The impact of the EU Water Framework Directive on irrigated agriculture in Italy: the case of the North-East fruit district[1]

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Abstract
The objective of the paper is to evaluate the sustainability of irrigated agriculture under Water Framework Directive (60/2000) and Agenda 2000. The methodology relies on scenario analysis combined to farm level multicriteria mathematical programming. The methodology is applied to the case study of fruit farming in Northern Italy.
The research shows that water pricing can improve irrigation efficiency, but the impact of water policy is strongly affected by agricultural policy scenarios. In order to make water policies more socially sound, it is necessary to consider a broader range of impacts and to provide a higher co-ordination between policy goals.

Keywords: *irrigation, water policy, multicriteria programming, decision support system, scenarios, sustainability*

Introduction

Agriculture is the main water-using sector in Southern European Countries, such as Italy. It is also responsible for some negative impacts on water quality, due to pollution from fertilisers, pesticides and manure. On the other side, irrigated agriculture is very relevant from the economic point of view, as it represents one of the most viable forms of agricultural activity. It also plays important social and environmental functions, such as employment and landscape maintenance.

The legal framework in the EU is today faced with the recent Water Framework Directive (WFD) (60/2000). The introduction of WFD could bring major changes for irrigated farming in the EU, particularly as a consequence of Cost Recovery (CR) and the Polluter Pays Principles (PPP). It also propose water pricing as a recommended instrument for controlling water use and pollution. The WFD clearly interacts with the Common Agricultural Policy (CAP): CAP affects incentives to water consumption through irrigation, while water policy impacts the profitability of irrigated agriculture.

The paper presents some intermediate results of the WADI Project[2], through the description of a case study related to a fruit district in Northern Italy. The objective of the research is to evaluate the economic, social and environmental sustainability of irrigated farming under different scenarios concerning CAP and water policy. On the basis of farm characteristics and behaviour, farm models are developed using multicriteria techniques. Water demand functions and a set of sustainability indicators are derived simu-

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lating farmers' reaction to increasing water prices under different scenarios.

The paper has the following structure. Section 2 illustrates the main issues in the application of WFD to Italian agriculture. Section 3 describes the methodology adopted. Section 4 summarises the main results, followed by a brief discussion.

WFD and irrigated agriculture in Italy

Italian agriculture plays a major role in water management, as it is the sector with the highest share in water consumption (50%), due mainly to irrigation. 55% of agricultural production is obtained by irrigated systems. In the last decade the irrigated surface has grown from 18% of the total agricultural area in 1993, to 25% in 2000. The share of irrigated area is very different among regions (ISTAT, 2000). For some crops (e.g. orchards, vegetables, flowers) the irrigated area is almost 100% of the total cultivated area. Irrigated crops account for 60% of Italian agricultural export.

Irrigation water is delivered by "reclamation and irrigation boards" (RIB). The RIBs are associations of farmers that manage water distribution over defined river basins. Water pricing works usually through surface based charges aimed at covering RIBs' costs, without clear incentives in terms of water saving or analogous. There are some examples of volumetric pricing.

Though the application of WFD should be strongly differentiated at regional level, according to river basin organisations, some major criteria are common for all countries (WATECO, 2002). The first is the principle of CR. According to this principle, the water user should bear the costs of water provision, thuogh the directive do not call for a compulsory recovering of the full cost. From an agricultural perspective this could mean a net increase of water prices, since today, in Italy, only a part of the operating costs for water provision are borne by the final users. A second major innovation introduced is the PPP. According to the PPP, water users should bear the cost of pollution. Putting things together, the price level should be high enough to cover the costs of water provision, the opportunity cost of water and environmental costs, while, at the same time, providing incentives in the direction of a reduction of both water use and pollution.

The WFD opens up the problem of estimating economic parameters needed for its implementation, to evaluate the likely impacts of the suggested policy measures and to design sutable implementation schemes at local level. The evaluation of the impacts of higher water prices is the main focus of this paper.

Methodology

Scenarios for CAP and water policy

The methodology includes two main stages. First, a qualitative analysis is carried out, with the aim to identify the likely scenarios for agricultural policy and markets. Later, simulation models are constructed, able to quantify the impact of different scenarios on the sustainability of irrigated agriculture.

The scenarios have been constructed by first identifying possible global futures; for each of them, agricultural scenarios are then defined. The identification of the main scenarios is made through the framework proposed by the British Foresight Programme (Berkhout et al., 1998), lately discussed and revised within the working group of WADI project (Berbel et al., 2002; Morris and Vasileiou, 2003) (Table 1).

For each CAP scenario, a parametrisation on water price is carried out, so as to estimate different demand curves for each scenario. Different water prices on the demand curve may be interpreted as differnt scenarios of implementation of the WFD.

Table 1. The scenarios

General scenarios	CAP scenarios	Main qualitative assumptions	Main assumptions
Provincial enterprise	Existing CAP (Baseline) (BA)	Consumption values prevail, but markets work on a regional scale	No changes
Global sustainability	Reformed CAP (GS)	Strong attention to sustainability, through values and instruments on a global scale	COP price: -5%; COP payments +2,5%; Fruit prices: unchanged
World markets	World agricultural markets (WM)	Consumption values prevail and work through markets on a global scale	COP price: +25%; COP payments: none Fruit prices: +10%
Local stewardship	Local management (LS)	Local social and environmental values prevail and are pursued on a local scale	COP price: +50%; COP payments: no changes Fruit prices: -10%

COP = Cereals, Oil and Protein crops

The models

Simulation models based on mathematical programming techniques are widely applied in agriculture and a large body of literature exists focusing on irrigation problems, among which Amador et al. (1998), Varela-Ortega et al. (1998), Amir and Fisher (1999), Garrido (2000). As the objective function is concerned, evidence from the literature shows that Multicriteria analysis is capable to offer a better interpretation than the simple profit-maximizing approach (Romero and Rehaman, 1989; Berbel and Rodriguez, 1998; Gomez-Limon and Arriaza, 2000). The Multi-Attribute Utility Theory (MAUT) paradigm (Ballestrero and Romero, 1998) has been chosen for the current investigation. The utility function is assumed to be linear and requires normalization since different units are involved[3].

The selection of the relevant objectives and the estimation of the related weights are conducted following the methodology proposed by Sumpsi et al. (1996).

Both short and long run models have been constructed, differing in terms of decision variables, objectives and constraints. Among the latter, crop rotations, commercial and policy aspects, as well as land, labour, capital and water availability are considered. All the models are static.

More in detail, short term (ST) models allow only for the choice of the annual crop mix and irrigation level, given available irrigation equipments, while orchard surface has an upper limit given by the existing share of farmland. Hired labour represents an additional decisional variable. The objective function quantifies gross margin (*GM)*[4].

The costs for water and water distribution are kept separate, thus permitting to derive water demand and elasticities via parametrization of water price.

In the long term (LT) models new orchards can be planted and the choice of irrigation technologies is endogenously determined. Irrigation determines ad hoc investments adding a fixed component to the total costs. Objectives may include the maximisation of profit or net income (*NI*), as well as the minimisation of hired labour, family labour and a variable quantifying crop management difficulty. Empirical investigation in the study area showed that risk averse behaviour is very important in decision making, thus confirming theoretical expectations (Hardaker et al., 1997). Commercial and climatic uncertainty in the area is dealt with mainly through crops diversification. Therefore a diversification objective has been added.

The model has been implemented in a Decision Support System (DSS) called DSIRR which operates as a Windows application using GAMS as the optimisation solver (Bazzani and Rosselli Del Turco, 2002).

Sustainability indicators

For each CAP scenarios and selected water prices, a whole range of sustainability indicators is calculated. The main indicators are selected among OECD agri-environmental indicators (OECD, 2001) (Table 2).

Table 2. Set of sustainability indicators

Area	Selected indicators
Economic balance	Farm income Farm contribution to GDP Public support
Social impact	Farm employment Seasonality
Landscape and biodiversity	Genetic diversity Soil cover
Water use	Irrigation technology Water use Marginal value of water
Nutrients and pollutants	Nitrogen balance Pesticide risk Energy balance

Farm income is defined as the difference between farm revenue and the total cost actually paid for by the farmer. Farm profit is given by farm income minus all calculated costs (such as the cost of farmer's labour). Farm contribution to GDP is the difference between farm revenue and intermediate consumption. Public support (subsidies) is the sum of all direct payments received by the farm. Total employment is the total amount of labour required on the farm.

Indicators for nutrients and pollutants are calculated as the difference between input and output at the farm gate. The energy indicator represents the amount of net energy consumption and should be expected to be negative and as high as possible in absolute value. As for nitrogen, the difference represents the net nitrogen surplus and should be as low as possible. For pesticides, the result is given by the input alone and corresponds to the toxicity value of the total pesticides distributed. The indicator represents the weight (in kilograms) of the population of rats that would be killed at 50% by the pesticides distributed. The soil cover is an indicator of the fraction of time that the soil is covered by crops. Water use is the amount of irrigation water required as measured at the farm gate.

Results

A pilot case study has been carried out in the area of the RIB "Romagna Occidentale", in Northern Italy. In this area, water distribution is based on pressure pipes. The typical production system is fruit farming. Prevailing crops are peach, nectarine and wine grape. The farm typology has been derived from a Cluster Analysis performed on a sample of 1969 farms. Among the clusters obtained, only the results of the largest one are illustrated here.

In the short term, the research conducted showed that farmers behave like income maximizers. Demand curve shows a three stage reaction to water prices (Figure 1).

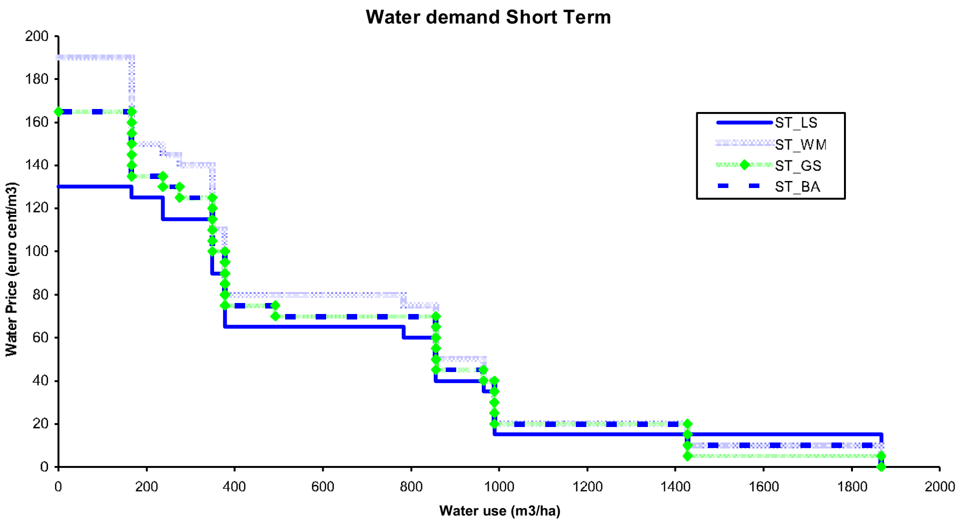

Figure 1. Water demand short term

In the first stage, for very low water prices, irrigation on annual crops may be profitable. Increasing water price, irrigation on annual crops is abandoned and the demand curve shows an area of relatively rigid response to water price, due to perennial crops. Above prices such as 60-70 euro cent/ m^3, the curve becomes elastic. In this area, irrigation is abandoned on tree crops that do not strictly need it, such as grapes and apricot. A further rigid area of the curve follows, up to points around 190 cent/m^3, where the more water needing crops, such as pear and nectarines, switch to rainfed.

The most evident differences between scenarios are located at the lowest and at the upper part of the curve. For low prices, global sustainability and world markets show the lowest possible demand curve, due to the cut in prices and/or payments to COP crops. Local stewardship shows a higher marginal value of water, due to increased prices of the same crops. This area of the curve is particularly relevant, as it is about the size of the present water price in the area (around 15 cent/m^3). Local sustainability stops irrigation at about 130 cent/m^3, while baseline and global sustainability carry on up to 165 cent/m^3. World markets keep irrigation up to 190 cent/m^3, due to the relatively higher increase of fruit revenue compared to COP.

In the long term three objectives were relevant for this cluster; the vector estimated is: profit 0,12, difficulty 0,11, diversification 0,77. Demand curve show a rather different and smoother behaviour (Figure 2).

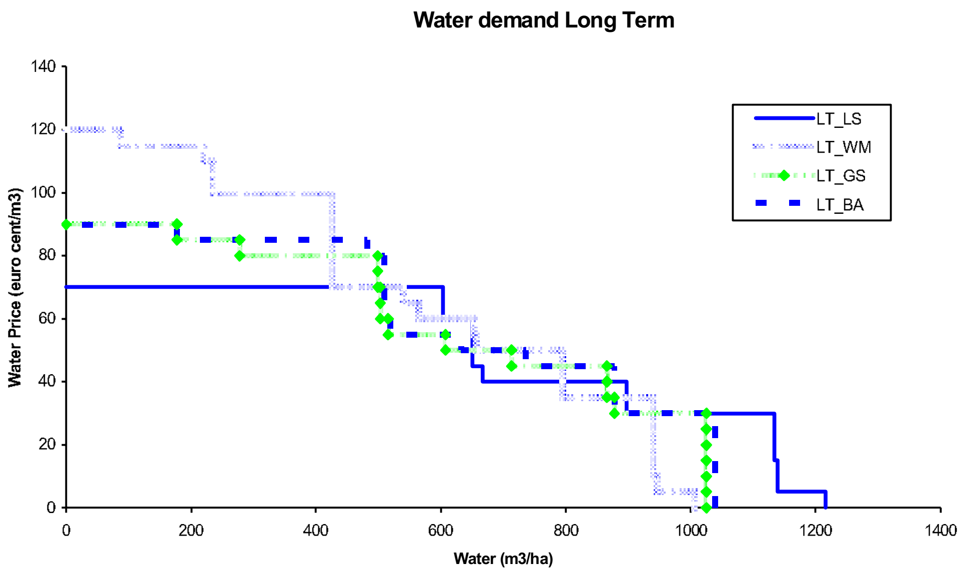

Figure 2. Water demand long term

The tail given by annual crops is almost completely eliminated due to equipment and family labour costs, that are now taken into account. On the opposite side of the curve, the exit price becomes much lower, due to the higher ability of the farm to adapt in the long term and to the lower marginal value of water due to the full consideration of labour and equipment costs.

The results of the indicators show the relevance of the different scenarios at the present prices and at a double price, which is thought to be a reasonable hypothesis in the case of application of WFD (Table 3).

The indicators show the relevant impact of different scenarios and price change on farm profit, as well as on water use. Other indicators, such as nitrogen, pesticides and soil cover, respond with minor changes to the shift from 15 to 30 cent/m^3. The resilience of the system to water price changes is due to the possibility to produce some crops without irrigation. Nevertheless, the strong effects on profit could put at stake the sustainability of the farm as a whole.

Discussion

Altogether, the results show the magnitude of likely impacts due to price changes connected to CAP and WFD in the North-East Italian fruit district. Different scenarios cause relevant changes of the demand curves, in particular for price ranges where irrigation may be profitable on annual crops. Major differences in water demand are also evident for very high water prices, that are, nevertheless, less likely to be reached.

Table 3. Impact on sustainability indicators (long term)

	Profit	Farm income	Subsidies	Contribution to GDP	Labour	Energy	Nitrogen	Pesticides	Soil cover	Water use
P=15 euro/m3										
BA	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
GS	10,9%	-2,3%	4,1%	-1,5%	-1,2%	-0,9%	-0,2%	-1,3%	-1,3%	-1,4%
WM	-88,1%	5,4%	-100,0%	3,4%	-8,3%	-6,5%	-1,3%	-9,2%	-3,9%	-9,5%
LS	40,1%	-4,9%	-4,8%	-3,1%	0,6%	-2,1%	5,5%	-10,5%	1,3%	9,2%
P=30 euro/m3										
BA	63,9%	-8,2%	-1,1%	-5,5%	-0,1%	-1,3%	0,4%	0,8%	0,0%	-15,4%
GS	74,1%	-10,4%	3,1%	-6,9%	-1,2%	-2,1%	0,2%	-0,6%	0,0%	-15,5%
WM	-29,5%	-2,0%	-100,0%	-1,4%	-8,3%	-6,5%	-1,3%	-9,2%	-3,9%	-9,5%
LS	107,9%	-14,3%	-5,0%	-9,5%	-0,4%	-3,5%	5,9%	-10,0%	1,3%	-13,6%

Water pricing permits to achieve significant water savings pushing annual crops to rainfed cultivation without excessive impact on farm income. This result can be reached at different prices according to the existing PAC scenario. Attempting to further reduce water use would lead to the rigid part of the demand curve, where incomes would be eroded without substantial changes of water use. It is likely that analogous results could be obtained at a lower cost through CAP changes involving a reduction in the price and/or payments of COP. In fact, this would allow to cut water use to a good extent, without affecting too much farms' profitability. Instead, higher protection on agricultural products combined with an increase in water prices would create a sort of competition between policies, increasing the amount of public expenditure without leaving the farmers better off.

On the other side, CAP payments on rainfed annual crops (such as wheat) encourage the substitution of irrigated crops with rainfed cultivations. However, in the case study, this applies only to the upper part of the demand curve, at prices that are unlikely to be reached in the medium term.

Beyond the detailed analysis of CAP-WFD interaction, the results emphasise the need of taking into account a broader range of impacts and to provide a higher coordination between different social objectives, in order to make future policy changes more socially valuable and politically feasible.

Notes

1. V. Gallerani coordination
   G.M. Bazzaniauthor 3.2 and model implementation
   S. Di Pasquale author 2
   D. Viaggi author 4
   M. Raggi author 3.1 and 3.3
   S. Morganti data collection
   ORDINE e PARAGRAFI
2. Sustainability of European Irrigated Agriculture under WFD and Agenda 2000, V RTD programme, EU (2001-2003).
3. $$U = \sum_{oma} Ow(oma) * \frac{Z^{+}(oma) - Z(oma)}{Z^{+}(oma) - Z^{-}(oma)} + \sum_{omi} Ow(omi) * \left(1 - \frac{Z^{+}(omi) - Z(omi)}{Z^{+}(omi) - Z^{-}(omi)}\right)$$

where: *U* represents the utility index, *Z*, *Z+*, *Z-* objectives values, ideal and nadir, *Ow* weights, *oma* and *omi* the subset of maximizing and minimizing objectives respectively. Questa sarebbe la nota della nota:

The *ideal* and the *nadir* represent respectively the best and worst case for a given objective.

4. $$\begin{aligned} GM = {} & \sum_{c}\sum_{i}\sum_{s} \mathrm{X(c,i,s)}*\left[\mathrm{Su(c)+Rev(c,i,s)\text{-}Vc(c,i,s)}\right] \\ & -\sum_{k}\sum_{l}\sum_{p} W(k,l,p)*Wp(k,l,p) - \sum_{c}\sum_{i}\sum_{j}\sum_{f}\sum_{p}\sum_{s} \mathrm{X(c,i,j,f,s)*Wit(c,i,j,p,s)}*Ir\_\cos t(f) \\ & -\sum_{p} LE(p) * Lsal - DEBT * Int \end{aligned}$$

where: c represents crop, k water provision (open channels, pipes, …), i irrigation level (the model permits to consider water-yields functions), j irrigation technique, f irrigation modality (internal or external, i.e. via contractor), p period, s type of soil. To distinguish among variables (endogenously determined) and parameters (exogenously fixed) the former are written in capital letters: X represents the activities (ha), Su subsidies (€), Re revenue (€), Vc variable cost (€), W water demand (m3), Wp Water price (€/m3), l identifying water provision levels permits to simulate an increasing pricing scheme, Wit equipment time for irrigation (h), Ir_cost Irrigation costs (€/h), LE hired labour (h), Lsal salary (€/h), DEBT indebtment (€), Int interest rate (%), GM gross margin (€). A separate equation quantifies the financial balance, while upper limit exists on indebtment. Water balance equations quantify water consumption by periods, other equations quantify labour demand.

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