

Analysis of nitrate pollution control policies in the irrigated agriculture of Apulia Region (Southern Italy): A bio-economic modelling approach

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Abstract

Nitrate leaching is one of the many forms of environmental pollution resulting from irrigation and intensive agriculture. In this work, a method of combining an agronomic simulation model (EPIC) and a mathematical multi-objective programming model is used to analyse the effects of three agricultural policies on farmer's revenue and nitrate leaching. An evaluation of the net social costs associated with the different policy measures is also given. The farmer's behaviour in different policy scenarios was studied in terms of selected crops, irrigation technique and method, and adopted management practices with focus on farm management practices and water application efficiency. Irrigation water pricing, subsidies to adopt improved management levels, and taxation on the use of nitrogen fertilizer were examined. A trade-off emerges between the levels of nitrate leaching and net farmer's revenue more pronounced for nitrogen tax policies than for water pricing. The results obtained indicate that nitrate leaching can be reduced by about 40% with an associated net social cost of 269 €/ha for the water pricing policy, 183 €/ha for the tax on fertilizer and 95 €/ha for subsidies to high efficiency management.

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1. Introduction

Agricultural activities might generate negative impacts on the environment.

Irrigation can affect the environment by favouring the adoption of intensive agricultural practices and boosting high cash crops with associated use of increasing amounts of water, fertilizers and pesticides (IEEP, 2000). Still, chemical-based pollution in agriculture is not exclusively related to irrigation.

Water pollution from agriculture is defined as non-point source pollution. Actors involved are numerous and it is a quite complex matter to define how and when polluting agent moves into the water bodies and who the polluters are.

The strong site-specific dimension of this phenomenon significantly affects the types of tools to be used to control it and their efficiency (Westra and Olson, 2001).

Economic theory has long since identified the control mechanisms of externalities – the main economic category by which the theme of pollution is tackled – but economic control instruments cannot be readily implemented nor can their efficacy be promptly assessed (Shortle and Dunn, 1986).

Policy mechanisms used for agricultural non-point pollution control are direct regulations (i.e. standards on the amount and use of potential pollutants and production practices) and pricing policy like taxes or subsidies. Taxes and subsidies can be applied directly to the polluting emissions (“effluent” taxes or subsidies) or based on some emission proxies like polluting inputs or certain agricultural practices (“influent” taxes or subsidies). Much less used are other economic incentives like tradable permits and contracts (Hahn, 2000), although the combined use of subsidies and contracts between farmers and some public

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agencies are increasingly adopted as it is the case of the European agri-environmental policies (Horan and Shortle, 2001).

Many studies have shown the potential role of water price policies in modifying farm-level irrigation decisions towards more environmentally friendly choices (Gardner and Young, 1988; Dinar et al., 1989; Varela-Ortega et al., 1998; Berbel and Gómez-Limón, 2000; Mimouni et al., 2000). Irrigation water seems to have all the attributes that make it a good base to design policy instruments for non-point pollution control: it is (i) correlated with environmental conditions, (ii) enforceable at reasonable cost and (iii) targetable in time and space (Braden and Segerson, 1993).

Many of the numerous studies addressing the economic theory of non-point pollution control (Deybe, 1994; Bouzahr et al., 1995; Teague et al., 1995; Dalton and Masters, 1997) have used a bio-economic modelling approach that combines biophysical and economic models to fit the complexity of the relationships between agriculture and environment. Still, studies conducted in the Mediterranean region are very few (Boussemart et al., 1996; Flichman et al., 1995; Flichman, 1997; Louhichi et al., 1999; Mimouni et al., 2000), in spite of the increasing severity of environmental problems in this area.

In the present work, and for the first time, this approach is applied to irrigation efficiency. We focused on the possible effect of improved farm management practices on water application efficiency and nitrate leaching reduction.

This paper reports the results of a study that analysed the farmer's behaviour in different policy scenarios in terms of strategies adopted when changing selected crops, irrigation techniques, irrigation methods and management practices to improve water application efficiency.

Water application efficiency (e_a) is defined as the ratio of the amount of water that effectively reaches the crop root zone (W_r) to the amount of water applied to the field (W_a), i.e.,

$$e_a = W_r / W_a \quad (1)$$

Our final objective was to assess the effects of different policy measures on farmer's revenue and nitrate leaching level and to evaluate their net social costs.

The policies examined include a gradual increase in the water price by unit of water consumed, a subsidy to the adoption of high level management practices and a tax on the use of nitrogen fertilizer in crop production.

In the investigated region (Apulia, Southern Italy), irrigated land covers 361,000 ha equal to 25% of total agricultural land and irrigated agriculture produces 1663 million euro (1997 data) representing 54% of the total value of the regional agricultural production (INEA, 2001).

Climatic conditions and the type of cultivated crops (high value crops such as vegetables, salads and soft fruits) make irrigation a must for the farmers to obtain acceptable revenue and, in turn, irrigated intensive agriculture makes these regions greatly exposed to severe nitrate leaching impacts (IEEP, 2000).

2. Study area

The study was carried out in a flat area farm, of almost 100 ha in Apulia region, typically grown with sown crops, cereals and some vegetable crops like tomato essentially used for processing.

The water pricing criteria adopted in the investigated area is a binomial and block-rate tariff, which consists of a fixed fee farmers pay to the Consortium per hectare of cultivated area and a variable tiered fee that depends on consumption. Such water pricing is applicable in that the on-demand pressurized distribution network is equipped with water meters.

Average rainfall is around 460 mm/year, with maximum temperature reaching 31 °C in July and minimum temperature of 5 °C in January and February. The soil is 120 cm deep, it has an average bulk density of 1.3 g/cm³ and an average texture throughout the profile with 45% sand, 42% clay and 13% silt on weight basis. It contains 1.24% of organic matter with a pH of about 8.5 and a cation exchange capacity of 290 mmol/kg. The field capacity and wilting point are 39% and 21%, respectively, of the total available water.

Five crops were grown – wheat, sorghum, sunflower, tomato and sugar beet – and the following was considered: (i) three irrigation regimes or techniques corresponding to a first level of deficit irrigation (T1), a second level of deficit irrigation (T2) and full irrigation (T3) plus the rain-fed regime for wheat, sunflower and sorghum (Table 1); (ii) three irrigation methods, surface, (R1), sprinkler (R2) and drip (R3); (iii) three management levels, low (M1), medium (M2) and high (M3). Management levels were defined according to some operations performed and equipment used such as: land levelling, days of expert consultation, number of water meters and tensiometers, pressure regulators, volumetric valves and water markers. Different levels of nitrogen fertilizer application were also considered and set on the basis of the actual fertilization practices in the area. In particular, wheat received a total of 120 kg-N/ha during the crop season and for each irrigation regime (T), with 45 kg-N/ha applied at sowing and 75 kg-N/ha applied at the shooting stage. Sorghum received a total of 100 kg-N/ha in the rain-fed case (T0 – half applied at sowing and half at the shooting stage) and a total of 200 kg-N/ha in all the other irrigation regimes (T1–T3 – equally distributed during the crop season and at each irrigation event). Sunflower

Table 1
Reference water (mm) and quantity of N (kg/ha) for each crop and technique

	T0		T1		T2		T3	
	W_r	N	W_r	N	W_r	N	W_r	N
Wheat	–	120	90	120	160	120	300	120
Sorghum	–	100	180	200	250	200	400	200
Sunflower	–	70	210	80	350	100	600	120
Sugar beet	–	–	250	150	450	200	700	200
Tomato	–	–	180	150	330	200	500	200

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