Water Supply and Water Footprint in the Urban Region of Madrid (Spain)

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Abstract

Spain, from a general perspective, conforms a primary urban network which highlights the urban region of Madrid, which has generated an extremely important economic and social space along with a demographic polarization in the center of the country. To this fact we have to add its diverse geographical features that create a complex reality in water supply. Where the analysis of water consumption becomes especially relevant, due to the importance of this resource for the social, economic and environmental development of the region. Over the last years, we have developed conceptual and methodological tools for this purpose, as the sustainability metabolic index known as water footprint. Specially in a context of global environmental change which shows projections with reduced water availability for southern Europe, such as those of the IPPC or the European Environment Agency. We must not forget that water has unique characteristics compared to other resources being human demand for water in direct competition with the water the environment needs to maintain its ecological functioning.

Keywords: urban region, water supply, water footprint, Madrid

1. Introduction

The role of water in our economy and environment is highly complex. On the one hand, it is one of the economic resources that society relies on. In this respect water, is similar to food, energy and materials. But water is also a key component in the production and management of these resources of food, energy and materials (EEA, 2012). In many locations in Europe, water used by agriculture, industry, public water supply and tourism put considerable stress on Europe's water resources, and demand often exceeds local availability — and this is likely to be further exacerbated by climate change impacts (EEA, 2010).

In southern Europe, climate change is projected to worsen conditions (high temperatures and drought) in a region already vulnerable to climate variability, and to reduce water availability, hydropower potential, summer tourism and, in general, crop productivity (IPPC, 2007). The problems related to water supply and consumption derived from its scarcity has an increasing visibility in European citizenship, as reflected in the surveys conducted by the European Commission.

According to the Eurobarometer report entitled "Attitudes of Europeans towards water - related issues", three fourths of Europeans believe that drought and excessive water consumption are major problems in their country. The highest percentages appear in Portugal (96%), Spain (95%), Italy (94%) and France (93%). Also there stands out the fact that six out of ten Europeans agree that water should be more expensive when its use has a greater environmental impact (European Commission, 2012).

Adaptation to the opportunities of globalization makes Madrid one of the fastest growing regions in Southern Europe. The spatial dynamics of globalization materialize in an urban form that overwhelms traditional Madrid metropolitan area (Navalpotro Sotelo, J.A. & Sotelo Pérez. M., 2013). Obviously all these facts will determine an impact on water resources in the urban region. Madrid is the largest urban agglomeration in the country, which takes the form of "region city", that is, a big city made up of a central urban agglomeration, - as a metropolitan area- and a dispersed city of difficult delimitation . Although the functional limit of this region city is a matter of debate and controversy, it may be agreed that for these purposes this limit is considered as the one of the Autonomous Community of Madrid.

Currently, the Autonomous Community of Madrid has one of the more complex urban water supply systems in Europe. The waters of the rivers of the region, coming down from the mountains, are stored in different reservoirs at the foot of the mountains and taken from there to the population centers through a great pipeline network. The supply system of the Canal de Isabel II consists of 14 reservoirs with a total storage capacity of nearly 1,000 hm^3 and a maximum reservoir area of 5,000 hectares. Thus, the water comes from the artificial regulation of river basins in Madrid´s mountain range, and even more distant locations, and groundwater collection performed in the tertiary basin.

This water is driven by a wide network of pipelines to drinking water treatment stations, and then to the regulation deposits and from there to users. Once the water is used, it is sent through the sewerage network to the sewage water regeneration stations and poured back again into the Manzanares and the Jarama river beds. Understanding the water cycle in the sustainable city is to understand the development of future society and understand that the quality of the natural environment is a reflection of our future quality of life. In this regard, the diagnosis of the water cycle in the city, refers to the origin of it in the city, its use and consumption by the population, and its subsequent return to the environment.

Nowadays water is available to the majority of the population in developed countries, but until recently reality was quite different. Water has become a good so accessible in today's society that we sometimes forget why it comes out through a tap, or where does it go once it escapes down the drain.Regarding water supply to Madrid, the Tajo Hydrographic Confederation, has been playing from the beginning a key role in the interaction of the people who inhabit the basin and the Tajo river waters , trying at all times to cover the main needs of people and ensuring adequate water quality conditions before and after human consumption . In this regard, we should remember the so-called Comprehensive Water Cycle or Comprehensive Water Exploitation Cycle, from which arise the notions of supply and sanitation, as its fundamental stages.

The Comprehensive Water Cycle for this purpose, covers several stages since the water is taken from its origin until its availability to people for its use and subsequently its return to the environment once it has been enjoyed, in the same condition as it was captured, avoiding negative interferences to the Hydrological Cycle. We should not confuse the concepts of Hydrological Cycle and Comprehensive Water Exploitation Cycle. While the first one refers to exclusively natural processes (rainfall, torrents and evaporation), the second is characterized by human participation in its development. This process involves two stages: water supply and sanitation. In the first stage we can sketch out the following steps: capturing, conduction, processing and distribution.

Table 1. Extra-municipal reservoirs for water supply in the Autonomous Community of Madrid

Designation	River	Capacity in hm^3
El Villar	Lozoya	22.4
Puentes Viejas	Lozoya	53.0
Riosequillo	Lozoya	50.0
El Vado	Jarama	55.7
Pinilla	Lozoya	38.1
Pedrezuela	Guadalix	40.9
Navalmedio	Navalmedio	0.7
La Jarosa	La Jarosa	7.2
Navacerrada	Samburiel	11.0
Manzanares	Manzanares	91.2
El Atazar	Lozoya	425.3
Valmayor	Aulencia	124.4
Los Morales	Los Morales	2.3
La Aceña	Aceña	23.7

Source: compiled from the data from Canal de Isabel II.

In general, conduction and distribution services are usually taken over by local councils but for historical reasons, in the case of Madrid, comprehensive management is entrusted to the Canal de Isabel II (CYII), entity depending on the Autonomous Community of Madrid. The municipality of Madrid has a well-developed infrastructure and distribution networks which in addition to offering a good service, rises supply guarantees and demand control. All these facilities ensure water supply to the distribution network of the municipality of Madrid.The Autonomous Community of Madrid has 100% of its population within the Tajo River basin, being this population, 82% of the entire population that need water supply within the basin.

This leads to a very uneven distribution of the population throughout the basin, causing a complication for the water supply. To this, adds the fact that the more populated areas are simultaneously bearing the lower values of total rainfall, therefore existing a strong imbalance between generated resources and demands.It is very important, along the water consumption derived from the population, the conservation status of supply networks. According to the White Paper of water in Spain, the loss percentage is around 30% (MIMAM, 2000). In this respect, considering that the urban region of Madrid is the largest in the country, it is necessary to act in reducing such losses as one of the primary objectives, but to do this we should act on the awareness and education of society as a whole. Is precisely in this sense, where the study of the water footprint in the urban region of Madrid plays a key role.

2. Conceptual and methodological approach to the calculation of the water footprint of the urban region of Madrid

The relation between water and environment, shown by the Water Framework Directive (2000/60), and the emergence of new concepts arising from this pairing, as the virtual water and the water footprint are helping to understand the relationships between our consumption habits and water resources at a local and also at a global level Virtual water is defined as the total volume of water required to produce a good or a service (Allan, 1998).

To measure the total volume of water used by the inhabitants of a certain region, 'the "water footprint" index was developed, a term proposed in 2002 by Arjen Hoekstra from the UNESCO Institute for Water Education and developed by Chapagain and Hoekstra (2004) who defined it as an indicator of water usage in relation to population consumption, usually expressed as volume of water used per year. A more complete definition of the "water footprint" index is the one that identifies it as "the total volume of water used to produce goods and services consumed by an individual, by a group of people or by a country, respectively" (Hoekstra, 2003; Chapagain and Hoekstra, 2004).

Chapagain and Orr (2009) consider that the water footprint is the expression of the content of virtual water, which lets us evaluate where the water originates (Navalpotro Sotelo, J.A. *et al*, 2012).This paper calculates the water footprint of the urban region of Madrid from the methodology developed by Chapagain and Hoekstra (2004) and updated in Hoekstra *et al*. (2009). Accordingly, as the population of a given geographical area is supplied by domestically produced and imported products, the water footprint consists of two components, domestic water and foreign water:

- Internal water footprint (IWFP): the water coming from national resources from a certain geographic area.

- External water footprint (EWFP): amount of water needed to develop products or services consumed in a certain geographic area, when they have been produced abroad.

The formula for its calculation is the following:

$WFP = IWFP + EWFP$

This method has been adapted to the available data for the urban region of Madrid the years 1996 and 2008. We have handled the data related to water in Spain, within the series of environmental surveys published annually by the National Institute of Statistics (INE). Water official surveys at a regional, provincial and municipal level take place in our country since 1996 (INE, 2008). Moreover, these data has been collated with that included in the Integrated Information System of Water in Spain, under the Ministry of Agriculture, Food and Environment.

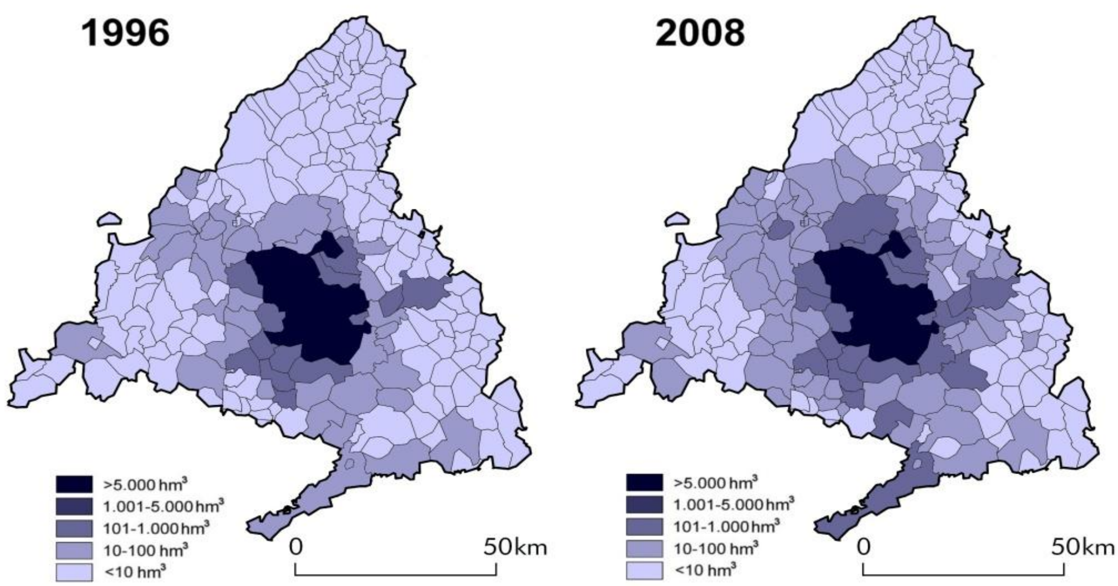
3. Analysis of the water footprint of the urban region of Madrid

The water footprint provides a global indicator of both direct and indirect freshwater use. The focus on freshwater is important because it is scarce; making up only 2.5% of the water on the planet, 70% of which is locked up in the ice and snow of mountainous regions, the Arctic and Antarctic (WWF, 2012). The average global water footprint between 1996 and 2005 was over 9,000 billion m^3 per year; with agricultural production accounting for 92% of this total. Although out-of-sight, rainwater stored in soil (green water footprint) was by far the largest water footprint component (74%), while blue water resources accounted for 11 % (Hoekstra and Mekonnen, 2012).

According to the results of the analysis, the water footprint of Madrid seems to organize into irregular belts, decreasing as we move away from the central city to its northern, southwestern and southeastern ends, with some exceptions such as the municipality of Aranjuez, which by the way we should say, has a billed consumption only slightly above the average of the Autonomous Community of Madrid. The belts, which are deformed according to the northwestern factor, this is towards the metropolitan west ring and Sierra Central (Map 1). Madrid, in general broadly fulfills the idea that cities don´t come out very well on the virtual water trade, as great debtors of other producing areas, of both real and virtual production water.

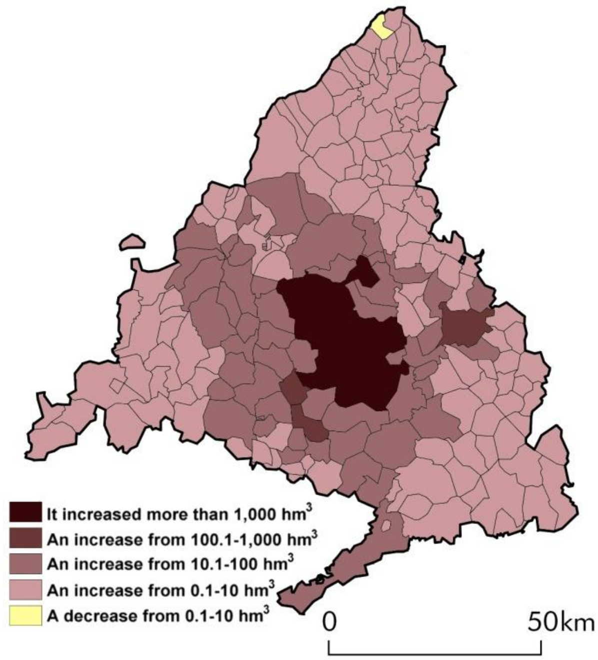
The territorial model corresponds to an urban region affected by important imbalances, among which are the hypertrophy of the capital and the excessive densification of the urbanized area as opposed to the existing emptiness due to speculative and financial reasons. The aforementioned spatial distribution of the water footprint of the municipalities that comprise the urban network, is the result of the characteristics of the physical environment and of a long process of historical evolution that involves social, economic and technological factors. Therefore, we can understand the progressive increase of the water footprint in practically all municipalities in the urban region of Madrid, especially in the more populated (Map 2).

Map1. Water footprint in the Autonomous Community of Madrid (1996-2008)



Source: own elaboration.

Map 2. Changes of the water footprint of the Autonomous Community of Madrid during period 1996-2008



Source: own elaboration.

4. Conclusions

One of the main factors determining the water footprint of the different regions are the consumption habits of its people both through direct water consumption, and virtual water consumption due to a strong demand for industrial products and a diet high in meat. It is still necessary to further into the "water footprint" studies to find the relationship between virtual water flows between regions, although much can be done at the level of awareness and water saving from direct consumption. Among the basic objectives the urban region of Madrid must consider, in order to control and reduce water consumption, we could highlight:

1. Further education in the field of environmental education. The main challenge is the continuity and proper diffusion in order to promote a behavior change towards more responsible consumption habits.
2. The stimulation of technology and of water saving construction.
3. The price of water, certainly affects final consumption. The current tariff system in Madrid is improvable in terms of incentivizing the saving point of view and one of the proposed strategies is the establishment of progressive tariffs which would penalize waste and reward savings.
4. The rationalization of irrigation in public and private spaces, including the planting of native plant species and implementing low consumption irrigation. Just as the reuse of treated water.

References

Allan, J. A., 1998. “Virtual Water: A Strategic Resource Global Solutions to Regional Deficits”. *Ground Water*, 36/4, pp. 545-546.

Chapagain, A. K. y Hoekstra, A. Y., 2004. “Water footprints of nations”. *Value of Water Research Report Series*, 16, Netherlands, UNESCO-IHE, Delft. Retrieved on: 12.03.2013. from http://www.unesco-ihe.org/Value-of-Water-Research-Report-Series/Research-Papers/(offset)/10

Chapagain, A. K. y Orr, S., 2009. “An improved water footprint methodology linking global consumption to local water resources: A case of Spanish tomatoes”. *Journal of Environmental Management*, 90, pp. 1.219-1.228.

Directiva 2000/60/CE del Parlamento Europeo y del Consejo de 23 de octubre de 2000 por la que se establece un marco comunitario de actuación en el ámbito de la política de aguas. *Diario Oficial de las Comunidades Europeas*, L 327/1, 22/12/2000.

EEA, 2010. *The European environment — state and outlook 2010: synthesis*. European Environment Agency, Copenhagen.

EEA, 2012 European waters — current status and future challenges*: synthesis*. European Environment Agency, Copenhagen.

European Commission, 2012. Attitudes of Europeans towards water – related issues, Flash Eurobarometer 344, Retrieved on: 19.05.2013. from http://ec.europa.eu/public_opinion/flash/fl_344_en.pdf

Hoekstra, A. Y. (ed.) 2003. “Virtual water trade: Proceedings of the International Expert Meeting on Virtual Water Trade”. *Value of Water Research Report Series*, 12. Netherlands, UNESCO-IHE, Delft. Retrieved on: 17.04.2013. from http://www.waterfootprint.org/Reports/Report12.pdf

Hoekstra, A.; Aldaya, M.; Mekonnen, M. y Chapagain, A. K., 2009. *Water footprints manual. State of the Art 2009*. Enschede, Netherlands, Network.

Hoekstra, A.Y. and Mekonnen, M.M. 2012. The Water Footprint of humanity. PNAS, published ahead of print February 13, 2012, doi:10.1073/pnas.1109936109.

INE, 2003. “Encuesta sobre el suministro y tratamiento del agua. Año 2001”. Madrid, Instituto Nacional de Estadística, Gabinete de prensa, 1 de julio del 2003.

INE, 2008. “Estadísticas e indicadores del agua. La información estadística, instrumento necesario para una mejor gestión del agua”. *Cifras INE. Boletín Informativo del Instituto Nacional de Estadística*, 1/2008, 12 p.

IPCC, 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

MIMAM, 2000. Libro blanco del agua en España. Centro de Publicaciones Secretaría general Técnica Ministerio de Medio Ambiente Madrid, 2000.

Sotelo Navalpotro, J. A., & Sotelo Pérez, M., 2013. Desarrollo y Medio Ambiente en Madrid. Hacia un nuevo modelo de desarrollo urbano. *M+A. Revista Electrónica de Medioambiente*, *14*(1), 22-55.

Sotelo Navalpotro, J. A., Olcina Cantos, J., García Quiroga, F., & Sotelo Pérez, M., 2012. Huella hídrica de España y su diversidad territorial. *Estudios Geográficos*, *73*(272), 239-272.

WWF, 2012. *The Living Planet Report*. WWF Internacional. Gland, Suiza.