$

By convention, it is accepted that the number of DMU must be equal to or higher than three times the number of inputs and outputs (Raab and Lichty 2002).

For evaluating the efficiency scores, we used one output (farm income) and eight aggregates of inputs: To calculate the efficiency indices, the prices of the inputs must be known. Consequently, aggregation is generally based on monetary value.

Inputs:

- *Land.* Because of the presence of several types of soil and of land tenure, it was not possible to compare the farms without taking these factors into account. To solve this problem, we used the cost of renting land as the basis of the weighting factor.



- *Labour*. For each farm and crop management operation we determined the number of working days per category (family or external labour). This input is expressed as a total number of days. We assumed that the cost of one working day was 35 DH/day for family members and 50 DH/day for external labour).
- *Mechanisation*. This aggregate corresponded to a number of cultivation operations (tillage, seedbed preparation and harvesting including transport of the yield). For each operation, the expenditure was collected at the farm level.
- *Water irrigation*. The expenditure included the cost of water delivered by the irrigation office and the cost of using water from private wells. In terms of rainfall, we assumed that the farms received equal amounts of rain and consequently we did not take it into consideration. The water input was expressed in m<sup>3</sup>/ha.
- *Seeds*. We introduced this input by allocating the market price to each seed type.
- *Pesticides*. Expenditure took into account all pesticides used during crop management (in DH).
- *Fertilisers*. In this aggregate, we included all the expenditure on the various fertilisers used during the crop cycle (in DH).

## 22.3 Results and Discussion

In this section, we first analyse the results of the DEA method for the various parts of the Gharb area (data are for the year 2007). First, the farms were grouped into efficiency classes to show the behaviour of the farmers and how they used their inputs. Second the farms were grouped by types of crop and we then identified the causes of the variations observed.

### 22.3.1 Farmers' Efficiency Scores by Zone

In the coastal zone, the farmers scored an average economic efficiency of around 73 %, with an average deviation of 23 %. A total of 54 % of the farms were not efficient. Each efficiency score measures the proportional reduction in inputs with no corresponding reduction in outputs. For example, farmers in the coastal zone were able to reduce their inputs by an average of 27 % while maintaining constant outputs.

In the Beht area, the average economic efficiency score of the 19 farmers was around 62 %, with an average deviation of 18 %. A total of 78 % of the farms were inefficient. This result (efficiency score) was a little lower than in the coastal zone (54 %), with a larger number of dots representing farmers located away from the efficiency limit on the scatter graph.

The central area had the lowest mean economic efficiency score at 58 % with an average deviation of 16 %. A total of 83 % of the farms were inefficient.

### 22.3.1.1 Efficiency Classes and Average Inputs/ha per Zone

The most efficient class (80–100 %) for the coastal zone has the highest income/ha (Table 22.1). The farmers manage to produce an average of 14 DH/m<sup>3</sup> of water but they also use the most inputs/ha, as well as an average of almost 7,600 m<sup>3</sup> of water per hectare. Their income/inputs ratio was also the highest. It would have been interesting to compare these results with the water requirement at the ETM<sup>5</sup> during the year under examination, which incidentally has not been specified (for example in 2006 it was useless to irrigate sugar beet in the Gharb).

The least efficient farmers (20–40 %) were those with the lowest income/ha, and those who used the least inputs/ha. These farmers did not use much irrigation water (less than half that used by the most efficient class), and the water used had a total value of only 5 DH/m<sup>3</sup>.

The efficiency levels of these farmers and the ratio of income to inputs were coherent, i.e. the most efficient farmers were those who had the highest income/input ratio and also the farmers who produced more outputs with proportionally fewer inputs.

In the Beht area, the most efficient farmers only obtained an income value of 27283 DH/ha (five times less than in the coastal zone) (Table 22.2). These farmers only used 6 DH/m<sup>3</sup> of water.

In terms of water productivity, the farmers in the 40–60 % efficiency class displayed better water productivity with 7 DH/m<sup>3</sup>; this is higher than 3 out of the 4 classes in the coastal zone.

In the central area, the least efficient farmers are those who use the most inputs/ha (Table 22.3), which is not justified by the level of production they achieve. Conversely, the most efficient farmers are those who use the least inputs/ha (6–10 % less). This situation contrasted with that observed in the coastal zone and in the Beht area, where the most efficient farms were those who used the most inputs/ha.

In terms of water productivity, the farmers in the central area did not achieve the threshold value of 3 DH/m<sup>3</sup>. This is very poor compared with the other areas.

### 22.3.1.2 Analysis of Crop Efficiency Scores

Our first analysis examined the production systems of the classes corresponding to the extreme scores. At the lowest level of efficiency (20–40 %), the farmers in this class used a cropping system based on either a cereal or sugar and earned more than 50 % of their income with these crops. In the 80–100 % efficiency class, 80 % of the most efficient farms were those which produced vegetables. We can thus conclude that it would be useful to continue the analysis based on the type of crops.

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<sup>5</sup> ETM Evapotranspiration maximum.

**Table 22.1** Efficiency classes and average inputs/ha (coastal zone)

Efficiency class (%)	Fertilisers (DH/ha)	Seed (DH/ha)	Plant protection products (DH/ha)	Labour (WD/ha)	Mechanisation (DH/ha)	Water (m <sup>3</sup> /ha)	Land (DH/ha)	Income (DH/ha)	Income/m <sup>3</sup> (DH/m <sup>3</sup> )	Inputs (DH/ha)	Income/inputs
80–100	11417	7252	6026	126	6271	7583	4000	102930	14	43170	2,3
60–80	5670	3691	1512	112	1463	8645	4000	31500	4	24575	1,4
40–60	2133	2388	1148	54	2059	3819	3403	22988	6	14923	1,5
20–40	1288	899	835	31	2220	2286	3250	11953	5	10723	1,1

**Table 22.2** Efficiency classes and average inputs/ha (Beht)

Efficiency class (%)	Fertilisers (DH/ha)	Seed (DH/ha)	Plant protection products (DH/ha)	Labour (JT/ha)	Mechanisation (DH/ha)	Water (m <sup>3</sup> /ha)	Land (DH/ha)	Income (DH/ha)	Income/m <sup>3</sup> (DH/m <sup>3</sup> )	Inputs (DH/ha)	Income/inputs
80–100	3051	268	540	67	2607	4940	2100	27283	6	13365	2,1
60–80	1694	634	719	41	2102	4285	2500	20683	5	11235	1,8
40–60	1641	865	1051	31	1909	2191	2700	15263	7	10354	1,4
20–40	1461	832	495	22	2388	2064	2750	9037	6	9693	0,9

**Table 22.3** Efficiency classes and average inputs/ha (Central area)

Efficiency class (%)	Fertilisers (DH/ha)	Seed (DH/ha)	Plant protection (DH/ha)	Labour (JT/ha)	Mechanisation (DH/ha)	Water (m <sup>3</sup> /ha)	Land (DH/ha)	Income (DH/ha)	Income/m <sup>3</sup> (DH/m <sup>3</sup> )	Inputs (DH/ha)	Income/inputs
80-100	522	159	88	11	1235	9261	3000	26170	3	10009	2,6
60-80											
40-60	1312	1450	342	15	1635	4227	3214	13340	3	10603	1,2
20-40	1122	1456	570	33	1174	3153	4000	6696	2	11057	0,6

Sugar beet turned out to be the least efficient crop (Table 22.4), producing the lowest income/ha and using the most inputs/ha. In the 20–40 % efficiency class, sugar beet used irrigation water the most efficiently, which can be explained by the fact that these farms used less irrigation water than farms in the other efficiency classes. On the other hand, apart from mechanisation (and irrigation), other inputs are higher than those of the other classes.

In the most efficient class, sugar beet generated the highest income/ha and used less inputs/ha than in the other efficiency classes.

In the most efficient class, sugar cane procured the highest income/ha and used the most inputs/ha, i.e. just the opposite of sugar beet, where the most efficient class used the least inputs/ha) (Table 22.5).

The best water efficiency was obtained by sugar cane in the most efficient class: 2.8 DH/m<sup>3</sup> of irrigation water.

The 80–100 % efficiency class included only 25 % of the farmers (who thus had efficient crops). This result shows that the crops were very badly managed in terms of inputs, as the majority of the sugar crops in our sample were inefficient. This raises the question of the way in which these crops were managed.

The observations made for sugar beet are also valid for cereals and citrus fruits (Tables 22.6 and 22.7). For example, the most efficient class was that which procured the highest income/ha and used the least inputs. The most efficient citrus fruits made the best use of irrigation water: 6 DH/m<sup>3</sup>.

Vegetable crops were the most efficient (Table 22.8) and procured the highest income/ha of all the other crops (2–7 times higher). Vegetable crops also made the best use of irrigation water, which reached 12.9 DH/ha in the 80–100 % efficiency class.

We observed that in order to be efficient, vegetable crops had to be grown intensively and well-managed (the more the inputs, the higher the income). The same was true for sugar cane.

### ***22.3.2 Example of Decision-Making Aid for the Farmers***

Table 22.9 summarises the results from three farms which illustrate how they can be used for decision making. Farm 1 does not manage its sugar crops very well: efficiency is low for sugar cane and very low for sugar beet, whereas cereals are very efficient. The general inefficiency of this farm (efficiency = 0.3) is due to the fact that the sugar crops occupied more than 60 % of the total surface area of the farm. To become more efficient, we need to see how this farmer could manage his sugar crops like farm 3, where the sugar cane management is highly efficient.

Farm 2 is efficient (efficiency = 1) and its indices are good for two crops, but there is nevertheless room for improving watermelon cultivation.

At this stage, we can say that a farm is inefficient because the farmer has managed some crops badly, but we cannot answer the question of why some crops are inefficient.

**Table 22.4** Income and inputs/ha per efficiency class for sugar beet

Crop	Efficiency class (%)	Income (DH/ha)	Fertilisers (DH/ha)	Seed (DH/ha)	Plant protection products (DH/ha)	Labour (WD/ha)	Mechanisation (DH/ha)	Water (m <sup>3</sup> /ha)	Income/m <sup>3</sup> (DH/m <sup>3</sup> )	Inputs (DH/ha)	Income/inputs
Sugar beet	80-100	23140	930	900	1624	35	1575	3800	6,1	8154	2,8
	60-80	21505	2050	1150	950	69	1564	3015	7,1	9636	2,2
	40-60	20045	4056	1100	1281	83	930	2706	7,4	11625	1,7
	20-40	17400	5193	1575	1927	94	800	2242	7,8	13906	1,3

**Table 22.5** Income and inputs/ha per efficiency class for sugar cane

Crop	Efficiency class (%)	Income (DH/ha)	Fertilisers (DH/ha)	Seed (DH/ha)	Plant protection products (DH/ha)	Labour (JT/ha)	Mechanisation (DH/ha)	Water (m <sup>3</sup> /ha)	Income/m <sup>3</sup> (DH/m <sup>3</sup> )	Inputs (DH/ha)	Income/inputs
Sugar cane	80-100	28917	2520	4733	800	50	1198	10389	2,8	16196	1,8
	60-80	15000	3125	1555	620	47	1000	11340	1,3	13615	1,1
	40-60	20167	1177	3200	452	50	2438	9647	2,1	13841	1,5
	20-40	18375	2395	1623	785	54	1225	9070	2,0	12453	1,5



**Table 22.6** Income and inputs/ha per efficiency class for cereals

Crop	Efficiency class (%)	Income (DH/ha)	Fertilisers (DH/ha)	Seed (DH/ha)	Plant protection products (DH/ha)	Labour (JT/ha)	Mechanisation (DH/ha)	Water (m <sup>3</sup> /ha)	Income/m <sup>3</sup> (DH/m <sup>3</sup> )	Inputs (DH/ha)	Income/inputs
Cereals	80-100	9301	990	631	401	15	1644			4191	2,2
	60-80	7370	869	711	536	20	1398			4214	1,7
	40-60	7969	1259	722	554	16	2240			5336	1,5



**Table 22.8** Income and inputs/ha per efficiency class for vegetable crops

Crop	Efficiency class (%)	Income (DH/ha)	Fertilisers (DH/ha)	Seed (DH/ha)	Plant protection products (DH/ha)	Labour (JT/ha)	Mechanisation (DH/ha)	Water (m <sup>3</sup> /ha)	Income/m <sup>3</sup> (DH/m <sup>3</sup> )	Inputs (DH/ha)	Income/inputs
Vegetable crops	80–100	71462	6609	4536	3504	65	1382	5534	12,9	21072	3,4
	60–80	37007	4219	3624	2431	80	1257	5200	7,1	16931	2,2
	40–60	35277	4078	5254	2502	116	1864	5400	6,5	20358	1,7
	20–40	15750	3431	2893	1079	60	1050	4400	3,6	12752	1,2

**Table 22.9** Crop and farm efficiency (DEA) for three farms

Farm	Crop	Area (ha)	DEA crop	DEA farms
1	Soft wheat	1	1.0	0,30
	Durum wheat	3.2	0.8	
	Sugar beet	4.7	0.35	
	Sugar cane	1.5	0.5	
2	Watermelon	3	0.5	1
	Strawberry	10.5	1.0	
	Melon	4	0.9	
3	Berseem clover	1	0.7	1
	Sugar cane	4	1.0	

To summarize, the results of the efficiency index analysis first showed that 73 % of the farms in the entire sample had very low efficiency scores (54 % for the coastal zone, 78 % for Beht area and 83 % for the central area) suggesting that:

- the majority of farmers do not master the available technology;
- the technical level of the farmers in one and the same zone is very similar; and
- using the available technology, the farmers in one and the same zone allocate their resources in similar ways. This implies that the farmers have the same technical information.

The efficiency of the farms in the coastal zone does not enable them to outclass farms in the other two areas. Admittedly 46 % of these farms are efficient, but the most efficient ranked only fifth out of the 49 farms in the sample, whereas four farms in the water-deficient Beht area took the first four places.

Indeed, although farmers in the Beht area lacked water for irrigation, this did not prevent them from being as efficient as farmers in the coastal zone, where there is no lack of water; this can be explained by the fact that the farmers in Beht have already acquired experience in optimally managing the available resources.

In the central area, the farmers were unable to farm as intensively as in the coastal zone and in Beht. Their income/ha and water optimisation are very low. This situation has encouraged the farmers to save on inputs, while in the coastal zone and in Beht farmers tended to intensify their modes of production.

## 22.4 Conclusion

We calculated and compared the economic efficiency of farming systems in different situations with respect to access to water resources in the Gharb plain. Our sample comprised differences in farming systems and in modes of access to water resources. The farmers in the coastal zone grew more vegetables and fruit using drip irrigation and had the highest total income and income/ha. In this zone, farmers diversified because water was abundant and accessible thanks to private

pumping directly from the water table. The crops cultivated in this zone made the most efficient use of irrigation water, for example strawberries with a value of 16.3 Dirhams/m<sup>3</sup>.

In the central and Beht areas, access to water is through the public irrigation network. Farmers in the central area (North sectors) used sprinklers, while farmers in Beht faced a water shortage and most farms were irrigated by gravity. Farms in the two areas presented similarities in their performance and in their use of irrigation water.

In the coastal zone, the most efficient farmers were those who made intensive use of production factors, because they had free access to water and were thus able to diversify. In the central area, where farmers had little opportunity to diversify, they managed inputs (efficiency is related to input control, i.e. load management).

However, examination of the individual results of farmers revealed that the four most efficient farmers of the sample were farmers in the Beht area, where water resources are limited.

The next step will be to confirm these results and to obtain partial efficiencies for each input. These partial efficiencies will enable us to explain why a particular crop is inefficient. It will then be possible to formulate more appropriate recommendations for farmers.

This approach should enable us to start by evaluating negative externalities such as environmental aspects (leaching of nitrates on a farm scale), and then to evaluate the efficiency of environmental outputs and to compare them with economic outputs.

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