Communication

Cost-benefit analysis of irrigation modernization in Guadalquivir River Basin

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Abstract: In water scarce areas, policy makers frequently opt for water conservation and saving technologies (WCSTs) as a measure to ensure resource use sustainability, although this policy is subject to scientific and political debate. This work presents an application of an integrated methodological approach for analysing the costs and benefits of using WCSTs to achieve water policy objectives. The focus is on the measures aimed at reducing irrigation water abstraction under the 1st and 2nd cycle of Water Framework Directive implementation in the Guadalquivir River Basin (Southern Spain). The method is a combination of a multicriteria assessment of the main effects of water-saving investments at basin level, estimated using a selected group of indicators. In a second stage, a cost-benefit analysis is conducted. The study finds a benefit-to-cost ratio of 4.1/1 for the Guadalquivir River Basin, thus concluding that irrigation modernization in this case study has been a good social investment. The method can be extended to other hydrological systems (aquifer basins) to draw general conclusions.

Keywords: Irrigated agriculture; Water conservation and saving technologies; ecosystem services.

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1. Introduction

The world's population is expected to grow to almost 10 billion by 2050, boosting agricultural demand leading to more intense competition for natural resources, especially water that appears as one of the most limiting factors to deliver sustainable food and agricultural production. While world population has rapidly increased the use of freshwater for human consumption, agriculture, industry, and other uses has increased six fold, with agriculture representing 70% of total water withdrawal and accounts for 86% of consumption (FAO, 2017). Nowadays water scarcity is considered one of the greatest risks facing the planet (World Economic Forum, 2016).

Increasing irrigation efficiency has been suggested as a solution to water scarcity. This work presents an application of CBA to investment in irrigation water saving measures in the Guadalquivir river basin (South of Spain).

The Guadalquivir river basin (GRB) contains 25% of Spain's irrigated land and the longest of the southern rivers (657 km); it can thus be considered one of the most important basins in Spain. It covers an area of 57,679 km2 and has a population of 4.3 million. The basin has a Mediterranean climate with a heterogeneous precipitation distribution. The annual average temperature is 16.8°C, and the annual average precipitation is 573 mm, with a range between 260 mm and 983 mm (standard deviation of 161 mm). The average renewable resources, that means the quantity of water that go into the basin each year, amount to a median value of 5.1 km3/year (Berbel et al., 2012). Reservoirs storage capacity is through a complex and interconnected system of 65 dams have a global storage capacity of 8.5 km3. The main land uses in the basin are forestry (49.1%), agriculture (47.2%), urban areas (1.9%) and wetlands (1.8%) (Confederación Hidrográfica del Guadalquivir, 2015).

2. Mehodology

CBA is an analytical tool for evaluating the economic advantages or disadvantages of an investment decision to assess the welfare change attributable to it. Our approach to CBA will be divided into three phases. Figure 1 illustrates phase 1, which is sub-divided into the following steps: i) the identification and characterization of water saving investment measures, ii) the identification of the different responses, iii) the identification of the direct and indirect outcomes.

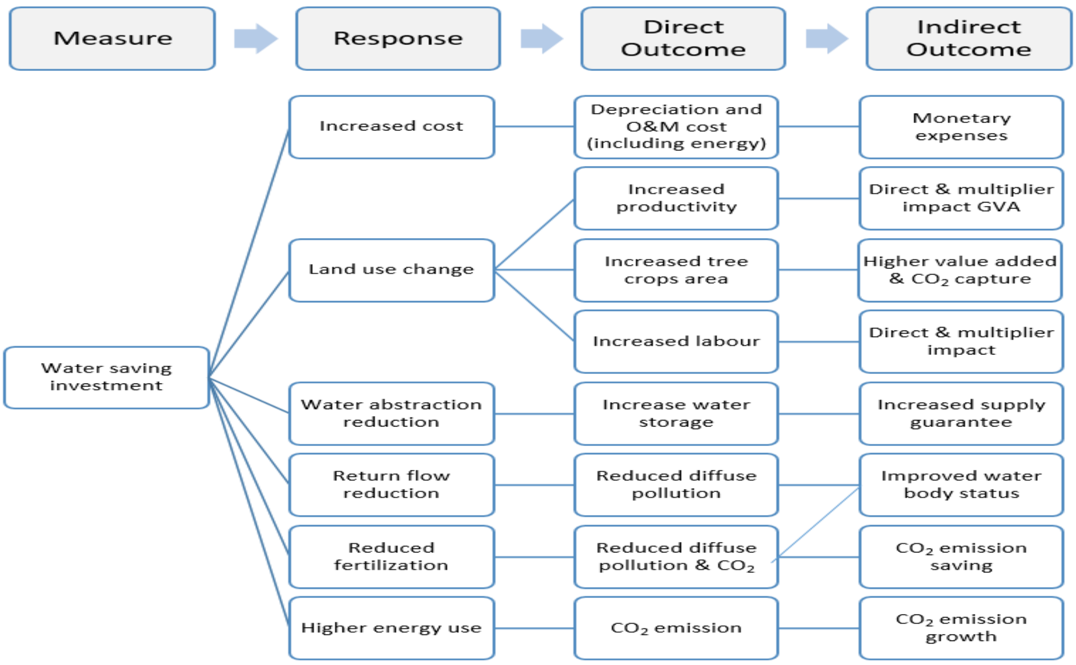

Figure 1: Phase 1 "Determination of direct and indirect outcomes".

Secondly, once both direct and indirect outcomes have been identified, a set of indicators is defined and evaluated to estimate these effects in economic terms.

Finally, a CBA is carried out to predict whether the multiple benefits of irrigation modernization policy (both monetary and non-monetary outcomes) outweigh its multiple costs (including non-monetary cost). The CBA will be carried out to evaluate and compare the various advantages and disadvantages of the investments in water saving measures in a structured and systematic way. The benefits are compared with the associated costs within a common analytical framework with clearly-defined spatial and temporal boundaries. Since these costs and benefits relate to a wide range of impacts measured in widely differing units, a monetary value is assigned as the common denominator to enable a meaningful comparison that includes discounting future cost and benefits.

The results of this analysis can be interpreted as a B/C ratio, that is, total benefits divided by total costs; a ratio greater than one indicates that the policy measure is beneficial from a social point of view and hence yields a welfare improvement.

3. Results

The results of the evaluation of water saving measures in the GRB are summarized in Table 1.

COSTS					
	Indicator	Unit	EUR/Unit	Total (10^6 EUR)	%
[A]	Annual Equivalent Cost (AEC)	-	-	121,2	97.5%
[B]	CO2 emissions cost	83,187 t CO_2	38.54	3,2	2.5%
[C]=[A]+[B]	Total			124,4	100.0%
BENEFITS					
	Indicator	Unit	EUR/Unit	Total (10^6 EUR)	% Direct effect
Provisioning Services					
[D]	Increase in water productivity	1,240 hm^3	0.12	148,8	36.6%
[E]	Increase in employment	6,006 UTA	10,080	44,5	11.0%
[F]	Increase in guaranteed water supply	2,205 hm^3	0.06	132,3	32.6%
Regulation Services					
[G]	Increase in tree crop area (CO2 capture)	2,048,277 t CO_2	38.54	78,9	19.4%
[H]	Decrease in fertilizer applied per ha	14,777 t CO_2	38.54	0.6	0.1%
[I]	Diffuse water pollution reduction	5,484 t N	2.08	1,1	0.3%
[J] = [D]+…[I]	Total Direct			406,3	100.0%
COST-BENEFIT RATIO (only DIRECT)				3.3	
[K]	Multiplier GVA whole economy			72,9	n/a
[L]	Multiplier labour whole economy			29,7	n/a
[M]=[F+.I]+[K+L]	Total direct + multiplier			508,9	n/a
COST-BENEFIT RATIO (including MULTIPLIER)				4.1	

Table 1: CBA of investments in water saving measures.

The results show a high social benefit compared to the cost. For GRB, the provisioning services [D, E and F] suppose 80% of the benefits, while the regulatory ecosystem services selected make up 20%.

4. Discussion

The analysis presented here is valid as a general method of assessment, but it should be carefully applied to the selected territorial unit. The GRB has come under close scrutiny, as it is one of the most important agricultural production areas in Spain. To our knowledge, this is the first attempt to apply a cost-benefit analysis including a set of indicators to the GRB; previous analyses have focused only on partial aspects.

Previous analyses of the social impact of water saving measures in Andalusia have shown an increase of 28.2% in agricultural employment (Corominas and Cuevas, 2017), which is a higher value than that estimated using our approach (4%). In our opinion previous estimates overvalue the impact as they compare rain-fed land with new irrigated land, whereas our estimation concentrates on the impact of WCSTs in land that is already irrigated. The value found in this study is in line with (Expósito and Berbel, 2017).

The increase in CO_{2eq} due to pressurized networks has been addressed previously; Fernández García et al. (2014) focus on energy costs, estimating that the water cost in the GRB has increased more than 100% in EUR/m^3 with energy in almost all the irrigation districts. Energy represents up to 50% of the total water costs in modernized GRB systems. Mushtaq et al. (2013) estimate that 120 hm^3/year of water savings achieved in Australia through drip irrigation adoption would increase GHG emissions by 250,000 t CO_{2eq} /year, (that is 2.08 kgCO_{2eq} /m^3); we estimate a volume of 83,187 t CO_{2eq} generated to achieve water savings of 259.5 hm^3 (0.32 kgCO_{2eq}/m^3). The differences may be explained by two differential factors: the energy mix, with a higher presence of renewables and nuclear power in Spain; and the effectiveness of water saving, with a compulsory reduction in water entitlements of around 50% in the Spanish case, which is not common in the Australian case.

The valuation of an increase in guaranteed water supply has not been included in previous research as a relevant output, but our analysis finds a high value for this output, with a direct economic impact of 32.6%. The valuation of guaranteed supply has been based on the different levels of guaranteed water supply established for water entitlements in the GRB. In the Murray Darling Basin, it is estimated at 0.10 EUR/m^3 based on water entitlement trade (ABARES 2018); this value is similar to the willingness to pay (WTP) for increased guarantee estimated for GRB farmers (Mesa-Jurado et al., 2012), which was in the range 0.05 to 0.07 EUR/m^3.

The impact of modernization in terms of improved quality is relevant at basin scale. The analysis to convert the reduction in nitrogen leaching into water bodies into an economic benefit is based on two references: the Jucar RB (Eastern Spain) (MAGRAMA, 2016), which estimates excess nitrogen in water bodies at 61 kg N/m^3; and García-Garizábal and Causapé (2010), who estimate a 20% reduction in the leached nitrogen after WCST implementation in an irrigation unit in the Ebro.

No attempt has been made to evaluate the non-market benefit of water quality improvement. Martin-Ortega et al. (2011) estimate a value of 46.5 EUR per capita in the GRB, which amounts to around 198 million EUR/year. This is higher than the estimate for regulatory services, but it should be borne in mind that modernization is only a part of the total RBMP, and urban water treatment is the most expensive measure and the one with the greatest impact on water quality. Nevertheless, the fact that quality improvement due to modernization indicators [G, H and I] account for circa 80 million EUR/year may be considered in the range of subjective welfare valuation (identified as willingness to pay or WTP). Finally, it should be mentioned that water-related benefits [D+F+H+I] are 70% of benefits with the remaining 30% related to climate change mitigation and social economic outputs, thus suggesting the need for an extended analysis of water policy that goes beyond water itself.

4. Conclusions

The results of the analysis done in this research show that investment in WCST measures for irrigation is a rational policy for water resources management that goes beyond resource efficiency to include benefits in terms of water environmental services, such as reduced pollution, increased productivity value, employment generation and improved reliability of water supply. Despite the relevance of the results, they refer to a river basin in Southern Spain and so the impact will be very location-specific. The methodology should therefore be considered as a proposal and evaluations of other regions where water saving measures have been adopted as a policy option should be carried out.

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