The major determinants of water economic productivity in agriculture: The case of large scale irrigation system in Morocco

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Abstract:
Water management in Morocco, like everywhere else, is tied to the management of other natural resources, and must address the needs of its three major users: agriculture, industry, and the household sector. Given the importance of the agricultural sector, inertia prevents the attaining of full and instantaneous benefits of liberalization. To ensure better economic performance of the agricultural sector is needed. In this context, accurate agricultural policies are important for enhancing attainment of the desired level of performance of this sector. Moreover, these policies should be linked to the appropriate uses of agricultural water. The objective of this study is to identify the determinants of water economic performances in Tadla region. How this productivity is affected by some structural and operational factors? And can we develop measures that will contribute to water use efficiency and its rational management? By conducting this study within the framework of Benchmark project in Tadla region for 104 farmers we have identified significant effects of farm size, improved variety use, and other technologies and water economic productivity.

Key word: Water, Productivity, Model, Cobb-Douglas, Elasticity, Irrigation, Agriculture

1. Introduction

Governance of water management in Morocco is very complicated and must satisfy the needs of its three major users: agriculture, industry, and the household sector. Annual rainfall is estimated at some 150 billion cubic meters (m^3) overall. However, two constraints must be noted: rainfall variation in time and space. Morocco has always had drought years, but their frequency and severity have greatly increased since the early 1980s.

Spatial distribution of rainfall in Morocco is characterized by declining gradients from north to south and from west to east. Certain regions receive 600 to 700 millimeters (mm) per year, while others receive less than 100 mm. Reduction of rural socioeconomic deficiencies is directly related to sustainable water management, whether for irrigation or for domestic and industrial consumption. Morocco is relatively well supplied compared to other countries of North Africa. In addition, the mountain ranges (Rif and Atlas), which cover a substantial part of the national territory, act as reservoirs.

Climate and land contour determine both the state of vegetation and the natural resources management policy followed by the government. The total area of the country, 71 million hectares, is divided into suitable agricultural land (13 percent), forest and alpha zone (12.5 percent), roadway terrain (30 percent), and uncultivated land (44.5 percent). As a result of management practices, 80 percent of the 150 billion m^3 of precipitation is lost each year through evaporation or discharge into the sea. Only 14 percent (21 billion m^3) of the total rainfall can be potentially used effectively. Currently 11.7 billion m3 are used, of which 75 percent is surface and 25 percent is underground water. So, this water capital can affect land uses and agricultural sector economic performances.

In Tadla-Azilal region agriculture is the main socio-economic activity, occupying 62% of the region’s labor force (some 300,000 individuals). This is owing to favorable climatic conditions, abundant underground and surface water resources as well as the availability of skilled labor. The region has a useful agricultural area exceeding 570,000 ha, accounting for 7% of the total national useful agricultural area and some 13% of the irrigated lands in Morocco (representing more than 192,000 ha).

The abundant water resources in the region make it a real water reservoir for the whole country. The Tadla-Azilal region is an area with a high water table (an exploitable potential of 350 million m^3). The region boasts 8 dams, 2 of which are among the most important in the whole country (Bin El Ouidane Dam and Ahmed El Hansali Dam).

The Oum Er-R’bia River runs through the entire length of the Tadla Plain, dividing it into two independent hydraulic regions: the Béni Moussa on the left bank and Béni Amir on the right. The average annual flow of the river is $37.4 m^3$/sec. The Tadla irrigation perimeter is a gravity-fed system covering an irrigated area of 117,500 hectares. To improve water management and water use efficiency appropriate programs were implemented by the government at the perimeter level and at the community level by involving key actors and using appropriate tools.

The TRM (Tadla resource management) project is one of the major programs implemented in the region in 1993. Conceived by USAID-Morocco in cooperation with the Moroccan Ministry of Agriculture and implemented by CHEMONICS International, the TRM was designed to improve water management and protect the natural resource base supporting the agricultural sector in Morocco. From 1993 to 1999, the project helped ORMVAT (Office Régional de Mise en Valeur Agricole du Tadla) to improve water management in Tadla’s irrigated zone. In carrying out this mandate, the TRM project introduced new technologies, strengthened water user groups, and served as an effective advocate for policy and institutional reform within Morocco’s agricultural sector. This project was followed by specific research and development project in order to improve crop water use efficiency by introducing new irrigation system in combination with nitrogen use, and related institutional and policy alternatives.

The Benchmark project is one of the projects that aim to combine technical, institutional and policy options to improve water management at the community level. To cover the different irrigation systems in MENA region (deficit irrigation, full irrigation and water harvesting), the project was conceived by ICARDA and conducted in tree satellite zones (Morocco, Egypt and Jordan). The originality of the project is the integration of tree major components: biophysics, hydrologic and socioeconomic aspects using a community approach.

The study reported in this article represents one of the tree major socioeconomic issues addressed by the project. It aims to develop appropriate tools that can help identifying the determinant of water economic productivity in two local communities in Tadla perimeter. It can be considered as a diagnosis of water productivity factors that can be considered in the technology transfer program and policy orientations. The main crops targeted by this study are bread wheat, sugar beet and alfalfa.

2. Research methodology

When economists and government ministers talk about productivity they are referring to how productive labor is. But productivity is also about other inputs. So, for example, in agriculture a farm could increase productivity of wheat by investing in new technologies which embodies the latest technological progress, and which reduces the amount of inputs required to produce the same amount of output. The Benchmark project's objectives are to improve water productivity by transferring new technical, institutional and policy options. To estimate the water economic productivity, it's necessary to present some theoretical concepts such as production cost and gross margin.

Costs are defined as those expenses faced by a farm when producing a good or service for a market. Every business faces costs and these must be recouped from selling goods and services at different prices if a business is to make a profit from its activities. In the short run a firm will have fixed and variable costs of production. Total cost is made up of fixed costs and variable costs:

TC (dh/ha) = VC(dh/ha) + FC(dh/ha)

VC: Variable costs

CF: Fixed costs

Net gross margin (also called net gross profit margin) is the difference between revenue and cost before accounting for certain other costs. Generally, it is calculated as the selling price of an item, less the cost of goods sold (production or acquisition costs, essentially).

NGM(dh/ha) = Y(ql/ha) x P_y(dh/ql) – TC (dh/ha)

Y: yield

P_y: the price of the output

TC: cost of production

The economic value of water is: $EVW\,(dh/m^3)\; = \frac{NGM + Water\ cost}{Total\ quantity\ of\ water}$

To estimate the economic water productivity, a survey was conducted in tow sites of Tadla large scale perimeter. A sample of 205 cases representing farmers of the two communities was drawn and a survey was conducted in 2010-2011 cropping season.

Tree econometric models were developed for bread wheat, sugar beet and alfalfa. These are the most water consuming activities in Tadla region. The selected mathematical form for the model is the Cobb-Douglas function. Such model can be used to evaluate the elasticity of substitution between the objective function which is water economic productivity and the following variables:

- Technology, as a dummy variable (0,1) and represents improved variety and tillage;
- Nitrogen quantity used in kg/ha;
- Seed rate in kg/ha for the variety used; and
- Weed chemical control in unit/ha.

2.1 Basic theory

The practical application of the production function method requires making certain assumptions, particularly on the functional form of the production technology, returns to scale, and characteristics of the technological progress, as well as of the functioning of markets.

The neo-classic two-factor Cobb-Douglas production function with Hicks-neutral technology is frequently used, including the assumptions of positive and diminishing marginal products with respect to inputs of labor and capital, constant returns to scale, no unobserved inputs and perfect competition. These assumptions restrict the elasticity of output with respect to labor and capital to values between zero and one and their sum to being equal to one. Given the assumptions, the theoretical technological coefficients are then in practice approximated with the help of the income share of labor in produced output. Since the technological coefficients are assumed to be stable, the share of factors in production should be stable in time. Furthermore, if there is no presumption that the aggregate technology would differ across countries, the labor shares should also be roughly similar across countries

In practice the Cobb–Douglas production function is widely used to represent the relationship of output and two inputs. Similar functions were originally used by Knut Wicksell, while the Cobb-Douglas form was developed and tested against statistical evidence by Charles Cobb and Paul Douglas during the period 1900–1947.

In the agricultural sector, the Cobb-Douglas production function can be presented as follow:

$$Y = y\ (K,L) = A\ .\ K^{\alpha.}\ L^{(1-\alpha)} \quad (1)$$

It’s a simple mathematical relation of two variables and express the quantity of output as a function of a quantity of inputs or production factors (K et L) for a given values of A, α and (1-α).

With α representing the partial elasticity of factor, k.(1-α) represents partial elasticity of factor L, and A as a value of the level of technology related to the production. So to estimate the marginal production function using the Cobb-Douglas form, we calculate the partial derivation:

$\frac{\partial y(K,L)}{\partial (k)} = \alpha . A . K^{(1-\alpha)} . L^{(1-\alpha)} = \alpha . \frac{y(K,L)}{K}$

$\frac{\partial y(K,L)}{\partial (L)} = (1-\alpha) . A . K^{\alpha} . L^{-\alpha} = (1-\alpha) . \frac{y(K,L)}{L}$

According to Euler's Lema, we can write $\frac{\partial y(K,L)}{\partial (\mathrm{k})} . K + \frac{\partial y(K,L)}{\partial (\mathrm{L})} . L = Y$

So we have: $\alpha\, y(K,L) + (1-\alpha) y(K,L) = Y$ *(2)*; with:

$\alpha\, y(K,L)$: Capital return

$(1-\alpha) y(K,L)$: Labor return

The parameters α and (1- α) of Cobb-Douglas function are respectively the partial elasticity of the capital and labor:

- Partial elasticity of capital: $e_{(Y,K)} = \frac{\partial y(K,L)}{\partial K} . \frac{K}{y(K,L)} = \alpha . \frac{y(K,L)}{K} . \frac{K}{y(K,L)} = \alpha$
- Partial elasticity of labor : $e_{(Y,L)} = \frac{\partial y(K,L)}{\partial L} . \frac{L}{y(K,L)} = (1-\alpha) . \frac{y(K,L)}{L} . \frac{L}{y(K,L)} = 1-\alpha$

It's usually important to calculate the marginal rate of substitution between factors because the marginal substitution measures the potential substitution between production factors.

$$\frac{\partial L}{\partial K} = -\frac{\frac{\partial y(K,L)}{\partial K}}{\frac{\partial y(K,L)}{\partial L}}$$

The specification of the production function is a special case of the constant-elasticity-of-substitution production function (CES), with the elasticity of substitution equal to one and with the usual theoretical assumptions used in the empirical literature. As mentioned earlier, positive and diminishing marginal products of each input (L, K) are assumed.

The Cobb-Douglas production function is a simple presentation of the reality. According to Samuelson, natural resources as water and soil, etc... should be considered as a public goods and considered in the national production. So the general presentation of the Cobb-Douglas function is as follow:

$$y = c \cdot \prod_i x_i^{a_i}$$

Where c , $a_i > 0$

i: production factor index

αi : Partial elasticity of factor i

2.2 Model choice justification

The concept of technical progress is closely related to productivity growth. In fact, productivity growth has been shown to be a major source of growth of aggregate output (Solow, 1957) and of agricultural output (Hayami and Ruttan, 1985). Hayami and Ruttan (1985) have shown that agricultural output can grow in two main ways: an increase in use of resources of land, labor, capital and intermediate inputs or through advances in production techniques which greater output is achieved through a constant or declining resource base.

The productivity is the increase of production per unit of factor used. In this case we use water productivity to express economic and technical performances of this factor. Mathematically, the partial derivation of the production functions for a given crop by the cubic meter of water used. By applying the model to the case of the selected crops in order to identify the factors affecting water economic productivity, the application of the Cobb-Douglas function is justified. In this case the function can be written as follow:

$$y = c \cdot \prod_i x_i^{a_i}$$

This form can be linearized as:

$$\ln(y) = \ln(c) + \sum_i a_i \cdot \ln(x_i)$$

To calculate the marginal factors productivity, we estimate the partial derivation of this function:

For one production factor (water in this case)

$$\frac{\partial\, ln(y)}{\partial(x_r)} = \frac{\partial\, ln(c)}{\partial x_r} + \Sigma\alpha_i . \frac{\partial\, ln(x_i)}{\partial(x_r)}$$

With:

$\frac{\partial \ln(y)}{\partial(xi)} = y$: Water economic productivity variable (PEE)

$\frac{\partial \ln(c)}{\partial xi} = \alpha_0$: Constant representing technology progress level

$\frac{\partial \ln(xi)}{\partial(xi)} = Xi$: Factors explaining PEE

αi : Parameters to be estimated and representing partial elasticity of factor i

So the model used can be expressed as follow:

$$\boldsymbol{y} = \boldsymbol{\alpha}_0 + \Sigma\boldsymbol{\alpha}_i \boldsymbol{X}_i \ (3)$$

3. Results and discussion

This study uses primary data from household surveys level to estimate measures of productivity. Variables were selected according to literature review and a consensus with specialist at the aridoculture center[1]. The correlation matrix presented in annex presents the variables selected from the cross section data of the two sites of Tadla region. The following variables were selected for the econometric analysis:

$$lnY = \beta_0 + \beta_1 (lnX_1) + \beta_2(lnX_2) + \beta_3(lnX_3) + \beta_4(lnX_4) + \beta_5 X_5 + \varepsilon\varepsilon_1$$

with:

- ε_1 model error
- β_0 the constant factor

[1] Dry land research center of the National Institute for Agricultural Research located in Settat Morocco

Y_1 = Economic water productivity of bread wheat

X_1 = Farm area in ha

X_2 = Seed rate i

X_3= Nitrogen quantity used kg/ha

X_4 = Weed chemical control in dh/ha

X_5= Improved variety and tillage technology as a dummy variable (0, 1)

The GLM (generalized linear model) regression is used for the estimation of the coefficients of the model. Its justified by the random character of the sample, the independence of the observations, the equality of variances and the normality of data. The model outputs are presented in table 1.

Table 1: GLM regression outputs

Crops	Nb. Obs	β_o	X_1	X_2	X_3	X_4	X_5	F	R^2
Bread wheat	144	1.292 (1.292)	-0.116[(c)] (0.061)	- 0.393[(c)] (0.250)	-0.004 (0.035)	+0.076[(c)] (0.048)	+0.949 [(a)] (0.088)	29.194 [(a)]	0.51
Sugar beet	70	- 0.295 (0.846)	-0.116[(c)] (0.05)	NA	+0.172 (0.130)	-0.036 (0.075)	+0.811 (0.091)	25.729 [(a)]	0.61
Alfalfa	148	1.008 (0.689)	-0.023 (0.037)	-0.045 (0.085)	-0.278[(a)] (0.098)	+0.174[(b)] (0.081)	+0.802[(a)] (0.530)	48.160 [(a)]	0.63

Significant levels: (a) 1%, (b) 5% and (c) 10%

The results show that all models are significant and explain more than 50% of the variability of water economic productivity among the tree crops. However, the effects of all factors are different and their effect amount is specific to the crop. Two factors seem to have the same effects on water economic productivity; farm size and the dummy variable for the improved technology used, but the signs are different.

In terms of elasticity, the farm size has a negative effect on water economic productivity witch means that if we increase this factor by one unit we decrease the productivity by 0.116 (11.6%).

This is an important result in comparison with studies conducted on economic or technical efficiency. Small farmers are more efficient in allocating resources than large farmers (Fadlaoui A., 1997, Azzam et al., 1994, Elis, 1988). So small farmers better value water than large farmers in Tadla and many socioeconomic factors can explain this behavior.

The same relationship is observed for the seed rate factor. With a negative coefficient, even if not significant for bread wheat, the relation has been largely confirmed by agronomists. Seed rate affects the settlement of wheat and therefore competition for factors of production which may result in grain and straw yields quantity and quality.

Regarding nitrogen, the significance level is at its limit, the sign of the coefficient confirms the results obtained by INRA researchers (Karrou, 2003; Dahan 2008). Nitrogen is essential for the growth and development of crops. Its use is related to several factors, especially soil, crop rotation, the variety and climatic conditions. All studies confirmed that nitrogen fertilizer can contribute to the improvement of grain and straw yields I properly used. For sure technical optimum use of nitrogen is completely different to the economic optimum. Fertilizer performances depend on the rate. In our case, it seems that nitrogen has a negative effect on water economic productivity for bread wheat and alfalfa meaning that any increase of fertilizer beyond the optimum will decrease water economic productivity.

However for sugar beet, the effect of nitrogen on water economic productivity is positive witch means that if we increase the nitrogen by on unit we will increase water productivity by 0.172 (17.2%). In this case, fertilize is not used at its technical optimum and farmers do have to increase the rate of nitrogen units used for this crop.

The effect of chemical weed control on water economic productivity is positive and significant in the case of wheat and alfalfa. This result shows that the use of this factor will contribute to reduce water competition by weeds and save more water for crops. The coefficient for alfalfa is higher than the one for wheat implies that weed control affect more the productivity of this crop and then its gross margin.

The use of improved tillage technologies and improved varieties influences positively water productivity. This finding confirms what has been demonstrated by several researchers. The use of new varieties, particularly the water efficient varieties developed by INRA since 1990 will have a high significant and a positive effect on water economic productivity.

4. Conclusion and recommendation

The analysis of water economic productivity can not be limited to technical or economic interventions such as subsidies and price but it is closely linked to climatic factors. According to the results of the different models, it is clear that the technology factor (tillage and variety) is one whose impact is most significant with a positive elasticity. However, the study shows that small farmers are more efficient in using water than the large. As the size of the activity is high, economic productivity of water is low.

The farm size coefficients showed negative contribution to water productivity for the three crops wheat, sugar beets and alfalfa. This negative relationship confirms the technical efficiency of smallholders (Azzam et al., 2004). This consideration should be taken into account in technology transfer or extension programs and in agricultural water pricing. The water fee should reflect the difference between small and large farmers as mentioned in water law 10/95.

The seed rate factor has generated two negative coefficients. These can be explained by seeding rates that vary from simple to double for some crops. More efforts are needed in irrigated areas to develop appropriate agronomic recommendations in order to improve water productivity.

The negative relationship between the amount of fertilizer and the economic productivity of water is consistent with what has been found in studying the relation between yield and fertilizer use.

Research in dry areas has developed appropriate recommendations for nitrogen use and water demand, particularly for wheat.

It's clear that from these results more efforts targeting, not only irrigation technique, but the whole package from tillage to harvesting. For sure, the irrigation technique can contribute to the reduction of water quantity used by the crop, but fertilizer, seed rate, variety and crop protection are also factors that can improve the use efficient water and therefore increase the economic productivity of the m^3 of water.

It is certain that input prices affect the level of factors used such as fertilizer, seed, etc.. Also, changes in commodity prices can affect the choice and size of agricultural activity. This is the case of fruits and vegetables that are very sensitive markets. Based on this data, all state intervention on prices through subsidies or other will affect the economic performance of producers and consequently the water economic productivity.

In conclusion, it should be noted that the application of econometric tools can help guide technology transfer and also target government interventions within the framework of Morocco Green Plan. The use of these tools can also improve research programs on water management and valuation.

Bibliography

Azam Azzedine (1990). Agricultural labor and technological change in Morocco. In Labor and Rainfed Agriculture in West Asia and North Africa, Dennis Tully Editor, ICARDA, pp. 273-297.

Belghiti M. L'agriculture irriguée au Maroc: enjeux et marges de progrès" Article N°139.juin 2009

Bouaziz A. et K.Belabbes (2002). Efficience productive de l'eau en irrigué au Maroc " Article 40 les politiques d'irrigation considérations micro et macro économiques, AGADIR.

Dahan Rachid (1988). Fixation symbolique de l'azote et fertilisation minérale des légumineuses alimentaire. Rapport d'activité INRA.

Ellis, Frank (1998). Peasant economics: Farm household and agrarian development. Cambridge University press.

Fadlaoui Aziz (2001). Analyse de l'efficience de production en agriculture et ses déterminants. Cas des producteurs de céréales d'une zone semi-aride au Maroc. Rapport de titutlarisation à l'INRA.

Heady E. & J. L.Dillon (1961). Agricultural production fonctions. Edition FACSIMILE.

El Bouari A. (2004). Conception participative de l'irrigation collective. Déroulement des études de réhabilitation de la petite et moyenne hydraulique au Maroc.

EL ALaoui Mostapha (2006). Développement de l'agriculture irriguée, dispositif juridique et institutionnel et stratégie de gestion de l'eau au Maroc. Document de travail

Elkhyari Thami (1987). Agriculture au Maroc. Thèse de Doctorat en Es sciences Economiques. Edition OKAD

Gittinger J.P. (1985). Analyse Economique des projets agricoles. Edition Economica

Haut Commissariat au plan. Prospective Agriculture 2030 Quels avenirs pour le Maroc ? En collaboration avec le Conseil général du développement agricole (CGDA)

Heady O. Earl and Dillon J. John (1961). Agricultural production functions. Facsimile edition. Iowa State University press.

Hyami Yujiru and Ruttan Vernon (1985). Agricultural development: an International perspective. The Johns Hopkins University press.

Mellouli H.J., Ben Naceur M., El Felah M., El Gharbi M.S, Kaabia M, Nahdi H.,.Slafer G.A. et Karrou M (2003). Efficience de l'utilisation de l'eau chez le blé et l'orge sous différents régimes hydriques et de fertilisation azotée dans des conditions subhumides de tunisie. Publication CIHEAM.