Water Footprint and Virtual Water Trade in Spain

NATURAL RESOURCE MANAGEMENT AND POLICY

EDITORIAL STATEMENT

There is a growing awareness of the role that natural resources such as water, land, forests and environmental amenities play in our lives. There are many competing uses for natural resources, and society is challenged to manage them to improve social well being. Furthermore, there may be dire consequences to natural resources mismanagement. Renewable resources such as water, land and the environment are linked, and decisions made with regard to one may affect the others. Policy and management of natural resources now require an interdisciplinary approach including natural and social sciences to correctly address our societal preferences.

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Policy Implications

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To my wife, Beatriz
A.G.

To my colleagues, Ramón Llamas
and Alberto Garrido
C.V.O.

To my parents, Chus and Suso
P.N.

To my parents and brother
R.R.C.

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M.M.A.

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Contents

Chapter 1
Introduction

1.1 General Framework

In most arid and semi-arid countries, water resource management is an issue that is both important and controversial. Most water resources experts now acknowledge that water conflicts are not caused by physical scarcity but are mainly due to poor water management (Rosegrant et al. 2002; Benoit and Comeau 2005; Comprehensive Assessment of Water Management in Agriculture 2007; Garrido and Dinar 2010, among others). The scientific and technological advances of the past 50 years have led to new ways to solve many water-related conflicts, often with tools that seemed unthinkable a few decades ago (Llamas 2005; Lopez-Gunn and Llamas 2008). This study deals with the estimation and analysis of Spain's water footprint, both from a hydrological and economic perspective. Its ultimate objective is to report on the allocative efficiency of water and economic resources. This analysis can provide a transparent and multidisciplinary framework for informing and optimising water policy decisions, contributing at the same time to the implementation of the EU Water Framework Directive (WFD) (2000/60/EC). It also responds to the current mandate of the Spanish Ministry of Environment and Rural and Marine Affairs, which recently issued instructions for drafting river basin management plans in compliance with the EU Water Framework Directive, with a deadline of end of year 2009 and then every 6 years (BOE 2008).

The water footprint (WF) is a consumption-based indicator of water use (Hoekstra and Chapagain 2008). The WF of an individual or community is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community (Hoekstra and Chapagain 2008). Closely linked to the concept of water footprint is the virtual-water concept (VW). The virtual-water content of a product (a commodity, good or service) refers to the volume of water used in its production (Allan 1997, 1999; Hoekstra 2003). Building on this concept, virtual-water "trade" represents the amount of water embedded in traded products (Hoekstra and Hung 2002). A critical issue related to the understanding of globalisation is whether international trade can save water globally. In principle, it does if a water-intensive commodity is traded from an area where it is produced with high water productivity (resulting in products with low virtual-water

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content) to an area with lower water productivity (Hoekstra and Chapagain 2008). For instance, Yang and Zehnder (2008) show that about 336 km^3/year could be saved through virtual-water "trade" in agricultural commodities alone. Nevertheless, the relevance of global water savings needs a more detailed study, because savings represent only about 5% of the global water footprint and the uncertainties and limitations of the estimations may be greater than this 5%. Although virtual-water "trade" evaluations have taken countries or even bigger regions as the trading partners, the concept can also be applied within countries and even river basins. In fact, this is the dual perspective of this study.

At the national or regional level, a nation can preserve its domestic water resources by importing products instead of producing them domestically. This is particularly relevant to arid or semi-arid countries with scarce water resources such as Spain. As this study explains, Spain imports water-intensive low-economic value crops (mainly wheat, maize and soybeans and soy products), while it exports water-extensive high-value commodities adapted to the Mediterranean climate, essentially olive oil, fruits and vegetables. However, most countries, including Spain, import and export the same or very similar commodities, with trade flows that vary by season, specific varieties and market trends of supply and demand. Because water is not the main input in virtually all traded goods, water scarcity and supply costs are poor explanatory factors of virtual-water "trade", except in very special contexts. As basic resources such as water and energy become increasingly scarce, the potential for international trade as a way to promote efficient use of these resources becomes more policy relevant. While virtual-water "trade" cannot be considered as the primary motivation for commodity trade, one can always test whether virtual-water "trade" can enable or facilitate more efficient water allocation among competing ends.

In addition to its potential contribution to water savings, it is also important to establish whether the water used originates from rainwater evaporated during the production process (green water) or surface water and/or groundwater evaporated as a result of the production of the product (blue water) (Falkenmark 2003). Traditionally, emphasis has been paid to the concept of blue water through the "miracle" of irrigation systems. However, an increasing number of authors highlight the importance of green water (Rockström 2001; Falkenmark and Rockström 2004; Allan 2006; Comprehensive Assessment of Water Management in Agriculture 2007). The economic and hydrological assessment of the water footprint and the virtual water (both green and blue) used in the different economic sectors could facilitate more efficient allocation and use of water resources, globally, nationally or locally, while providing a transparent interdisciplinary framework for policy formulation. Furthermore, the Achilles' heel of the current emphasis of rainfed agriculture (green water) is climate variability, which will increase, as most studies focusing on the Mediterranean región indicate (MMA 2007; Bates et al. 2008). In order to mitigate drought episodes, water works such as dams and canals have been built, and wells have been drilled to complement surface water supplies. In the last half century, however, there has been a silent revolution in groundwater-irrigated agriculture. This is a relevant fact recognised by many authors today (Briscoe 2005;

Llamas and Martínez-Santos 2005; Shah et al. 2007; Villholth and Giordano 2007). As a matter of fact in some countries, mainly in India, groundwater development is much more important than surface water irrigation (Mukherji et al. 2009).

While rainfed crops depend only on meteorological conditions, irrigated crops depend both on rain regimes and water supply. The combination of these regimes and the interdependencies between international commodity markets and domestic production create opportunities to ensure that water is allocated to the most valuable ends.

This book mainly deals with Spain's water footprint and offers a virtual-water analysis that differentiates green and blue (surface and groundwater) components, both from a hydrological and economic perspective. It looks at the potential of these concepts in helping achieve an efficient allocation of water resources. First of all, it defines the concepts of virtual water, the colours of water, virtual-water "trade" and the water footprint and analyses the impact of economic growth on the latter. A glossary with key terms is included at the end of the document. The study then explores the different economic sectors in detail at the national, provincial and river basin levels. Special attention is given to crop production that accounts for about 80% of the total consumptive use (or water footprint) of use of green and blue water resources. This is followed by assessments of the footprints of livestock, industry, energy and urban water use. Virtual-water "trade" is evaluated both within the EU and with third countries. Finally, the policy implications of this analysis are assessed. A better knowledge of the water footprint and virtual-water "trade" in Spain and in other arid and semi-arid countries can be very useful for developing a comprehensive instrumental framework across time and space to support water management decisions. Ultimately, this knowledge-based tool can be used by the water authorities to achieve a more efficient allocation of water resources. Spain has already largely adopted the "more crops and jobs per drop" paradigm, but it struggles to achieve the new goal of "more cash and nature per drop", because water productivity in many areas of the economy is already high. Furthermore, the literature has rarely considered the actual opportunity cost of the water that is used and exported in virtual form. For countries suffering continuous water shortages, this poses a serious limitation to drawing policy-relevant conclusions from the concepts of water footprint and virtual-water "trade". In this respect, the generally higher economic efficiency of groundwater irrigation deserves a more thorough analysis, expanding on the earlier assessment of Andalusian irrigation (Hernandez-Mora et al. 2001; Vives 2003).

For the time being and in almost the entire world, water footprint analyses have focused on hydrological aspects, based on volumetric evaluations. A significant innovation of this work is to emphasise the imperative challenge of considering economic and ecological factors, with the aim of moving towards a policy that will enable to balance the trade-off between water for nature and water for rural livelihoods, that is to seek for "more cash and nature per drop". Water footprint analyses provide new data and perspectives for a more optimistic outlook on the frequently cited looming "water scarcity crisis". This new knowledge is changing traditional water and food security concepts that most policy makers have held until now.

1.2 Objective

The objective of this study is to assess and analyse Spain's virtual-water "trade" (VW) and water footprint (WF), differentiating the green and blue (surface and groundwater) components, both from a hydrological and economic perspective. The research program that provided the results reported in the following chapters was envisioned and designed with the following criteria:

1. A multi-layered perspective – international, national and regional (basin level) is needed to understand and analyse a country's water policy. The geographical analysis casts light on regional controversies lived in Spain since 2000.
2. As water use and productivity change over time and vary geographically, a wealth of interpretative data can be gathered, analysed and placed in a global context (both as a cause and an effect of the observed changes at the national level).
3. Agriculture being the largest water consumer, it is of utmost importance to understand how green and blue water components vary with time and from place to place. This variation has implications for water productivity, water allocation and drought management, which in turn are linked to international trade.
4. Water is an economic good and provides market and non-market services (Costanza et al. 1997). Its economic dimension must be included in the kind of "motion pictures" featuring the water footprint and virtual-water "trade" that we are aiming to produce in this study. This criterion is entirely consistent with the approach of the WFD and the most recent trends in Spanish water policy.

With these points in mind, this study aims to contribute to the WF and VW literature in the following areas (see Fig. 1.1 for a schematic description):

- By evaluating both WF and VW over time and at the provincial scale, the analysis allows for policy-relevant conclusions at the river basin level.
- By separating green and blue water components and evaluating all crops at the provincial level, the study enables a finer analysis of how WF and VW vary during droughts and water shortages as well as during wet periods. The linkage between commodity trade and water scarcity will be explored to determine the extent to which virtual-water "trade" has the potential to deal with water-stressed periods. This is a crucial factor for water management in arid and semi-arid countries
- By also evaluating WF in terms of m^3/€ – bringing the pioneering approach of WF based on m^3/ton to a socio-economic context – the productive economy is better integrated in the analysis. This provides a distinctive view of WF and allows for a closer linkage between water productivity and water scarcity, in physical and economic terms.
- Water scarcity is evaluated in terms of opportunity cost, both for virtual-water "trade" and WF, which in this study is corrected with the water quality status of the rivers in each province. This analysis, therefore, includes both market and non-market dimensions.

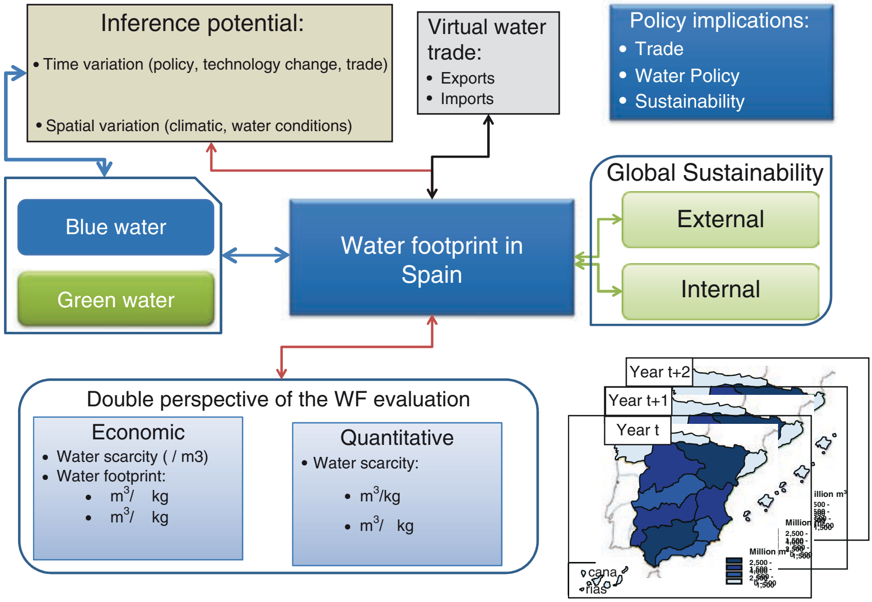

Fig. 1.1 Schematic description of the project

This research study mainly builds on an earlier study by Chapagain and Hoekstra (2004), who estimated the water footprint of nations for the 1997–2001 period. This study, however, covers 1997–2006 and analyses the Spanish water footprint variations from year to year, not only at a national but also at provincial and river basin levels. In both studies, water footprints are assessed following the top-down approach. A significant innovation of this work is to emphasise the challenge of considering economic aspects. Concerning the spatial dimension, this study explores the different sectors at the national, river basin and provincial levels. Furthermore, it refines the methodology of earlier studies (Hoekstra and Hung 2002; Chapagain and Hoekstra 2004; Hoekstra and Chapagain 2008) including a number of modifications to adapt the general approach to the Spanish context. Results obtained by Rodríguez Casado et al. (2009) show that, using this detailed method, the Spanish agricultural footprint is 50% of the equivalent footprint estimated by Chapagain and Hoekstra (2004).

Finally, an open debate is necessary both on the concept of VW and WF and on the available data. This report hopes to make a down-to-earth contribution to this debate through up-to-date, detailed evaluations that enable a closer evaluation of the water footprint and virtual-water "trade". This study will also help explain the roots of regional water conflicts and the role of water markets, through a detailed geographical analysis of water productivity changes across provinces and throughout the study period.

Chapter 2
Literature Review

2.1 The Concept of Virtual Water

First introduced by Allan (1997, 1999), the concept of "virtual water" refers to the volume of water used to produce a commodity, good or service. This term can be defined from two distinct perspectives. From the production-site standpoint, the virtual-water content of a product is the volume of freshwater used to produce a product measured at the place where it is produced (Hoekstra and Chapagain 2008). From the consumption-site standpoint, it refers to the volume of water that would have been required to produce a product where it is consumed (Hoekstra and Chapagain 2008).

The present study uses the first definition. The adjective "virtual" refers to the fact that most of the water used to produce a product is not contained in it; the real-water content of products being generally negligible compared with the virtual-water content (Hoekstra and Chapagain 2008). The volume of virtual water to produce a crop mainly depends on climatic conditions, water management options and agricultural practices. While significant research is being done to find ways to increase harvests and reduce water applications (Fereres 2010), real and significant changes in water demand can occur, changing the land that receives irrigation water and the crops that are irrigated. In the EU, cropping patterns have been profoundly influenced by farm and trade policies (Varela-Ortega 2008), but now, due to more decoupled modes of farm income support, EU farmers are responding more to market signals. And most of these originate from global markets, offering broad opportunities to exploit the connections between food markets and farm trade and water policies.

As this book will explain, water shortages and scarcity result from endogenous processes linked to policies and consumption that promote water demand which in turn results in bigger water footprints. One of the contributions of this study is to think of virtual water not only as the physical amount of resource embedded in the consumed and traded goods, but also as an economic good with opportunity cost that varies over time and according to quality and location. Not all virtual water that is traded – for example, in wheat, oil, meat or automobiles – is equally valuable.

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2.2 The Colours of Water

The virtual-water content of a product consists of three components: green, blue and grey water. For the purpose of policy formulation, it is essential to distinguish the various water components since they have different characteristics (Hoekstra 2007).

First, the green virtual-water content of a product is the volume of rainwater that evaporated during the production process (Hoekstra and Chapagain 2008). This is particularly relevant for agricultural products, where it refers to the total rainwater stored in the soil as soil moisture and evaporated from the field during the growing period of the crop (including both evapotranspiration by the plants and evaporation from the soil).

Second, the blue virtual-water content of a product is the volume of surface or ground water that evaporated as a result of its production (Hoekstra and Chapagain 2008). In the case of crop production, the blue water content of a crop is defined as the sum of the evaporation of irrigation water from the soil and the evaporation of water supplied from irrigation canals and artificial storage reservoirs. In industrial production and domestic water supply, the blue water content of the product or service is equal to the part of the water withdrawn from ground or surface water that evaporates and thus does not return to the system it came from. Evaporated water is considered unavailable for other uses, even though it may come back as rainfall (usually hundreds of kilometres away). Many irrigated crops are also receiving some rainfall, so total water demand is often satisfied by a mix of natural and artificial sources. Furthermore, the amount of blue water demanded for irrigation varies because weather conditions vary significantly. A technical evaluation in Andalusia (with almost 900,000 ha of irrigated land) found that crop blue water evapotranspirative demand varies from 3.4 to 5 billion m^3, depending on weather conditions during the growing season (Aquavir 2006).

The distinction between green and blue water originates from Falkenmark (1995). Blue and green water resources fundamentally differ in their scope of application and thus opportunity cost (Chapagain et al. 2005). Green water cannot be automatically re-allocated to uses other than natural vegetation or alternative rainfed crops, whereas blue water can be used for irrigating crops and also for other urban, agricultural and industrial water uses (Fraiture et al. 2004; Hoekstra 2007). Furthermore, the use of green water in crop production is considered more sustainable than blue water (Yang et al. 2006), although that is not necessarily the case if blue water sources are exploited below their sustainable yield. In the semi-arid and sub-humid regions of the world, water is a key challenge in food production, due to the extreme variability of rainfall, long dry seasons and recurrent droughts, floods and dry spells. The key challenge is to reduce the water-related risks posed by high-rainfall variability rather than coping with an absolute lack of water (Comprehensive Assessment of Water Management in Agriculture 2007). There is generally enough rainfall to double and often even quadruple crop yields in rainfed farming systems, even in water-constrained regions (Comprehensive Assessment of Water Management in Agriculture 2007), but often it is available at the wrong time,