Title: The magnitude and cost of groundwater monitoring and control in agriculture.

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Abstract

The implementation and effectiveness of a groundwater pricing policy crucially depends on enforcement capacity, sanctioning systems, and the need for the generation of information and its management. Key issue in groundwater management is the size of the groundwater user community. Implementing an on-farm monitoring and control system typically involves a fixed component such as installing measuring devices, setting up administration and facilities, and a variable component that increases with the water proceeds (i.e. monitoring and collection activities). Monitoring/detection, may include both measuring the performance of water users and monitoring their compliance with regulation, as well as the development of monitoring technologies.

The aim of this research is to define a framework analysis of groundwater monitoring and control in agriculture in order to assess its cost. The case of Capitanata irrigation basin (Puglia region, South of Italy) is used to carry out the cost assessment of at-farm-gate monitoring and control systems on irrigation groundwater. According to the results the magnitude of cost for an individual monitoring may oversize the expected economic return of groundwater control.

Keywords: groundwater; monitoring and control cost; irrigation board

1. Introduction

EU directive 60/2000 recommends the full cost recovery and suggests the direct water pricing as the most effective to reduce irrigation water demand. As pointed out by Field and Field [1] there is a natural tendency among people to think that enacting a law automatically leads to the rectification of the problem to which it is addressed.

In order to enforce the EU regulation, the metering of water uses and the monitoring and control (M&C) is a prerequisite. In the case of groundwater sources, which are distributed and (often) managed directly by farmers, the metering as well as its recording may result in a costly activity. Key issue in groundwater management is the size of the groundwater user community. In general farmers operate in rural areas, therefore the costs for an individual point control on groundwater withdraw are expected to be highly relevant at territorial level. Enforcement ultimately requires energy and resources thus it turns into a costly activities.

As a whole, there is a gap in the literature regarding the estimation of monitoring and control cost for the compliance of policy, in particular for environmental measures. While specific studies for the case of irrigation groundwater are not available, some studies in the literature deals with cap and trade mechanisms for irrigation water. Examples are reported in [2] for Colorado and California.

In this paper, we attempted to estimate the monitoring and control cost of irrigation groundwater. The case of Capitanata irrigation basin (Apulia region, South of Italy) is used to carry out the cost assessment of at-farm-gate monitoring and control system on irrigation groundwater. The case study refers to the province of Foggia, which is a very relevant area for Mediterranean agriculture, already affected by groundwater over-exploitation.

2. Materials and Methods

Puglia exhibits a Mediterranean climate, characterized by warm to hot, dry summers and mild to cool, wet winters. Irrigation plays a relevant role in the overall economy of region and especially in the agriculture. As a whole in 2009/2010 farming years, the total irrigated land amounted to 238,546.02 ha [3]. Permanent crops such as olive tree and grape are widespread followed by fresh-cut vegetables (brocoli, carrot, spinach, artichoke, asparagus, etc.) and processing tomatoes. As a whole, these crops account for 80% of region's irrigated land.

The average farm size for irrigated land is less than 5 ha with 87,463 farms applying irrigation (32.2% of total farms). While more than 60% of groundwater exploitation is used for irrigation, abstraction increases considerably in severe drought periods, as it was the case in 1982, in 1988-89 and in 2002 [4]. In many areas where groundwater is the main freshwater source, pumping rates exceed the natural recharge rate and cause

continuous water table drawdown, well depletion, increased pumping costs, and more severe seawater intrusion in coastal areas.

Groundwater use is subject to permit rights use issued by the public authority, which should also undertake the monitoring and control on water volumes. Although the drill of private wells is subject to public authorization or licensing, in many cases the monitoring and control system is fragmented. In fact, there no exist any facility belongs to the regional Government witch is in charge of groundwater monitoring and control.

The absence of direct services providing a groundwater monitoring and control makes the cost assessment of M&C operations difficult. In order to carry out an appraisal of such cost, a framework analysis of groundwater monitoring and control in agriculture is firstly defined.

For sake of simplicity, for an effective groundwater management the follow steps would be taken: i) initial allocation; ii) registration mechanism and maintained registry system; iii) functioning monitoring system; iv) enforcement of the limits set by the individual; v) credible sanctioning system. In this research we consider the fact that the regional Government has already moved away from the first step (i.e. initial allocation) and the second (i.e. registration mechanism and maintained registry system). By contrast, the other steps are still not taken.

Implementing an on-farm monitoring and control system typically involves a fixed component such as installing measuring devices, setting up administration and facilities, and a variable component that increases with the water proceeds (i.e. monitoring and collection activities). Monitoring/detection may include both measuring the performance of water users and monitoring their compliance with regulation, as well as the development of monitoring technologies [2]. On the other side, sanctioning includes persecution/inducement/conflict resolution costs incurred if lack of compliance is detected.

According to the Regional law on groundwater use, farmers are requested to install on-farm metering device while measuring the performance of water users and monitoring their compliance with regulation is actually in charge of public administration. As a consequence, herein the cost for monitoring and control is assessed in the event of the on-farm withdraw points are known and already provided with metering devices.

In order to evaluate such cost, we considered the M&C as a service provided by a firm. The provision cost of monitoring and control services was calculated as shown in Figure 1.

$$K = W + Q + T + M + I$$

Where:

K = provision cost of the monitoring and control service;

W = wages of employees involved in the M&C operations, both from manual and from intellectual labor;

Q = costs for depreciation expense and insurence policy of the machinery inventory used in M&C;

M = miscellaneous expenses for M&C operations;

I = interests accumulated on capital paid in advance to settle W, Q, T and M.

Figure 1 - Criterion of estimation.

Example of companies operating in the sector of water M&C in agriculture are the Reclamation and Irrigation Boards. In the Puglia region, the best example is the Reclamation and Irrigation Board of Capitanata (CBC). The key points of choosing the CBC as reference company are: i) the high number of the on-farm water delivering points (28,000) widespread across 400,000 ha of administrated farmland; ii) the volumetric pricing policy applied which implies iii) an at-farm-gate monitoring and control service.

By analyzing the costs faced by the CBC for the M&C operations the magnitude of such service was estimated. We considered an optimal situation where the CBC detains a perfect knowledge of the water delivering points, already provided with metering devices, in order to collect consumption data.

In order to carry out the cost analysis by CBC three types of data sources were used: i) interviews to experts of environmental resources management; ii) accounting data of CBC (2014 and 2015 results), and iii) in-depth interview to Director of CBC.

3. Results and Discussion

Thanks to the different data sources just listed in the previous chapter, we became aware of M&C framework of CBC (Table 1).

The Table 1 put in evidence that CBC does not rely on a full committed team to the M&C operations. This is because the operations of M&C happen simultaneously to other operations (e.g. reparations of water delivering points).

Table 1 - Resume data of CBC monitoring and control service

item	value
on average total cubic meters delivered	112,689,721 (m^3/anno)
on average total distribution water delivering points annually utilized	28,000
employees partially dedicated (from 25 to 50 % of their work's hours) to M&C	86
full-time employees dedicated to M&C	4
vehicles partially utilized (40% of their use work) for M&C operations	65

In the table 2, the cost of each item is reported according to the service function shown in Figure 1.

Table 2 - M&C costs for each estimation item

item	on avarage annual cost
W	1,085,187 €
Q	92,481 €
T	4,252 €
M	440,167 €
I	39,468 €
K	**1,661,155 €**

On the results shown in Table 2, it should be notice that the most expansive item is the wages of workers engaged in the M&C services (about 65% of the total M&C service annual cost). The unit cost per volume of M&C incurred by CBC amounts to 0.015 €/m^3, while the unit cost per delivering point is estimated of 59 €, with 28,000 delivering points to be annually checked (Table 3). The total yearly cost amounts to 1,661,155 € which accounts for 7% of ordinary annual financial balance of CBC.

Table 3 - Results of the estimation

item	on average annual cost
total annual cost of the CBC's M&C service	1,661,155 €
M&C annual cost per cubic meter delivered	0.015 €/m^3
M&C annual cost per each water delivering point	59 €
percentage of M&C service's costs on total amount of ordinary annual balance sheet	7%

The already issued groundwater rights in the Province of Foggia are 36,359 (a farmer can exploit more wells depending on the farmland size and number of plots). With the exception of *Motta Montecorvino*, all other 60 municipalities are faced with groundwater

users. The idea of carrying out a point-to-point monitoring and control service will entail an expenditure of almost 2 million € per year.

4. Conclusions

The full cost recovery and the direct water pricing are seen as the most effective way for the water use enhancement. Nevertheless, the cost incurred to implement a volumetric pricing in the case of groundwater is often neglected. In this research, we attempted to assess the cost due to perform a monitoring and control service on irrigation groundwater. We assessed a unit cost per point (well) of almost 60 €. In addition, considering the whole community of groundwater users in Province of Foggia, more than 2 million per year must be spent by public administration.

Viaggi et al [5] discussed water pricing under asymmetric information in the context of the directive 60/2000 arguing the economic feasibility of volumetric pricing in agriculture due to the cost incurred for irrigation water metering. In line with them, the findings of our research points to the disproportionality of point-to-point M&C costs in the case of groundwater sources.

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