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Analysis of Farms Performance Using Different Sources of Irrigation Water: A Case Study in a Semi-Arid Area

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Abstract

Improving production efficiency is the main objective of government action to avoid efficiency losses and to increase the income of farmers. The aim of this study was to analyze performance levels of farms in the irrigated perimeter of Tadla in Morocco, according to the source of irrigation water. Thus, technical, allocative and economic efficiency were analyzed for farms in this area. To estimate the efficiency indices, the approach adopted is based on Data Envelopment Analysis method. Sixty samples of farms were chosen according to the mode of access to irrigation water. The results showed significant variability in technical, allocative and economic efficiency between the observed farms. The source of irrigation water is an important determinant of farm performance in the Tadla region. Thus, the average of economic efficiency varies between 45% and 83% according to the source of irrigation water. In terms of water valuation, farms that use only groundwater achieve a better value of irrigation water (2.19 MAD[1] /m^3) in comparison with those that combine between surface and groundwater and those which are limited to the use of surface water.

Keywords:
Farm efficiency; Water valuation; Source of irrigation water; Irrigated perimeter of Tadla, Morocco

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[1] At the time of writing (mid-May 2015), MAD1.00 was approximately equivalent to £0.07, $US0.10, and €0.09.

INTRODUCTION

In the world, irrigated areas produce more than half of all foodstuffs and thus contribute hard to food security. This activity consumes about 72% of available water resources (Geerts and Raes, 2009; Seckler *et al*., 1999). The importance of the irrigated area has been reiterated with the launch of the Green Morocco Plan's Strategy (GMP) in 2009. This strategy aims, among other things, to adapt Moroccan agricultural sector to climate change and to improve farmers' profits (MAPM, 2009). The interest, henceforth, will be focused not only on increasing production, but rather on an economically efficient production, that valorize, as well as possible, the available natural resources, especially water.

Across regions of Morocco, the Green Morocco Plan's Strategy was declined in regional agricultural programs. Tadla-Azilal region, equipped with an irrigated perimeter (Tadla perimeter), has benefited from a regional agricultural program focusing on the efficiency of production and water use, and on increasing of farmers' incomes. The agricultural development projects created under this strategy are based on the aspects of production, spatial distribution, water scarcity, land status and the integration of the maximum of agricultural value chains.

In the irrigated perimeter of Tadla, agricultural activities depends on climatic conditions, which makes water management as a technical and economical imperative and an excellent means for socio-economic development (Lionboui *et al.,* 2014). However, irrigation efficiency is still low with the dominance of traditional irrigation techniques (flood irrigation) which the rate of efficiency does not exceed 50% and which dominate 90% of the irrigated area. In addition, productivity does not yet reached the potential per irrigated hectare for some farms and the cubic meter of water is not sufficiently valued by crops. The valuation of water resources is an important element for sustainable water resource management (Edens and Graveland, 2014). Therefore, stakeholders in the study area are expected to improve production inputs efficiency, especially, irrigation water.

In this context, the study focuses on the analysis of the indices of technical, alocative and economic efficiency, as well as the valuation of irrigation water, through a sample of sixty farms selected according to the mode of access to irrigation water. The objective of the paper was to investigate the influence of different sources of irrigation water on Tadla farms' performance. We adopted a non-parametric approach based on linear mathematical programming through the "Data Envelopment Analysis (DEA)" method.

This paper is divided into three parts. The first part introduces the concepts and methodological approach. The second part is devoted to present the main results and the final section discusses the implications and recommendations emanating from the results of this work.

MATERIALS AND METHODS

Study area

The study area is the Tadla plain. It is located in central of Morocco (Figure1). The agricultural area is about 106,000 ha, including 98,300 ha of irrigated areas. The rainfall, in the study area, is mainly characterized by an annual irregularity and interannual variability, with an average amount of 330 mm/year (DRA, 2012).

Created in the 1940s, Tadla perimeter was among the first large irrigation schemes in the country and was aimed at benefiting small farmers and introducing modern farming techniques and industrial crops (Préfol, 1986). The irrigated perimeter of Tadla is divided into two sub-schemes by the Oum-Er-Rbia River flowing from east to west and taking its source in the Middle Atlas. The sub-scope of Beni-Amir is supplied from the Ahmed-Al-Hansali dam (capacity of 750 million m^3) built on the Oum-Er-Rbia river. On the left bank of the Oum-Er-Rbia River the Beni-Moussa sub-perimeter is fed by the waters of the Bin-El-Ouidane dam (capacity of 1.5 billionm^3). Also, Beni-Moussa and Beni-Amir Groundwater are used for agriculture in the Tadla plain. In addition to these two sources, much pumping is done from other superimposed layers, where the Turonian aquifer utilized by drilling 80 to 150

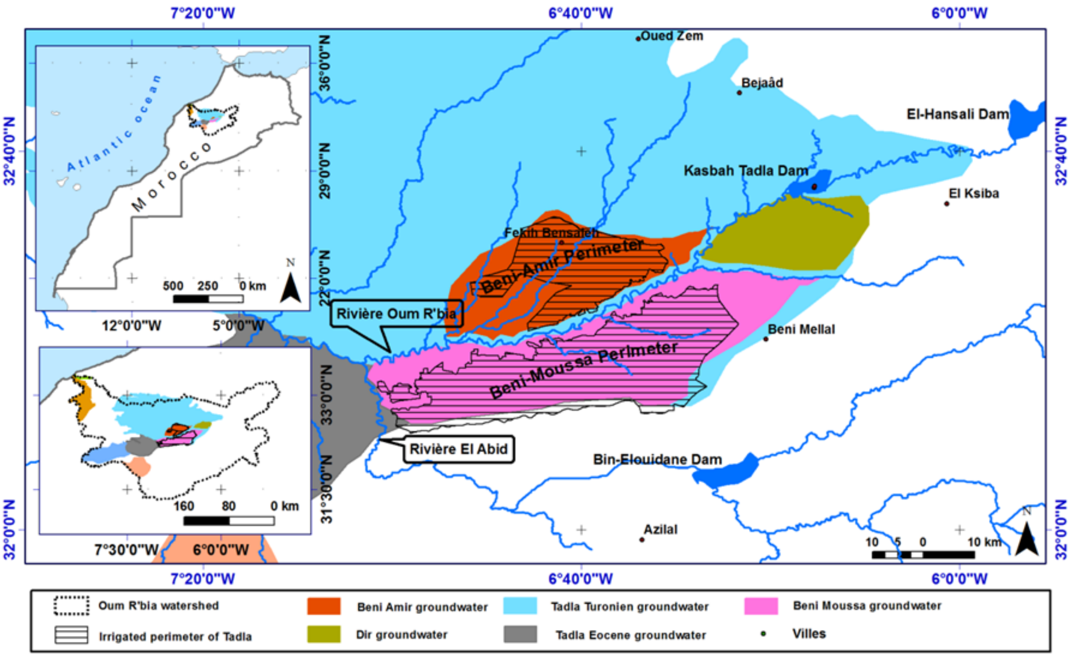

Figure 1: Irrigated perimeter of Tadla in Morocco

m depth (ABHOER, 2012).

On the concept of efficiency

Several indicators may be used to measure performance. In this work we focus on Technical Efficiency (TE), Allocative Efficiency (AE) and Economic Efficiency (EE).These three types of efficiencies were developed by Farrell (1957).

The first type measures the ability of one system to produce a maximum of output by using a limited quantity of input. This is the level of output that represents the production frontier (Barnes *et al*., 2011). The technical efficiency index is given by the ratio of the actual volume produced on the potential volume (maximum). Thus, the technical inefficiency is the complement to one of the index calculated;

The second one consists of maximizing production using the least costly combination of inputs (Al-Feel and Al-Basheer, 2012). Indeed, it takes into account the prices of inputs and it is assumed that the optimal mix of inputs is one which ensures that the ratio of substitution marginal rates is equal to the ratio of prices. In other words, it is necessary that the producer equalizes the marginal value of outputs to marginal costs of inputs;

Finally, the last one takes into account the previous two types of efficiency (technical and allocative efficiency). In this sense, it is not enough to choose the most technically efficient output-input combination, but, it is necessary that this combination is also the one which occurred with the least cost. This complementarity allows providing meaningful criteria to assess the performance level of production systems. Two approaches are commonly used to measure efficiency: the non-parametric approach and the parametric approach.

In this work, we opted for a non-parametric approach based on mathematical programming through the "Data Envelopment Analysis (DEA)" method.

Data Envelopment Analysis (DEA)

Through the "Data Envelopment Analysis (DEA)" method we opted, in this work, for a non-parametric approach based on mathematical programming. This method enables us to compare all similar decision making units (DMU) in a given population, taking into account several dimensions simultaneously (Heinrichs *et al*., 2013).

We collected data on input and output quantities of each DMU and we determined the efficiency frontier from the perspective of the best practice. The empirical application of this method consists in constructing a non-parametric piece-wise surface over the data through mathematical programming. The production frontier is estimated using a convex polyhedron enveloping all observations, which the most efficient are located on the frontier (Seiford and Thrall, 1990).

Compared to other methods of efficiency measurement, Data Envelopment Analysis (DEA) allows to avoid requirements to specify a functional form of the production function and restrictions on the inefficiency distribution (Yang *et al.,* 2015). DEA can be conducted under the assumption of constant returns to scale (CRS) or variable returns to scale (VRS). While the CRS assumption is only appropriate when all farms are operating at an optimal scale, the use of the VRS specification permits the calculation of efficiency devoid of scale effects (Coelli *et al.*, 1998). We assume that the farms involved in the study do not all operate at an optimal scale. Thus, we opted for data envelopment analysis model input-oriented under the assumption of variable returns to scale to analyze the efficiency of Tadla farms according to mode of access to irrigation water. This model allows determining input cost savings that can be achieved for each production unit of the sample if it is efficient.

Data used in the analysis of farms' performance

The data used are obtained from the farms survey conducted over the irrigated perimeter of Tadla during 2011/2012 cropping season (from September to August). Thus, we had applied a farm typology to understand the diversity of production potential at the regional level. Previous work on farmer strategies in terms of water management and agricultural production in the Tadla region has been useful to choose the typology. To analyze the diversity observed in the farmers behaviour, especially towards water management, we used the typology generated by Bacot (2001), based on the mode of access to irrigation water. This typology considers four types of farm types: a- farms with an easy access to groundwater and surface water (A_SGW); b- farms with an easy access to surface water and with limited access to groundwater (A_SW); c-farms with easy access to groundwater and not having access to surface water (A_GW); d- farms who don't have access to surface water and groundwater (R_A).

Considering the objectives of this study, collected information can be grouped into the following categories:

• Structural data of farms: farm size, employment, family labor and farm equipment's.

• Cropping selection, obtained yields, marketed quantities and selling prices.

• Use and costs of inputs for different cultures.

The sample includes sixty farms, chosen according to the source of irrigation water. The price data has considered into account 2012 as the reference year.

Data analysis by DEA method

In the Data Envelopment Analysis method (DEA), the efficient frontier is defined by the best performing practices of the sample used (Hoang, 2013). To define the efficiency frontier that serves as a reference for the measures of technical, allocative and economic efficiency, it is necessary to define the outputs and the inputs used in the production process. To calculate the scores of technical, allocative and economic efficiency, an aggregate of outputs and five aggregates of inputs were considered.

Outputs

The farms of this study are characterized by the diversity of their products (outputs). Therefore, the aggregation of outputs will be expressed in monetary value. Plant production is used in this study, as one aggregate of production. It includes the monetary value of all crops for each farm.

Inputs

The aggregation of production factors will be based on the quantities. Furthermore, we need to know the prices of these production factors (inputs) to calculate efficiency indices. Thus, production factors retained in this study are:

Irrigation water: It includes surface water delivered through the water supply network (0.32 MAD/m^3) and groundwater coming from wells or boreholes and designed for privately irrigation (0.6 MAD/m^3).

Sowing - Fertilization - Phytosanitary treatment:

This aggregate comprises quantities used in seeds, fertilizers and phytosanitary treatment.

Labor: Labor is expressed in Agricultural Work Unit (AWU) for each operation. The price of this aggregate is fixed in 50 MAD for each AWU.

Mechanization: This aggregate presents the different operations of agricultural preparation and maintenance of soil and harvesting. For each operation, the prices paid by farmers are available.

Agricultural land: the variation in land prices as well as the multitude of soil types in the irrigated perimeter of Tadla makes comparison between farms so delicate. To overcome this difficulty, we used the average rental price per hectare in the region according to the installed crop.

Water valuation indicator

The valuation of water resources by the agricultural sector is at the heart of the debate on the competitiveness and sustainability of this sector in the irrigated perimeter of Tadla. With the aim of preserving water, we need to know the farms which valuate better water. Through concrete examples of sixty farms in the irrigated perimeter of Tadla, we proceeded to assess indicators of water valuation for these farms relating to the mode of access to irrigation water resource.

The valuation of irrigation water has been discussed from the perspective of the community, that is to say in terms of value added per cubic meter of water used (VA/m^3). While gross margin appears to involve the enrichment of individual agents, the value added measures wealth creation for the community as a whole (including labor income). It represents the sum of labor remuneration, financial costs and taxes or subsidies, in addition to the gross profit of the agent (producer).

Therefore, the value added is not only an element of enrichment, but also a form of representation of the distribution of income to four fundamental agents of the national economy: households (labor remuneration), financial institutions (financial costs), government (taxes and subsidies) and non-financial companies (gross profit). The main crops that have been observed in the examined farms are: durum wheat, soft wheat, alfalfa, sesame, corn silage, sugar beets, olives and citrus.

RESULTS AND DISCUSSION

Farms efficiency

The economic or overall efficiency is jointly determined by the concepts of technical and allocative efficiency. The obtained results show certain homogeneity of efficiency scores in the observed farms. In terms of technical efficiency, the average score was 0.90 with amplitude ranging from 0.51 to 1. On the one hand, the results suggest that globally farmers could increase their production by almost 10% without increasing the level of inputs used. This indicates that these farmers do not use all of the available technological knowledge. On the other hand, 48.33% of observed farms have an index of

Table 1: Frequency distribution of technical, allocative and economic efficiency indices

Classes	Technical efficiency		Allocative efficiency		Economic efficiency	
	%	Cumulative	%	Cumulative	%	Cumulative
0.0 – 0.5	-	-	18.33	18.33	20.00	20.00
0.5 – 0.6	3.33	3.33	6.67	25.00	15.00	35.00
0.6 – 0,7	5.00	8.33	8.33	33.33	11.67	46.67
0.7 – 0.8	8.33	16.66	16.67	50	23.33	70.00
0.8 – 0.9	18.33	34.99	21.67	71.67	15.00	85.00
0.9 – 1.0	65.00	99.99	28.33	100.00	15.00	100.00
Average	0.90		0.75		0.69	
Standard Deviation	0.13		0.20		0.20	
Min	0.51		0.30		0.27	
Max	1.00		1.00		1.00	

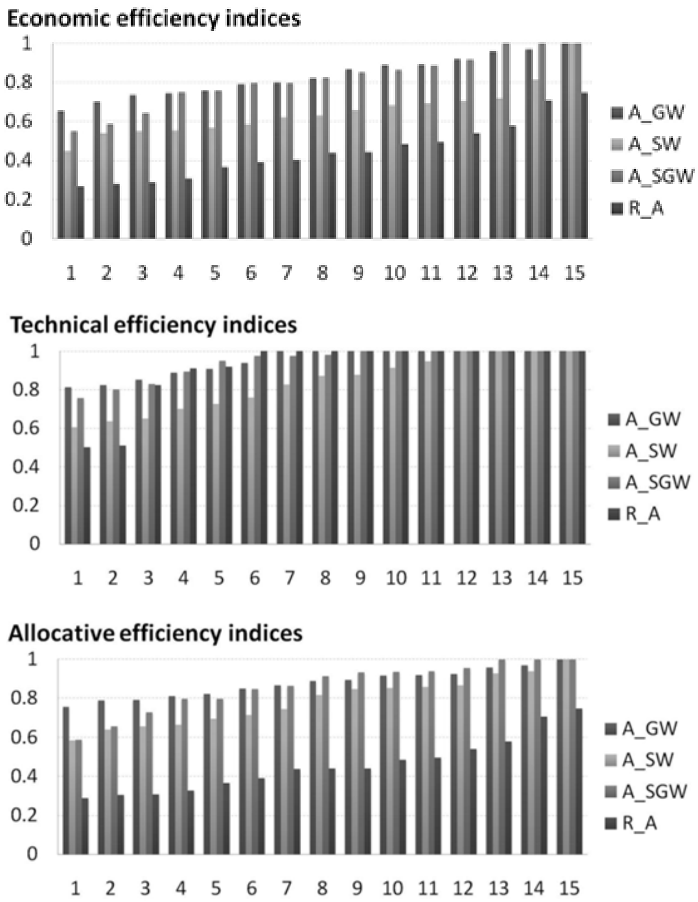

Figure 2: Efficiency indices distribution according to the mode of access to irrigation water

technical efficiency equal to 1%. This indicates that, these farms have mastered the technology available, and the improvement of productivity for this group of farm can be achieved only through technological progress (Table 1).

Concerning allocative efficiency, about 18.33% of farmers have efficiency scores lower than 0.5. This indicates that these farms do not optimally allocate production resources to produce a given goods level. For the latter, significant shortfalls can be recovered in terms of allocative efficiency. Nearly one farmer of ten has a score of allocative efficiency at around 1.

The economic efficiency combines simultaneously technical and allocative efficiency. The average index of economic efficiency is about 0.69. It should be noted that 20% of farms have an index of economic efficiency less than 0.50, which gives an idea about the potential scope for improving production and increasing farmers' income. Moreover, 8.33% of observed farms have an economic efficiency index equal to 1. This shows that the concerned farms have mastered the available technology and they are able to equalize the marginal value of their products to the marginal costs of production factors.

Farms efficiency according to mode of access to irrigation water

Indices of technical allocative and economic efficiency at the different types of farms in the irrigated perimeter of Tadla are presented in the following figure (Figure 2).

According to the figure below (Figure 3), we observe that the farms conducted in "A_GW" mode are technically the most efficient followed by those conducted in "A_SGW" mode with technical efficiency indices of 0.95 and 0.94 respectively on average. Then, the farms conducted in "A_SW" mode are in the third ranking with an index of technical efficiency equal to 0.84. Finally, farms conducted in "R_A" mode have the lowest technical efficiency index 0.82 on average. Furthermore, we note that there is no

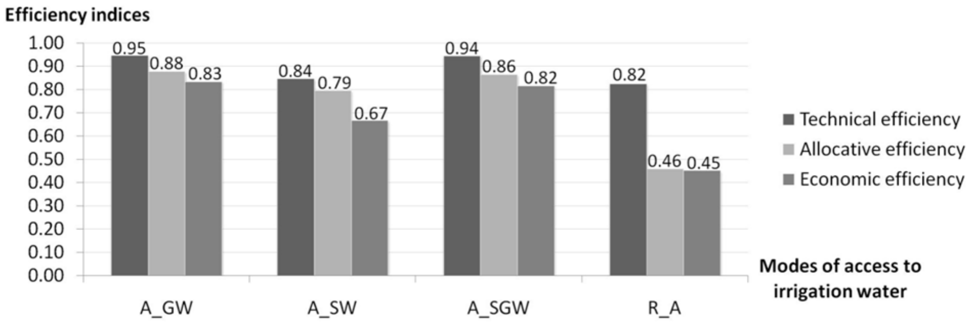

Figure 3: Average efficiency according to the mode of access to irrigation water

a big difference between the average indices of technical efficiency for the different types of farms. Therefore, there is no significant heterogeneity between farms types in mastery of available technology.

Except for farms conducted in "R_A" mode, which present an average allocative efficiency index of 0.46, we observe that there is not much difference between the average indices of allocative efficiency for the three other types of farms. Hence, we observe that farms conducted in "A_GW" mode are the most efficient in terms of resource allocation, with a score of 0.88, followed by those conducted in "A_SGW" mode, which have an index of allocative efficiency around 0.86. Then, the farms Conducted in "A_SW" mode come with an average allocative efficiency index equal to 0.79.

The results of this work show that there is no great difference between the average indices of economic efficiency for the first two types of farms. Farms conducted in "A_GW" mode, are the most economically efficient with an average index of 0.83. Farms conducted in "A_SGW" mode come in second place with an average economic efficiency index of 0.82. Both of these types of farms are characterized by the fact of having the ability to irrigate when considered appropriate to their crops and to designate the best suited irrigation technique for the context of the farm. Then farms conducted in "A_SW" mode come with an economic efficiency index of 0.67. This value can be explained by the irregularity of surface water supplies through the canals of the irrigation network. Also, this group of farms receives irrigation water in inappropriate times, in the opinion of farmers, and the majority of these farms are using a traditional irrigation called flood irrigation. At last, farms conducted in "R_A" mode come with an economic efficiency index of 0.45. These farms are directly dependent on rainfall which quantity differs according to the climatic years.

Efficiency and irrigation water valuation

In Morocco, the issue of water valuation is at the focus of interest of policymakers. Most studies that analyze this concept, consider water valuation indicator as the gross margin per cubic meter of water used (e.g. Sali and Monaco, 2014; Stanley, 2005; Waughray and Rodríguez, 1998). However, the interest of the farmer is not necessarily similar to that of the community, which is more interested in the overall income and in several development goals in the long term like the conservation of water resources. In this paper, water valuation indicator has been approached according to the community interest, that is to say, in terms of value added per cubic meter of irrigation water used by farm (Table 2).

The results show that while farms conducted in "A_SGW" mode realize the highest gross

Table 2: Water valuation and gross margin by mode of access to irrigation water

Farm Type	Water Valuation (MAD/m^3)	Gross margin (MAD/ha)	Use of irrigation water (m^3/ha)
A_GW	2.19	17,931.80	8,771.34
A_SW	1.83	11,637.33	7,305.08
A_SGW	1.98	18,002.24	9,859.97

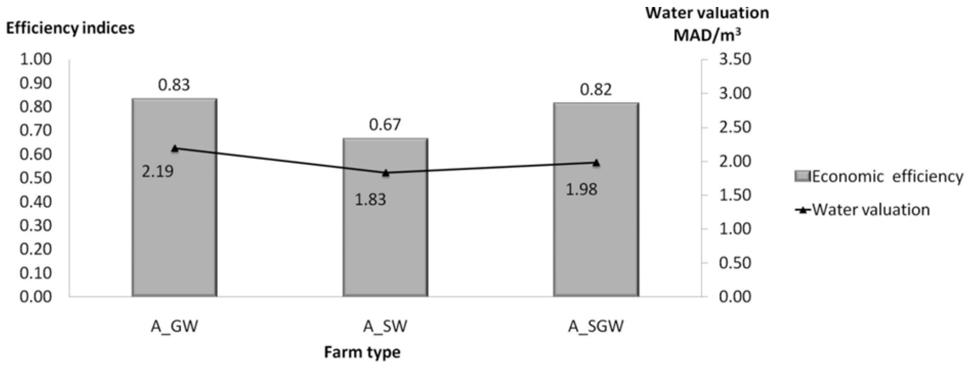

Figure 4: Economic efficiency and water valuation indicators by farm type

margin. In water valuation they come in second place (1.98 MAD/m^3) after farms conducted in "A_GW" mode (2.19 MAD/m^3). The interests of the community and those of farmers are divergent. It is therefore important, in this case, for policymakers to consider in addition to farms profitability, the valuation of scarce resources. Finally, farms conducted in "A_SW" mode are classified in last position, with an indicator of water valuation of 1.83 MAD/m^3.

In order to determine the relationship between water valuation and economic efficiency of farms in the irrigated perimeter of Tadla, following figure shows the average indices of economic efficiency and water valuation indicators for each farm type, according to the mode of access to irrigation water (Figure 4).

This figure shows, first, that even if there is no significant difference between farms conducted in "A_GW" mode and those conducted in "A_SGW" mode relating to economic efficiency, the last type of farms values less irrigation water than the first. This proves that the efficiency of farms and water valuation are two objectives that do not always converge. Farms conducted in "A_SGW" mode achieve more value added and they realize high yields because they have the ability to irrigate at the appropriate moment and with sufficient quantities of water relatively less expensive compared to those using only groundwater. Farms in this latter type, however, use less important quantities of irrigation water than the first, which allows them to achieve a good water valuation. Finally, we note that farms conducted in A_SW mode which are economically less efficient, have also the lowest indicator of water valuation (1.83 MAD/m^3).

CONCLUSIONS

The results of this research show that there is a considerable variation in technical, allocative and economic efficiency between farmers of the studied sample. In terms of technical efficiency, a substantial number of farmers have a high value. For these farms, the potential gains through available production technologies are minimal. Therefore, the adoption of new technologies is the effective way to increase their productivity. However, for farmers with a low level of technical efficiency, productivity could be increased by improving their expertise in the available technologies through mentoring and outreach.

One of the main guidelines of the Green Morocco Plan's Strategy (GMP) is one that concern the mechanism of a double integration of the actors. Vertical integration of upstream and downstream of the value chains activities, and horizontal integration which is more concerned about stakeholders and agricultural institutions. In terms of allocative efficiency, this mechanism could significantly reduce the inefficiency observed in the studied farms. Indeed, this mechanism is supposed not only able to circumvent the production constraints (financing, supply and management) but also, farmers can benefit of profit margins previously held by intermediaries in addition to gains due to economies of scale and the reduction of transaction costs.

In a region where the limiting factor is not the land, it is important to focus on the scarce resource, especially water in the case of irrigated perimeter of Tadla. Thus, the water valuation has been approached relating to the community interest, which is to say in terms of value added per cubic meter of water. It appears that irrigation water is better valued by farms which use only groundwater (2.19 MAD/m^3) followed by those that combine between surface and groundwater (1.98 MAD/m^3). For farms which are limited to the use of surface water, they are classified in last position, with an indicator of water valuation of 1.83 MAD/m^3. Also, the results suggest that efficiency does not always reflect water valuation by crops: an efficient farm for the farmer is not necessarily the one that values better irrigation water.

Accordingly of the results obtained in our study, and in order to remedy the failures in scores of technical, allocative and economic efficiencies, as well as in the water valuation indicators, the recommendations that could improve the efficiency and water valuation levels of Tadla Farms are:

• Take into account the water scarcity in the agricultural policies, and the valuation of this resource must remain at the heart of all strategies.

• Give more interest to extension services and organize awareness campaigns to circulate information between farmers.

• Allocate more importance to issues concerning the acquisition price, the quality and marketing channels of inputs.

• Take into account economically efficient farms by extension services which can serve as a reference model for inefficient farms.

• Allocate water resources to crops which value it at most.

In conclusion, on the one hand, farms, examined through this study have consistently required efforts to increase their efficiency levels. On the other hand, the preservation of water resources and especially their allocation should be subject of a public debate to reflect strategies and perceptions of local actors by involving them in a common prospective reflection.

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