The water footprint of Milan
D. Vanham and G. Bidoglio

ABSTRACT

This study quantifies the water footprint of consumption (WF<sub>cons</sub>) and production (WF<sub>prod</sub>) of Milan. The current WF<sub>cons</sub> amounts to 6,139 l/cap/d (a volume of 2.93 km<sup>3</sup> annually), of which 52 l/cap/d (1%) is attributed to domestic water, 448 l/cap/d (7%) to the consumption of industrial products and 5,639 l/cap/d (92%) to the consumption of agricultural products. The WF<sub>prod</sub> is 52 l/cap/d. Milan is thus a net virtual water importer, predominately through the import of agricultural products. These are produced outside city borders, both in Italy and abroad. This shows the dependency of city dwellers on water resources from other river basins. In addition, the WF<sub>cons</sub> for a healthy diet (based on Mediterranean Food-Based Dietary Guidelines) and a vegetarian diet are analysed. The current Milanese diet consists of too much sugar, crop oils, meat, animal fats, milk and milk products and not enough cereals, rice, potatoes, vegetables and fruit. The latter two diets result in substantial WF<sub>cons</sub> reductions: –29% (to 4,339 l/cap/d) for a healthy diet and –41% (to 3,631 l/cap/d) for a vegetarian diet. Indeed, a lot of water could be saved by Milan citizens through a change in their diet. A sustainable city should account for its impacts beyond its borders.

Key words | city, Italy, Milan, urban, water footprint, water use

INTRODUCTION

The water footprint (WF) concept has been brought into water management science in order to show the importance of consumption patterns and global dimensions in good water governance (Galli <i>et al.</i> 2012; Hoekstra & Mekonnen 2012; Vanham & Bidoglio 2013). It is important to distinguish between the WF of production (WF<sub>prod</sub>) and the WF of consumption (WF<sub>cons</sub>). The first is the sum of direct and indirect use of domestic water resources. The second is the sum of direct and indirect use of domestic and foreign water resources through domestic consumption (Hoekstra <i>et al.</i> 2011; Hoekstra & Mekonnen 2012). A balance between the two is reached by virtual water (VW) flows (import or VW<sub>i</sub> and export or VW<sub>e</sub>) (Hoekstra <i>et al.</i> 2011; Vanham & Bidoglio 2013). An overview of the Italian national WF accounting scheme is displayed in Figure 1. It shows that 61% of the WF<sub>cons</sub> is external. As the VW<sub>i</sub> is larger than the VW<sub>e</sub>, Italy is a net VW importer. When expressed per capita, Italian consumers have one of the largest WFs in the world (Aldaya & Hoekstra 2010; Vanham & Bidoglio 2013).

The analysis of WFs of cities has not been the focus of much research to date. However, in an urbanizing world, it is important to show the dependency of city dwellers on resources (like land and water) outside city borders. As a case study, the WF of the city of Milan is taken. Milan is the economic capital of Italy, and it is located in the Po basin. This basin is characterised by the highest density of urban, industrial and agricultural activities in Italy (Bocchiola <i>et al.</i> 2013; Vanham 2013), and it is highly dependent on mountain water from the Alps (Vanham 2012). In this paper, the current WF (reference situation) of Milan is analysed, as well as the WF for two other diets (a healthy diet and a vegetarian diet). The total WF consists of a domestic WF, a WF related to industrial products and a WF related to agricultural products.

METHODS/MATERIALS

To assess WF values, the approach of (Hoekstra <i>et al.</i> 2011) is applied. WFs consist of a blue, green and grey component. Following the definition of Rockström <i>et al.</i> (2009), green water is the soil water held in the unsaturated zone, formed by precipitation and available to plants. Blue water refers to liquid water in rivers, lakes, wetlands and aquifers. Irrigated agriculture receives blue water (from irrigation) as...
well as green water (from precipitation), while rainfed agriculture receives only green water. The green WF is thus the rainwater consumed by crops. The grey WF is the volume of water needed to dilute a certain amount of pollution such that it meets ambient water quality standards (Hoekstra et al. 2011); it is an indicator of the degree of water pollution. National WF\textsubscript{prod}, WF\textsubscript{cons} and VW flows (import and export) values for Italy were obtained from (Mekonnen & Hoekstra 2011), for which the reference period is 1996–2005. This reference period is therefore also chosen in this paper.

To quantify the domestic WF (for which WF\textsubscript{cons} = WF\textsubscript{prod}) of Milan, data on population, water use (water withdrawal) and wastewater treatment were assembled from ISTAT (Italian National Institute of Statistics) and the Municipality of Milan (Municipality of Milan). During the last decade, the population in the municipality increased by about 9% to its current 1.37 million (Figure 2), mostly due to immigration. The Milan public water supply is served 100% by groundwater. The water treatment service became fully operational in 2005 (three treatment plants) and can serve a total of up to 2,550,000 population equivalent (Metropolitana Milanese). Currently, 100% of the population is connected to wastewater treatment plants (Figure 2). The domestic WF is actually quantified based upon municipal water use (or public water use) and not domestic water use. Municipal water use includes domestic water use (on average 234 l/cap/d for 2000–2010, Figure 2) and commercial water use (or water for services). The latter includes water supply to small businesses, hotels, offices, hospitals, schools. Public water use also represents water for non-permanent residents (like commuters or tourists). Municipal water use averages 529 l/cap/d for 2000–2007 (Figure 2).

The blue WF (blue water consumption) is calculated based upon the municipal water use (or withdrawal) in 2005 (518 l/cap/d). The major sources of actual consumption consist of water lost through evapotranspiration from

Figure 1 | The Italian national accounting scheme for the total WF (in l/cap/d or lcd and km\(^2\)), average annual values for the period 1996–2005. Data source: Mekonnen & Hoekstra (2011).

Figure 2 | For the city of Milan: (left) water use (water withdrawal) data from 2000–2011; (right) population connected to wastewater treatment (primary vertical axis) and population data (secondary vertical axis). Data sources: Italian National Institute of Statistics (2013); Municipality of Milan (2013).
leaking supply and sewerage pipes, from watering plants and recreational areas, washing streets, and garden plots. The extent of the evapotranspiration also depends on climatic conditions. In a modern Mediterranean city like Milan, it is acceptable to estimate the blue water consumption at 10% of water withdrawal. This accounts for low leakage but higher than average (European) evapotranspiration. The grey WF is quantified to be zero, as all grey water (discharge water, the difference between withdrawal and consumption) has been treated in treatment plants since 2005. Wastewater treatment can bring the grey WF down to zero when the concentration of pollutants in the effluent is equal to or lower than the concentrations in the water as it was abstracted.

The WFprod for industrial products for Milan city is assumed to be zero. This is a simplification, as some industrial production also takes place within city borders. However, in modern European cities like Milan, industrial activities have generally moved outside city borders. The national WFprod for industrial products amounts to 267 l/cap/d (blue WFprod 39 l/cap/d, grey WFprod 228 l/cap/d) (Mekonnen & Hoekstra 2011). To calculate the WFcons for industrial products for Milan, the national value is taken. The latter is 448 l/cap/d (blue WFprod 49 l/cap/d, grey WFprod 399 l/cap/d), of which 35% is internal and 65% external to Italy. Data on household expenditure (Italian National Institute of Statistics 2013; Municipality of Milan 2013) show higher amounts for certain product groups (e.g. clothing and footwear, furnishings, household equipment) in Milan as compared to national values. However, consumer price indices are often also higher. As detailed data on industrial product consumption values quantifying differences between Milan and national per capita amounts do not exist, average national WFcons are chosen for Milan.

Like the WFprod for industrial products, the WFprod for agricultural products for Milan city is assumed to be zero. Agricultural production within city borders as compared to national values is negligible. To assess the WFcons for agricultural products for Milan, the national average value is taken. This WFcons value is calculated based upon FAOSTAT Food Balance Sheet (FBS) data (Food & Agriculture Organization 2013). Such extensive data are not available on a regional level (Hoff et al. 2013; Italian National Institute of Statistics 2013). The Italian WFcons for agricultural products is 5,639 l/cap/d, of which 37% is internal and 63% external to Italy.

To assess the effect of different diets on the WFcons for agricultural products, the approach by (Vanham 2013b; Vanham et al. 2013a, b) is followed. As Food-Based Dietary Guidelines for a healthy diet (HEALTHY), the recommendations for a Mediterranean diet were chosen (Bach-Faig et al. 2011). Table 1 shows the

<table>
<thead>
<tr>
<th>Product group</th>
<th>Quantity chosen (g/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals, rice, potatoes</td>
<td>4–6 servings daily (400 g/d chosen)</td>
</tr>
<tr>
<td>Sugar</td>
<td>Max. 60 g/d (most countries with a recommendation on sugar intake suggest that less than 10% of daily energy intake comes from sugar)</td>
</tr>
<tr>
<td>Pulses, nuts and oilcrops</td>
<td>Olives and nuts 1–2 servings daily; legumes ≥2 servings weekly as alternative for meat; total 45 g/d chosen</td>
</tr>
<tr>
<td>Fruit</td>
<td>3–6 servings daily (300 g/d chosen)</td>
</tr>
<tr>
<td>Vegetables</td>
<td>6 servings daily (400 g/d chosen)</td>
</tr>
<tr>
<td>Crop oils</td>
<td>Main source of dietary fat is olive oil, which replaces solid fats (butter and margarine); 3–5 servings daily (40 g/d chosen for eating and cooking)</td>
</tr>
<tr>
<td>Animal fats</td>
<td>Restrict intake; substituted by olive oil; 0 g/d chosen</td>
</tr>
<tr>
<td>Meat</td>
<td>200 g meat and 200 g fish (substituted by meat) per week</td>
</tr>
<tr>
<td>Milk and milk products</td>
<td>2 servings daily = 150 g/d milk/yoghurt and 40 g/d cheese (320 g milk eq.) = total 470 g/d</td>
</tr>
<tr>
<td>Eggs</td>
<td>2–4 eggs per week (1 egg 60 g) (3 eggs chosen)</td>
</tr>
<tr>
<td>Stimulants</td>
<td>No specific recommendations, current intake values chosen</td>
</tr>
<tr>
<td>Alcohol</td>
<td>Thresholds 20 g/d for men and 10 g/d for women (minimum age 16)</td>
</tr>
</tbody>
</table>
intake amounts chosen. Data on reference period food consumption were taken from FAO FBS. For the vegetarian diet (VEG), the healthy diet is used, with all meat substituted by additional pulses and oilcrops (with the same kcal and protein content).

RESULTS AND DISCUSSION

Figure 3 shows the calculated $WF_{prod}$ and $WF_{cons}$ components for Milan. The $WF$ of domestic water use equals 52 l/cap/d. The total $WF_{cons}$ of Milan is 6,139 l/cap/d.
(5,639 l/cap/d for agricultural products, 448 l/cap/d for industrial products, 52 l/cap/d domestic water). Green water contributes by far the most to the total WF\textsubscript{cons}. As the WF\textsubscript{prod} for agricultural and industrial products is zero, the total net VW\textsubscript{i} to Milan equals the sum of the WF\textsubscript{cons} for agricultural and industrial products, i.e. 6,087 l/cap/d.

As shown in Figure 1, this VW\textsubscript{i} originates partly from within Italy and partly from abroad. Agricultural products account for 90% of total VW\textsubscript{i}, with main foreign flows originating from France, Germany, Brazil and Indonesia (Aldaya & Hoekstra 2010; Mekonnen & Hoekstra 2011; Food & Agriculture Organization 2013; Tamea et al. 2013). In particular, animal products and certain crops and crop products are responsible for high values. These are (with main import countries): meat, milk, sugar and cereals from France and Germany; soybeans and soybean cake from Brazil and Argentina, palm oil from Indonesia, coffee from Brazil and cotton from Turkey, Uzbekistan and Greece. Main export countries attributing to high VW\textsubscript{e} values for Italy include France, Germany, the UK and the USA, especially for crops and crop products like pasta, fruit, tomatoes, roasted coffee, wine and olive oil. Mineral water (Niccolucci et al. 2011) is not included in these assessments, although Italy is the biggest exporter worldwide, predominately to France (Food & Agriculture Organization 2013).

Figure 4 shows that the citizens of Milan should reduce their intake of some product groups (sugar, crop oils, meat, animal fats, milk and milk products) and increase the

**Figure 6** | The WF\textsubscript{cons} of Milan for agricultural products for the three diets, for (left) the green and blue WF and (right) the blue WF.
intake of others (cereals, rice, potatoes, vegetables and fruit). In particular, the intake of meat should be substantially reduced. Current meat intake in many Mediterranean countries is amongst the highest in the EU (Westhoek et al. 2011; Food & Agriculture Organization 2013; Vanham & Bidoglio 2013).

The effect of different diets on the WFcons for agricultural products is shown in Figure 5. The reduced intake of meat has an especially strong effect on WFcons reductions. For HEALTHY a reduction of 32% is observed, for VEG a reduction of 44%. For the edible products only (without the group non edible agricultural products), the reductions are even higher (≈37% for HEALTHY, ≈52% for VEG). For the edible products the WFcons of VEG is thus less than half the REF WFcons.

Figure 6 displays the green and blue (without grey) as well as the blue WFcons for agricultural products for the different diets. For the green and blue WFcons, the reductions (in %) are almost identical to the total WFcons (Figure 5). For the blue WF the reductions (in %) are slightly less. Some authors choose not to include the grey WF, due to the strong uncertainties inherent in its determination and therefore there is a need for further standardization (Thaler et al. 2012; Tamea et al. 2013; Vanham & Bidoglio 2013). However, within water management science the inclusion of green water is now generally accepted and recommended (Falkenmark & Rockström 2006; Vanham 2012b).

The total WFcons of Milan (WF of domestic water, industrial and agricultural goods consumption) for the three diets is displayed in Figure 7. Depending on the WFcons components included (green, blue, grey) reductions range from 22 to 31% (HEALTHY) and 30 to 43% (VEG). A shift to a healthy or vegetarian diet by Milan citizens would indeed save a lot of water.

CONCLUSION

This paper quantifies the WF of Milan. It shows the dependency of city dwellers on water resources outside city borders and the potential to derive a more sustainable city life through different diets.

The total WFcons (green + blue + grey WFcons) of Milan adds up to 6,139 l/cap/d, of which 52 l/cap/d (1%) is attributed to domestic water, 448 l/cap/d (7%) to the consumption of industrial products and 5,639 l/cap/d (92%) to the consumption of agricultural products. In other words, if the citizens of Milan want to reduce their WF the largest contribution can be made through adaptations in their diet. These agricultural products are produced both in Italy (outside city borders) and abroad, resulting in virtual water import (VW) and potentially contributing to water stress in these production regions. VW from abroad involves animal products like meat and milk as well as certain crops and crop products (sugar, cereals, soybeans and soybean cake, palm oil, and cotton).

The current diet of the citizens of Milan consists of too much sugar, crop oils, meat, animal fats, milk and milk products and not enough cereals, rice, potatoes, vegetables and fruit, in line with Mediterranean healthy diet recommendations. With
respect to a healthy diet, a WF_{cons} reduction of 29% (to 4,339 l/cap/d) is observed as compared to the current situation. This reduction equals for the total population of Milan (1,308,735 in 2005) a daily volume of 2.36 million m³. The original WF_{cons} of 6,139 l/cap/d equals for the total Milan population on a yearly basis 2,933 million m³. For the healthy diet the WF_{cons} of 4,339 l/cap/d equals a yearly volume of 2,072.75 million m³. For a vegetarian diet the reduction is 41% (to 2,933 million m³). For the healthy diet the reduction equals for the total population of Milan (1,308,735 cap/d) is observed as compared to the current situation. This scenario on crop yield and water footprint of maize in the Po valley of Italy.

References

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