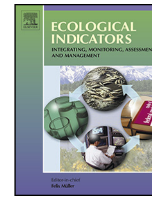
Ecological Indicators 74 (2017) 119–129

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind



Original Articles

Food consumption and related water resources in Nordic cities

D. Vanham*, B.M. Gawlik, G. Bidoglio

European Commission, Joint Research Centre, Directorate for Sustainable Resources, Via E. Fermi 2749, 21027 Ispra, VA, Italy

A R T I C L E I N F O

Article history:
Received 11 May 2016
Received in revised form 10 October 2016
Accepted 14 November 2016

Keywords:
Water
Footprint
City
Urban
IWRM
Management
Water footprint
Nordic
Scandinavian
Food consumption
Diet
Nutrition
Food
Food security
Water security
Virtual water

A B S T R A C T

Many modern cities have strongly invested in the sustainability of their urban water management system. Nordic cities like Stockholm or Copenhagen are amongst pioneers in investments towards integrated urban water management. However, cities can never be fully self-sufficient due to their dependency on external (water) resources. In this paper, we quantify this water dependency with respect to food consumption in nine cities located in the five Nordic countries (Sweden, Denmark, Finland, Norway and Iceland), by means of the water footprint concept. Detailed urban water footprint assessments are scarce in the literature. By analysing national nutrition surveys, we find that urban food intake behaviour differs from national food intake behaviour. In large Nordic cities people eat generally less potatoes, milk products (without cheese), meat and animal fats and they drink less coffee than outside city borders. On the other hand, they generally eat more vegetables and vegetable oils and they drink more tea and alcoholic beverages. This leads consistently – for the six large Nordic cities Stockholm, Malmö, Copenhagen, Helsinki, Oslo and Reykjavik – to slightly smaller food related urban water footprints (−2 to −6%) than national average values. We also analyse the water footprint for different diets based upon Nordic Nutrition Recommendations (NNR) for these cities. We assessed three healthy diet scenarios: 1) including meat (HEALTHY-MEAT), 2) pesco-vegetarian (HEALTHY-PESCO-VEG) and 3) vegetarian (HEALTHY-VEG). This shows that Nordic urban dwellers 1) eat too many animal products (red meat, milk and milk products) and sugar and drink too much alcohol and 2) they eat not enough vegetables, fruit and products from the group pulses, nuts and oilcrops. Their overall energy and protein intake is too high. A shift to a healthy diet with recommended energy and protein intake reduces the urban WF related to food consumption substantially. A shift to HEALTHY-MEAT results in a reduction of −9 to −24%, for HEALTHY-PESCO-VEG the reduction is −29 to −37%, for HEALTHY-VEG the reduction is −36 to −44%. In other words, Nordic urban dwellers can save a lot of water by shifting to a healthy diet.

1. Introduction

Cities can never be fully self-sufficient to provide its population with water, food and energy security (Elmqvist, 2014). In a steadily urbanising world (UN, 2014), characterised by rapid population growth, cities are however key to sustainability (Rees and Wackernagel, 2008). To what extent urban citizens consume resources is essential for sustainable global development. One of these resources is water, which urban dwellers consume in a direct (through water from the tap) but also indirect way (through e.g. food consumption). The latter refers to the water required to produce the goods urban citizens consume, quantified by means of the water footprint concept (Hoekstra and Mekonnen, 2012).

In the past, many cities have made efforts to improve urban water management and to move to integrated urban water management, a holistic mode of strategic planning (Bahri, 2012). They have reduced direct urban water use, e.g. by means of general rehabilitation of aging water infrastructure (Scholten et al., 2014), pipe leakage reductions (Lahnsteiner and Lempert, 2007; Vanham et al., 2016b), citizen awareness campaigns on domestic water use (March et al., 2015) or the installation of individual water meters. Cities have invested in decentralised water infrastructure systems (Marlow et al., 2013; Rauch and Morgenroth, 2013) or water treatment plants treating 100% of wastewater (Van Leeuwen and Sjerps, 2015). Many northern European cities, including Stockholm or Copenhagen, therefore have high scores regarding direct urban water management in rankings like the Green City Index (Economist Intelligence Unit, Siemens, 2012). However, indirect water use is generally not included in such rankings. Especially with respect to the water-food-energy-ecosystems nexus (Vanham,

* Corresponding author.
E-mail addresses: davy.vanham@jrc.ec.europa.eu, davy.vanham@yahoo.de (D. Vanham).

http://dx.doi.org/10.1016/j.ecolind.2016.11.019

Table 1
Nine Nordic cities assessed in this study.

Country	City	Population			Comment
		Total	% women	% men	
Sweden	Stockholm	912,401	49.3	50.7	year 2014, source (Statistics Sweden, 2016). Statistics Sweden classifies Swedish cities in H-regions according to population density (Statistics Sweden, 2015). Stockholm is H1; Malmö belongs to H2 (Storstäder – big cities); Eslöv, Helsingborg and Kristianstad belong to H3 (Större städer – Larger cities, municipalities with more than 90,000 inhabitants within a 30 kilometre radius from the municipality centre). The national nutrition survey 2010-2011 (Amcoff et al., 2012) also uses this classification.
Sweden	Malmö	317,375	49.2	50.8	
Sweden	Eslöv	32,210	50.4	49.6	
Sweden	Helsingborg	134,978	49.2	50.8	
Sweden	Kristianstad	81,686	49.6	50.4	
Denmark	Copenhagen	683,376	49.1	50.9	Københavns Municipality and Frederiksberg, year 2015, source (Statistics Denmark, 2016)
Finland	Helsinki	620,715	47.2	52.8	year 2015, source (Statistics Finland, 2016)
Norway	Oslo	647,676	49.9	50.1	year 2015, source (Statistics Norway, 2016)
Iceland	Reykjavik	121,822	49.6	50.4	year 2015, source (Statistics Iceland, 2016)

2016), the consideration of this indirect water resource use is very important.

Water footprint assessments on the city level have not been the focus of research in the past (Engel et al., 2011; Paterson et al., 2015). During recent years, several studies have however been conducted, e.g. Drechsel et al. (2014), Hoff et al. (2014), Jenerette et al. (2006), Ma et al. (2015), Vanham and Bidoglio (2014), Vanham et al. (2016a, 2016b). One of these studies quantifies the WF of Milan for different diets. More recently, an assessment of the WF related to food consumption for different diets was conducted for selected Dutch cities (Vanham et al., 2016b). Also for other footprints, research has started on the city level. Jan et al. (2013) e.g., assessed the carbon footprint (CF) of UK cities. Chavez and Ramaswami (2013) quantified the CF of selected US cities. Also some studies on the ecological footprint (EF) of cities were carried out, like the EF of the San Francisco area (Moore, 2011). Other studies include the ecological footprints of Vancouver (Moore et al., 2013) and Cardiff (Collins et al., 2006).

In the framework of the forthcoming Pan-European Atlas of Urban Water Management of the European Commission, the Joint Research Centre analyses the water footprint (WF) related to food consumption in selected, mostly European, cities. In this paper, we analyse the WF of the 9 Nordic cities which will be displayed in the atlas (Fig. S1 and Table 1), i.e. 5 Swedish cities as well as the capitals of the 4 remaining Nordic countries (Denmark, Finland, Iceland and Norway).

We quantify the WF of these cities for different diet scenarios, more particularly:

- The reference period or REF (1996–2005) as annual average over a decade
- A healthy meat diet (HEALTHY-MEAT) based on the new Nordic Nutrition Recommendations (NNR) of 2012 (Nordic Council of Ministers, 2012). All five Nordic countries base their national food-based dietary guidelines (FBDG) on these recommendations
- A healthy pesco-vegetarian diet (HEALTHY-PESCO-VEG) based on the NNR of 2012 (Nordic Council of Ministers, 2012)
- A healthy vegetarian diet (HEALTHY-VEG) based on the NNR of 2012 (Nordic Council of Ministers, 2012)

Table 2
Food waste fraction (corr2) for the different food product groups. These values are Danish national values. When particular product group values for Denmark were not available, average EU values are used. These values apply to all cities.

	Food waste fraction (corr2)
Cereals	13
Potatoes	19
Sugar	7.5
Crop oils	5
Vegetables	19
Fruit	16
Pulses, nuts and oilcrops	5
Meat	7
Offals edible	7
Animal fats	7
Fish and seafood	7
Milk and milk products	10
Eggs	7
Stimulants	7.5
Spices	7.5
Alcoholic Beverages	5

2. Methodology

2.1. Accounting framework

To quantify WF amounts, the approach of Hoekstra et al. (2011) and Hoekstra and Mekonnen (2012) is applied. The WF is an indicator of freshwater use that looks at both direct and indirect water use of a consumer or producer. We use the blue and green WF components. Blue water refers to liquid water in rivers, lakes, wetlands and aquifers. Green water is the soil water held in the unsaturated zone, formed by precipitation and available to plants (Rockström et al., 2009). Irrigated agriculture receives blue water (from irrigation) as well as green water (from precipitation), while rainfed agriculture receives only green water. We do not use the grey WF, as its quantification is very dependent on data availability (Thaler et al., 2012; Vanham and Bidoglio, 2013). The inclusion of green water is a necessity in integrated water resources management (IWRM), as argued by most authors and institutions working on IWRM (Gerten et al., 2013; Hoekstra, 2016; Hoff et al., 2014; Jalava et al., 2016, 2014; Karimi et al., 2013; Miina et al., 2016; Ran et al., 2016; Rockström et al., 2014; Schyns et al., 2015; Vanham, 2012).

To compute the water footprint of food consumption, we use national FAO Food Balance Sheets (FBS) for the five Nordic countries for the reference period 1996–2005. We obtain WF of consumption (WF_{cons}) amounts from Mekonnen and Hoekstra (2011a, 2011b). We also include a WF for fish and seafood, based upon Pahlow et al. (2015), which is quite new in WF literature. We use the terminology WF in this study as being the WF of consumption (WF_{cons}). Important is the distinction with the WF of production (WF_{prod}). The