Science of the Total Environment 565 (2016) 232–239

Contents lists available at ScienceDirect

Science of the Total Environment

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

Urban food consumption and associated water resources: The example of Dutch cities

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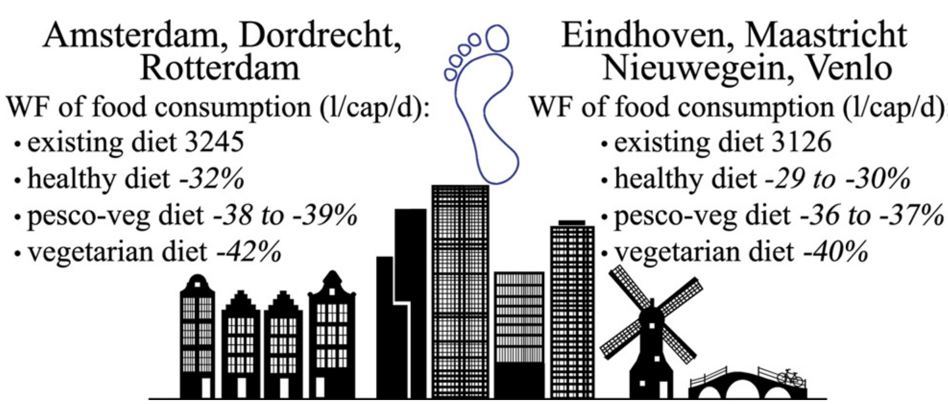
HIGHLIGHTS

- Dutch cities score high on water management in international city rankings.
- They are however dependent on external water resources for the food they consume.
- Inhabitants of large Dutch cities have slightly different dietary patterns.
- Dutch urban citizens eat too many animal products, crop oils and sugar.
- They can save a lot of water by shifting to a healthier or (pesco)-vegetarian diet.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 3 March 2016
Received in revised form 20 April 2016
Accepted 24 April 2016
Available online 9 May 2016

Editor: Simon Pollard

Keywords:
Urban
City
Water
Food consumption
Diet
Footprint

ABSTRACT

Full self-sufficiency in cities is a major concern. Cities import resources for food, water and energy security. They are however key to global sustainability, as they concentrate a rapidly increasing and urbanising population (or number of consumers). In this paper, we analysed the dependency of urban inhabitants on the resource water for food consumption, by means of Dutch cities. We found that in extremely urbanised municipalities like Amsterdam and Rotterdam, people eat more meat and cereals and less potatoes than in other Dutch municipalities. Their current water footprint (WF) related to food consumption is therefore higher (3245 l/cap/day) than in strongly urbanised cities (3126 l/cap/day). Dutch urban citizens who eat too many animal products, crop oils and sugar can reduce their WF (with 29 to 32%) by shifting to a healthier diet. Recommended less meat consumption has the largest impact on the total WF reduction. A shift to a pesco-vegetarian or vegetarian diet would require even less water resources, where the WF can be reduced by 36 to 39% and 40 to 42% respectively. Dutch cities such as Amsterdam have always scored very high in international sustainability rankings for cities, partly due to a long history in integrated (urban) water management in the Netherlands. We argue that such existing rankings only show a certain – undoubtedly very important – part of urban environmental sustainability. To communicate the full picture to citizens, stakeholders and policy makers, indicators on external resource usage need to be employed. The fact that external resource dependency can be altered through changing dietary behaviour should be communicated.

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http://dx.doi.org/10.1016/j.scitotenv.2016.04.172

1. Introduction

According to the UN (2014), by 2050 nearly 70% of the global population will live in cities, up from around 50% today. The figure for Europe is even higher: some 78% of the population – about 580 million – are expected to live in cities by 2050, up from 69% today. The UN has identified sustainable cities and communities as one of its Sustainable Development Goals (SDGs). To provide water, food and energy security within a nexus context (Vanham, 2016) to cities is a major challenge in a world with rapid population growth, changing economic development, limited planetary boundaries and climate change. Sustainable urbanisation is therefore a key to successful global development.

Until now environmental sustainability of cities has been measured and communicated to the public with rankings such as the Green City Index (Economist Intelligence Unit and Siemens, 2012) or the City Blueprint (Koop and Van Leeuwen, 2015), where western and northern European cities including Amsterdam, Copenhagen or Stockholm tend to receive high scores. However, such indices are generally only based on – though very important - direct urban best practices such as waste collection, energy efficiency of city buildings or efficiency in water management. They generally neglect the dependency of cities on resources outside city borders. Already in 1996, Rees and Wackernagel (2008) wrote: "Why Cities Cannot Be Sustainable – And Why They are A Key to Sustainability". More recently, Elmqvist (2014) wrote: "Urban sustainability has until now rarely been applied beyond city boundaries. Cities can however never become fully self-sufficient."

In this study, we addressed food and water security in seven selected cities in the Netherlands, a country world famous for water management engineering and science. Due to the availability of food consumption data differentiated according to urbanisation level (National Institute for Public Health and the Environment, 2016; Van Rossum et al., 2011), we were able to analyse whether food consumption behaviour in Dutch cities differs from other regions. We also analysed whether these urban diets are healthy or not through a range of diet scenarios. We quantified direct urban water use as well as the water resources required to produce the food consumed (for different diet scenarios) by means of the water footprint concept. As such, our aim was to demonstrate the dependency of cities on resources outside city borders and the possibility to reduce this dependency by changing food consumption behaviour.

2. Methods

2.1. Cities

We have chosen seven cities, as displayed in Fig. 1. Statistics Netherlands (2016) distinguishes for Dutch municipalities five degrees of urbanisation, based on the surrounding address density per km^2 (SI

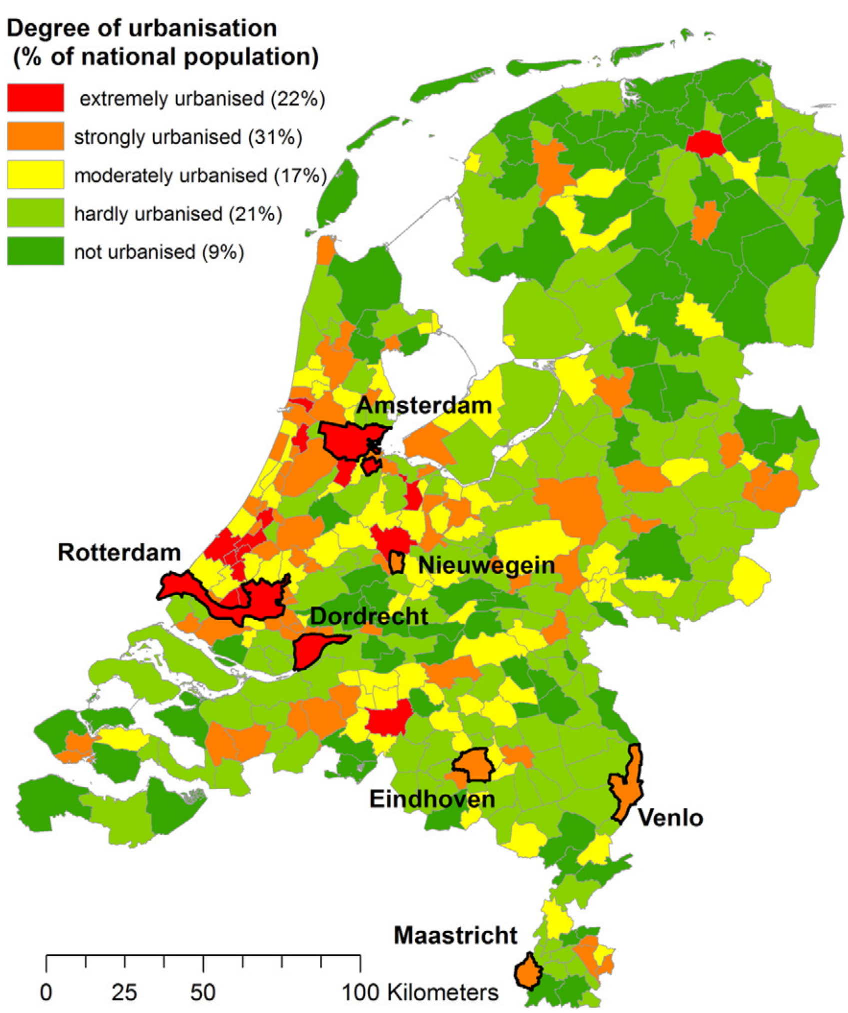

Fig. 1. Map of the degree of urbanisation of Dutch municipalities in 2015 according to data from Statistics Netherlands. Also the percentage of the national population that lives in each of the five classes is computed.

Table S1). Extremely urbanised municipalities are municipalities with 2500 addresses or more per km^2. Strongly urbanised municipalities are municipalities with 1500 to 2000 addresses per km^2. Within the group "extremely urbanised municipalities", Amsterdam, Dordrecht and Rotterdam were selected. Within the group "strongly urbanised municipalities", Eindhoven, Maastricht, Nieuwegein and Venlo were selected.

2.2. Urban food consumption

To compute urban food consumption differentiated in food product groups, we used two datasets:

- FAO Food Balance Sheet (FBS) food supply values (reference period or REF 1996–2005) as provided by FAOSTAT (Food and Agriculture Organization, 2016). These data are average national data for the whole country
- Data from the latest Dutch National Food Consumption Survey (DNFCS) (National Institute for Public Health and the Environment, 2016; Van Rossum et al., 2011). As these data are divided by characteristics such as region, they provide for the possibility to differentiate food consumption amounts according to urbanisation level. Many European and non-European countries conduct regularly dietary surveys, but not all include or publish a regional component. Therefore, the Dutch survey data provide a unique opportunity to analyse water footprints at the urban level.

We calculated the average national food intake in the Netherlands based upon FAO FBS food supply values These are data on food that reach the consumer in private households as well as outside home, i.e. restaurants, catering establishments, schools, hospitals, and others. The data are given on an "as purchased" basis, i.e. as the food leaves the retail shop or enters the household by other means. Quantities are provided on the basis of "primary equivalents". In order to compute food intake amounts (food quantities people actually eat) based upon FAOSTAT FBS food supply amounts, two correction factors are necessary. With the first one (corr1), food consumption (retail product) amounts are computed from food supply amounts. E.g., instead of listing flour of wheat, bread or pasta separately in the FBS, they are quantified as wheat equivalent. Similarly, meat (reaching consumers in many forms, e.g. for chicken as—amongst others—a whole chicken, chicken filet, sausages or chicken nuggets) is quantified as carcass weight in the FBS.

The second one (corr2) accounts for consumer food waste (both at home and at the food service/catering level) and computes food intake amounts from food consumption (retail product) amounts. For all product groups these values are listed in SI Table S2.

This methodology was also used and described previously (Vanham et al., 2015; Vanham et al., 2013a). Corr1 values were obtained from different sources (FAO, 1972; FAO, 1989; PVE and PPE, 2013; Vanham et al., 2013a; Westhoek et al., 2011). Consumer food waste proportions (corr2) were taken from Vanham et al. (2015).

As an example, we take cereals. FAO FBS food supply of cereals in the Netherlands is 75.1 kg/cap/r, i.e. food reaching the consumer (at home and outside) and expressed in cereal equivalents (SI Table S2). By computing different corr1 values for respective cereal products (e.g. 0.8 for wheat, as 1 kg of wheat only leads to 800 g of wheat flour), we obtain an edible food consumption (retail product) amount of 56.9 kg/cap/year. A part of this food is wasted by consumers (both at home and outside, i.e. 12%), resulting in a real national average food intake of cereals of 50.1 kg/cap/year.

To compute food intake amounts for the cities, we used data from the latest Dutch National Food Consumption Survey (DNFCS) (National Institute for Public Health and the Environment, 2016; Van Rossum et al., 2011). This survey provides the following food consumption data: DNFCS-Young adults (2003), DNFCS-Young children (2005–2006), DNFCS-Core Survey 7–69 years (2007–2010) and DNFCS-Older adults (2010 − 2012). These data are divided by characteristics such as region, sex, age or education level. The variable region in the survey refers to the five degrees of urbanisation as defined by Statistics Netherlands (2016) (Fig. 1 and SI Table S1).

As such, we performed mixed linear regressions to assess whether there are differences in the consumption of food product groups by the degree of urbanisation. All models were adjusted for age, sex, and education level, and weighted for socio-demographic factors, season and day of the week. Linear regression analysis was used because it is a robust statistical technique to estimate the association between a continuous dependent variable and an independent variable, while it allows other confounding factors that may affect the relationship to be accounted for. In this instant, regression was used to estimate the mean consumption of a food group per unit change of urbanisation, while other influencing factors such as age, sex and education level were being held constant. Mixed linear regression models are extensions of linear regressions that account for the correlations in the data due to the survey design, whereby repeated measurements of the same statistical unit (i.e. consumption g/day) have been made on the same survey respondent over two non-consecutive recall days. It is therefore important to correct for this within-person variability using mixed linear regression models to give a more accurate estimation of associations between the degree of urbanisation and mean consumption level.

When significant differences were found ($p < 0.05$) in the mixed linear regressions, we adapted - for each city - national food intake values computed from the FAO FBS, according to the ratio of the national food intake values to the food intake value of the specific urbanisation rate.

2.3. Diet scenarios

Apart from the current situation (reference period 1996–2005 or REF), we analysed three diet scenarios: 1) a healthy diet as recommended by the Dutch Food Based Dietary Guidelines (FBDG) (Voedingscentrum, 2011) or HEALTHY; 2) a pesco-vegetarian diet or PESCO-VEG and 3) a vegetarian diet or VEG.

HEALTHY is based upon Dutch FBDG (Voedingscentrum, 2011), which recommend for different product groups intake amounts dependent on age and sex. These product groups generally are identical to the ones defined in the FAO FBS. Based upon populations statistics obtained for each city (Statistics Netherlands, 2016), city specific intake amounts could be quantified for all food product groups, as displayed in SI Table S3. Relative intake amount proportions of particular products within product groups are kept constant.

PESCO-VEG is identical as HEALTHY, but all meat and offals are substituted with products from the product group pulses including oil crops (beans, peas, soybeans, etc.). Animal fats are substituted with crop oils. All these substitutions results in the same total kcal and protein values.

VEG is identical as PESCO-VEG, but all fish is substituted with products from the product group pulses (with the same kcal and protein values).

2.4. Direct household water use

Important is to make the distinction between water abstraction (or water withdrawal) and water consumption (or consumptive water use). The difference between the two is returned water. Urban household water use (also referred to as domestic water use) refers to blue water use by households in a city. Blue water refers to water in rivers, lakes, wetlands and aquifers. Municipal water use includes domestic water use and commercial water use (or water for services). Commercial water use includes the water use of small businesses, hotels, offices, hospitals, schools and other institutions. Municipal water use also represents water for non-permanent residents (like commuters or tourists). Other water users in a city include large industries. In our paper, water use and WF are expressed as l/cap/day (l per capita per day).

Household water use amounts for the selected cities were assembled through different data sources (de Fooij, 2015; Van Leeuwen and Sjerps, 2015; van Thiel, 2013; VEWIN, 2015).

2.5. Water footprint (WF) of food consumption

We follow the Global Water Footprint Standard developed by the Water Footprint Network to compute the WF of food consumption (Hoekstra et al., 2011; Hoekstra and Mekonnen, 2012). We use the green and blue components of the WF. Data on the WF of consumption for edible agricultural products (crops and livestock) for the Netherlands are obtained from Hoekstra and Mekonnen (2012). In the latter study, the WF of consumption of agricultural products is calculated with the bottom-up approach, based upon direct underlying national data on consumption from FAO FBS.

We also included a WF for fish consumption, which up to now has not been done in most studies. Aquaculture will soon surpass wild fisheries as the main source of seafood. This reflects the transition that happened on land in the past with the evolution from hunting to farming. Neglecting the WF of fish and seafood consumption therefore underestimates the WF related to food consumption. For feed, the average green and blue WF values from Pahlow et al. (2015) are taken (50% of fish are assumed to be aquaculture products and fed). For pond evaporation, the blue WF value Verdegem et al. (2006) compute is 5200 l/kg. However, it is assumed that 100% of the fish are marine (which is backed by FAOSTAT FBS values), so pond evaporation is not included in the calculations.

The period for which the analyses were made is 1996–2005. Hereafter this period is referred to as REF.

3. Results

3.1. Urban food consumption

Our analysis showed that – even in a highly urbanised country like the Netherlands – the quantities consumed for some food product groups differ from the national average in extremely urbanised municipalities (Fig. 1) like Amsterdam, Dordrecht and Rotterdam. In particular, urban dwellers in these cities eat significantly more meat (+11%, $p < 0.05$) and cereals (+13%, $p < 0.05$) as well as fewer potatoes (−7%, $p < 0.05$) than average Dutch citizens. In strongly urbanised municipalities (Fig. 1) like Eindhoven, Maastricht, Nieuwegein and Venlo, no statistically significant differences in food intake amounts from the national average were found. Strongly urbanised municipalities, where 31% of the Dutch population lives (Fig. 1), seem to represent average Dutch citizens.

Fig. 2 shows quantities consumed per product group for Amsterdam and Eindhoven, as representative cities for these two urbanisation degrees (as displayed in Fig. 1). Total reference period (REF) food intake (902 and 896 kg/cap/year respectively) are only slightly different, due to the differences in these three product groups. With 53 kg/cap/year Amsterdam inhabitants eat significantly more meat than the inhabitants of Eindhoven. The same is true for cereals (57 and 50 kg/cap/year). They however eat significantly fewer potatoes (75 kg/cap/year) as compared to inhabitants of Eindhoven (81 kg/cap/year). This could be explained by the fact that potatoes are the more traditional staple food.

3.2. Diet scenarios

We tested whether Dutch urban dwellers have a healthy diet, by comparing the reference period diet (REF, being the period 1996–2005) with Dutch Food-Based Dietary Guidelines (FBDG)(Voedingscentrum, 2011),

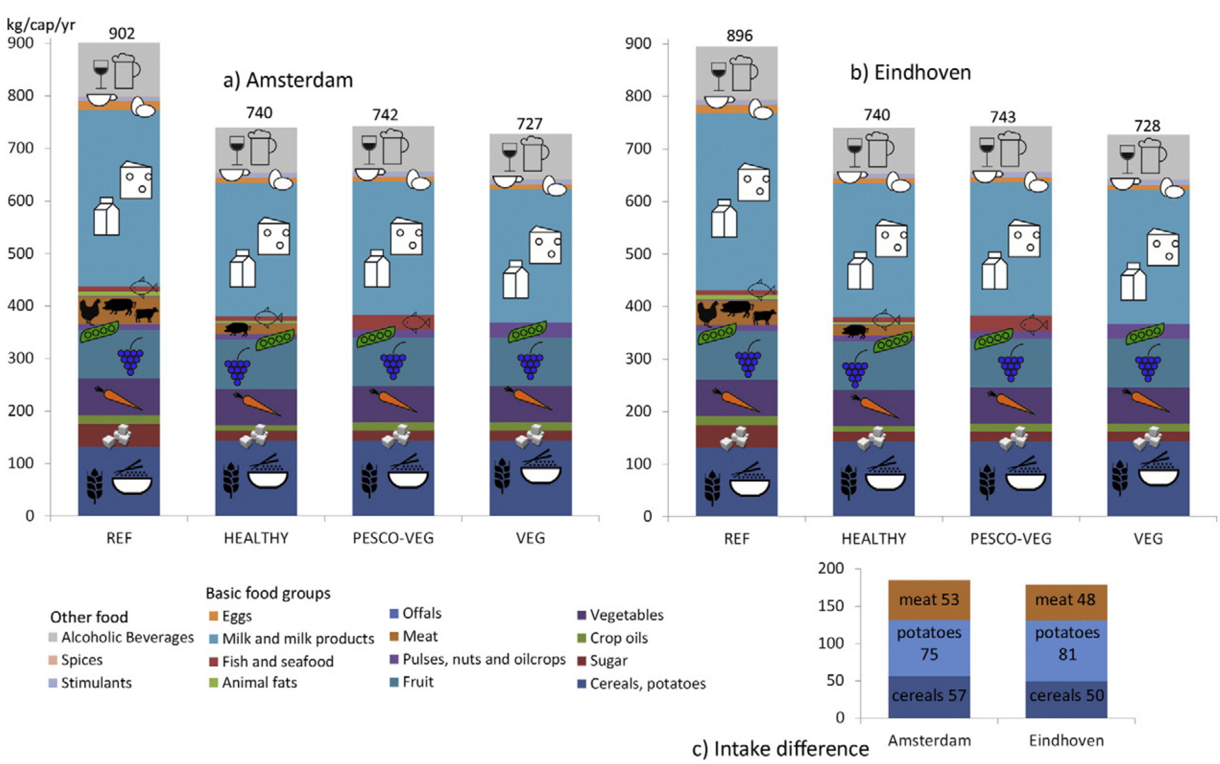

Fig. 2. Food intake (in kg/cap/year) in a) Amsterdam and b) Eindhoven for the reference period (REF) and the three scenarios (HEALTHY, PESCO VEG and VEG). Data based on FAO Food Balance Sheets (FBS) as well as the Dutch Nutrition Survey. Milk products are displayed as milk equivalents. For three product groups there is a difference in intake (REF), as displayed in c).

defined as the scenario HEALTHY. Recommended intake values per food product group for each city are listed in SI Table S3. FBDG give for each food product group recommended intake values according to age and sex groups. Depending on the specific population distribution of a city, total values slightly differ between cities.

Dutch urban citizens clearly consume too much sugar, animal products (meat, milk and milk products, animal fats, eggs), crop oils, and not enough cereals. They also drink too much alcohol. According to FAO Food Balance Sheets (FBS) they eat enough vegetables and fruit, although the form of particular products (e.g. partially as fruit juice) might not totally comply with FBDG recommendations. As representative cities for the two evaluated urbanisation levels (Fig. 1), Amsterdam and Eindhoven show recommended intake values per product group in Fig. 2. Especially large reductions in intake need to take place for sugar (about −60% to max 18 kg/cap/year) and meat. For meat the reduction in Amsterdam is larger (from 53 to 62% to 20 kg/cap/year) than in Eindhoven (from 48 kg/cap/year - 58% to 20 kg/cap/year). Although more cereals are eaten in Amsterdam as compared to Eindhoven, in both cities the current intake is below recommended amounts.

3.3. Direct household water use

In the three extremely urbanised cities Amsterdam, Rotterdam and Dordrecht household water use (blue water abstraction) amounts to 131 l/cap/day (SI Tables S5 and S6). In the strongly urbanised cities of Eindhoven, Maastricht and Venlo, this quantity amounts to 117 l/cap/day, in Nieuwegein to 116 l/cap/day. These are very low values, which are mainly the result of past efforts to reduce household water use by installing low water consuming toilets and efforts from the industry to produce more water efficient washing machines (SI Table S4, (VEWIN, 2015)). As such, domestic water use has decreased continuously in the Netherlands over the last two decades, although water use for showering has increased (VEWIN, 2015). Total water use in the extremely urbanised cities is also slightly larger as people tend to shower for longer (de Fooij, 2015; van Thiel, 2013).

For Amsterdam, household water use accounts for 68% of total water distributed to the city (Table S6). Another 29% is for small and large business water use, whereas only 3% is lost through leakage (OECD, 2016; Van Leeuwen and Sjerps, 2015). Such low leakage rates, typical in the Netherlands (Rosario-Ortiz et al., 2016), are one of the reasons why Dutch cities score high on existing international city rankings like the Green City Index (Economist Intelligence Unit and Siemens, 2012) or the City Blueprint (Koop and Van Leeuwen, 2015).

3.4. Water footprint (WF) of food consumption

We calculated the blue and green water resources related to the production of food consumed in Dutch cities, by means of the water footprint concept. This food is produced outside city borders with external (water) resources, both in the Netherlands and abroad. The reference period (REF) WF in the three extremely urbanised cities amounts to 3245 l/cap/day (Fig. 3). In the four strongly urbanised cities, the REF WF amounts to 3126 l/cap/day (Fig. 4), i.e. 3.7% less than the value for extremely urbanised cities. Food products that require a lot of water to produce - like animal products, but also crop oils, sugar and stimulants (SI Table S2) – contribute large proportions to these total values. Meat accounts for the largest proportions: 31% (995 l/cap/day) for the extremely urbanised cities and 29% (895 l/cap/day) for the strongly urbanised cities.

A shift to a healthy diet would reduce the WF substantially by 32% for the three extremely urbanised cities (Fig. 3) and by 29 to 30% for the four strongly urbanised cities (Fig. 4). Especially the decrease in meat intake has a major effect on the WF reduction.

For the three extremely urbanised cities (Fig. 3), the PESCO-VEG scenario reduces the WF by 38 to 39% and the VEG scenario reduces the WF

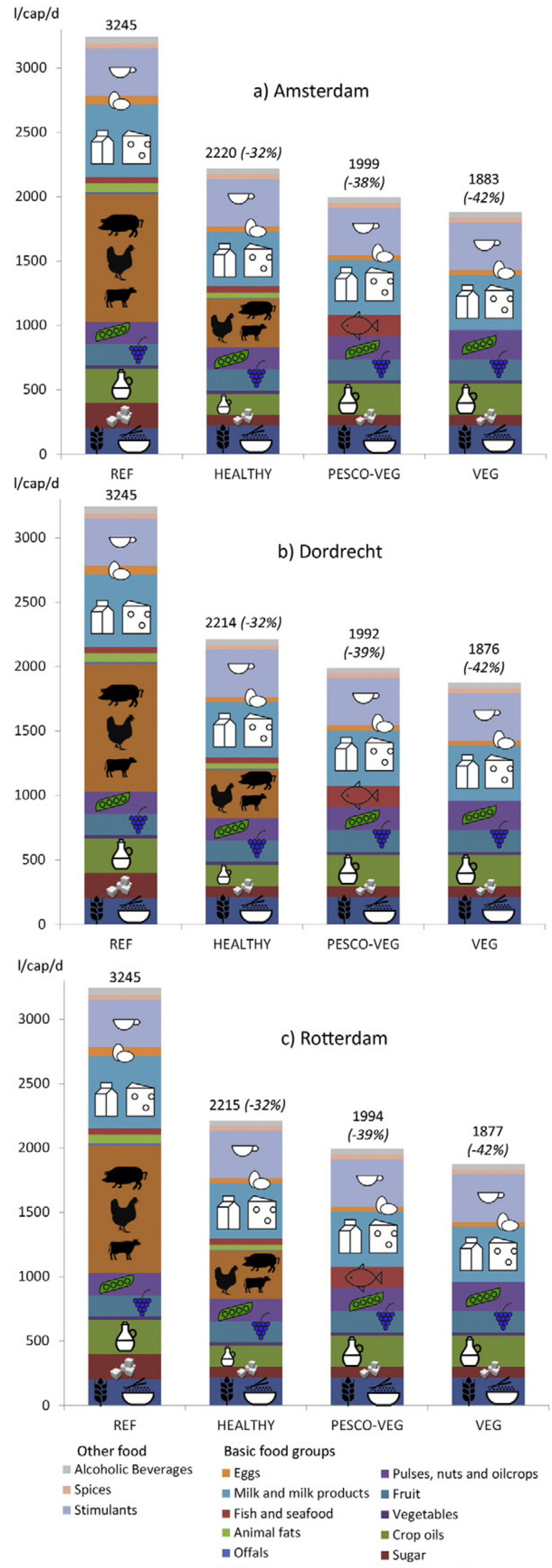

Fig. 3. The water footprint related to food consumption (in l/cap/day) in a) Amsterdam, b) Dordrecht and c) Rotterdam for the reference period and three scenarios.

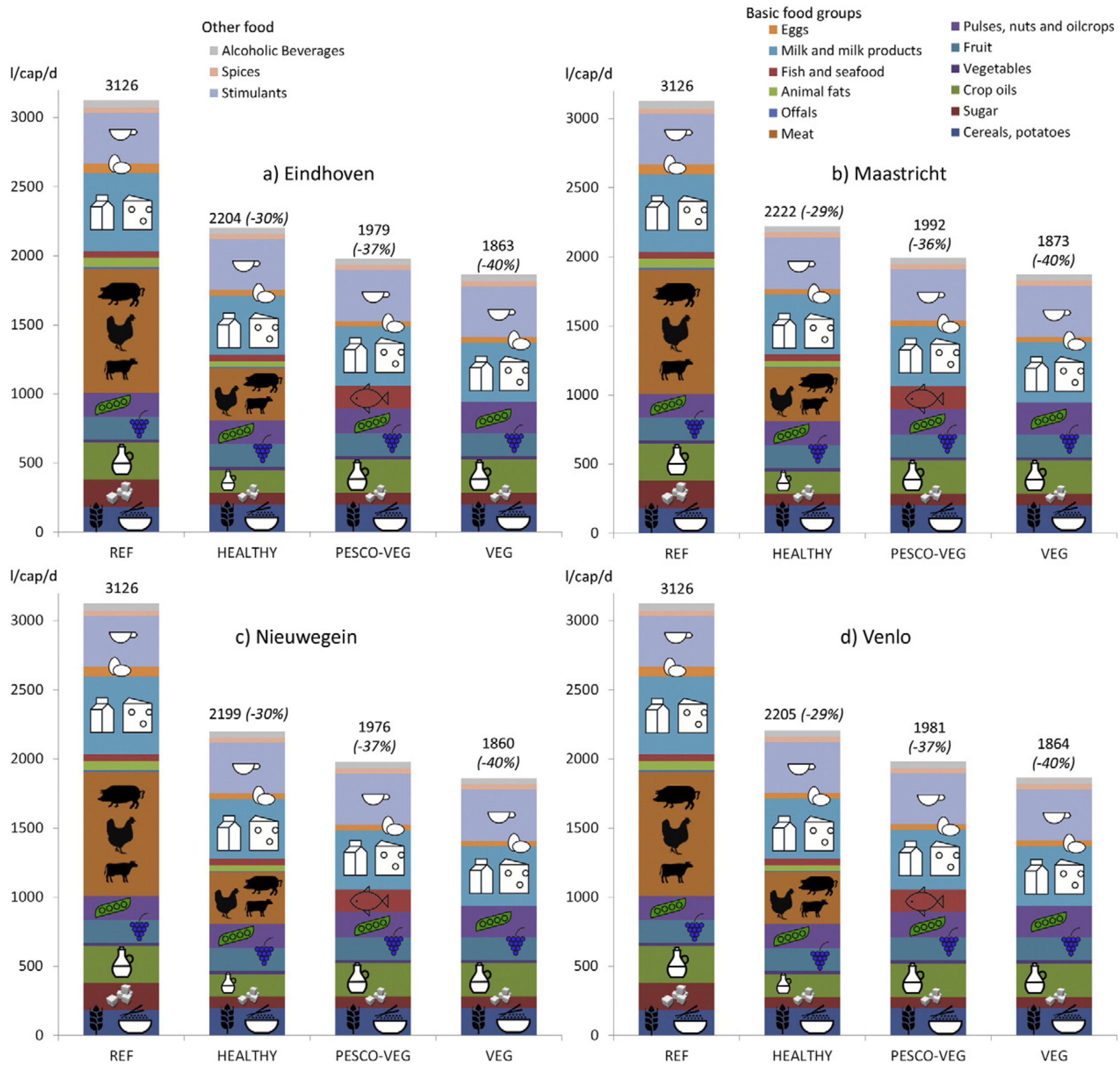

Fig. 4. The water footprint related to food consumption (in l/cap/day) in a) Eindhoven, b) Maastricht, c) Nieuwegein and d) Venlo for the reference period and three scenarios.

by 42%. For the four strongly urbanised cities (Fig. 4), the PESCO-VEG scenario reduces the WF by 36 to 37% and the VEG scenario reduces the WF by 40%.

4. Discussion

We showed that water quantities related to food consumption in Dutch cities are of a whole other magnitude than the quantities required for direct household use. The reference period food consumption WF in the three extremely urbanised cities of 3245 l/cap/day is about 25 times the amount for household use (131 l/cap/day). For the strongly urbanised cities, this factor is 27 (WF of 3126 l/cap/day as opposed to 116 or 117 l/cap/day). Water for direct use in cities is already mostly an external resource, as it originates generally from outside city borders. Few cities in the world are self-sufficient for direct water use. An example is Singapore that invested a lot of money and efforts to close its urban water cycle by steadily increasing the share of recycled water use (Luan, 2010). However, water for urban food consumption is generally exclusively an external resource. Apart from small quantities of food produced by urban farming, food consumed in cities is produced elsewhere and imported.

As such, current rankings that assess the (environmental) sustainability of cities display only part of the picture. In the European Green City Index (Unit and Siemens, 2009) e.g., Amsterdam ranked number one for water. The household water use of 131 l/cap/day and water loss rate of 3% are the lowest of European capitals. In addition, wastewater treatment is 100% and Waternet (the water supply company) policies include the use of renewable sources of energy, the generation of energy from sewage sludge as well as phosphate recovery from wastewater (van der Hoek et al., 2015; Van Leeuwen and Sjerps, 2015). Amsterdam also scores number one amongst 45 cities assessed so far in the City Blueprint Ranking (Koop and van Leeuwen, 2016), a set of 25 indicators. The use of external (water) resources is not included in these rankings.

Wealth matters in many of current rankings. The European Green City Index shows a close correlation between wealth and overall performance (Unit and Siemens, 2009). This link is not only evident in infrastructure, but also in policy: richer cities appear more ambitious with their goals. One of the closest correlations in the data collected for the index is that between the GDP per head of cities and their overall score. Also the Blue City Index is positively correlated with the GDP per person (Koop and Van Leeuwen, 2015).

Rankings such as the Green City Index address many issues: energy efficiency of buildings, waste collection and recycling, transport, urban water management, air quality, energy consumption and CO_2 emissions. These are all very important issues and essential to address the environmental sustainability of cities. However, the external use of resources, most notably through food consumption, is neglected. These resources not only include water, but also land, nitrogen, phosphor or energy. Only by including this external resource use, rankings would provide a full picture of urban sustainability.

It is also expected that many western cities that now score very high on existing rankings would see a decrease in their overall score when indicators on external resource use were to be included. Our analysis shows that Dutch cities are characterized by overconsumption of resource intensive food products. Previous research (Zhang et al., 2008) already showed that increasing wealth generally leads to increased consumption of resource intensive nutrition. Increasing wealth can thus have both positive and negative effects on city sustainability. It is expected that, when including external resource use, cities from transition or developing countries would move up the sustainability index scale, not at least because their urban diets are closer to recommended diets and/or not so resource intensive.

Indeed, with a limited availability of global blue and green water resources (Hoekstra et al., 2012; Hoekstra and Wiedmann, 2014; Mekonnen and Hoekstra, 2016; Rockstrom et al., 2009; Schyns et al., 2015), solutions in integrated water resources management and the sustainable use of water resources need to come from both the supply and the demand side. Supply-side options include efficiency in urban water supply, measures to close yield gaps and an increase in agricultural water efficiency (Brauman et al., 2013; van Ittersum et al., 2013; Vanham and Bidoglio, 2013). Demand-side options include efficiency in urban water use (Koop and van Leeuwen, 2016), the reduction of food losses and food waste (Liu et al., 2013; Vanham et al., 2015) and an adequate consumption of water-intensive products like livestock products (Hoekstra, 2014; Jalava et al., 2014). During the last decades, the intake of e.g. meat has increased to too high levels as compared to national/regional FBDG in western countries, leading to high water footprint amounts (Vanham, 2013; Vanham et al., 2013b). The same observation can now be made for many transition and developing countries, where the diet of an increasing part of the population is characterized by a too high intake of water-intensive livestock products and sugar (Afshin et al., 2015; Liu and Savenije, 2008; Zhang et al., 2008). As such, a shift to healthier diets with lower water footprints by Dutch urban citizens is also relevant for the sustainable use of global water resources. This means that city-related water challenges also need to be solved by actors outside the traditional water sector (Koop and van Leeuwen, 2016).

Acknowledgment

We would like to thank Tadek Dyba of the Joint Research Centre for his help with statistical analyses of food survey data. We acknowledge RIVM for providing data on the Dutch Nutrition Survey (VCP 2007–2010, RIVM). We also acknowledge the constructive comments of two anonymous reviewers.

Appendix A. Supplementary material

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.scitotenv.2016.04.172.

References

Afshin, A., Micha, R., Khatibzadeh, S., Fahimi, S., Shi, P., Powles, J., et al., 2015. The impact of dietary habits and metabolic risk factors on cardiovascular and diabetes mortality in countries of the Middle East and North Africa in 2010: a comparative risk assessment analysis. BMJ Open. http://dx.doi.org/10.1136/bmjopen-2014-006385.

Brauman, K.A., Siebert, S., Foley, J.A., 2013. Improvements in crop water productivity increase water sustainability and food security—a global analysis. Environ. Res. Lett. 8, 024030. http://dx.doi.org/10.1088/1748-9326/8/2/024030.

de Fooij, H., 2015. Wastewater as a Resource: Strategies to Recover Resources from Amsterdam's Wastewater (MSc thesis in Civil Engineering and Management) University of Twente.

Economist Intelligence Unit, Siemens, 2012. The Green City Index - A Summary of the Green City Index Research Series, Munich.

Elmqvist, T., 2014. Urban resilience thinking. Solutions 5, 26–30.

FAO, 1972. Technical Conversion Factors for Agricultural Commodities. Food and Agriculture Organization of the United Nations.

FAO, 1989. Yield and Nutritional Value of the Commercially More Important Fish Species. Food and Agriculture Organization of the United Nations, Rome.

Food and Agriculture Organization. FAOSTAT on-line database, http://faostat.fao.org. FAO, Rome, 2016.

Hoekstra, A.Y., 2014. Water for animal products: a blind spot in water policy. Environ. Res. Lett. 9, 091003. http://dx.doi.org/10.1088/1748-9326/9/9/091003.

Hoekstra, A.Y., Mekonnen, M.M., 2012. The water footprint of humanity. Proc. Natl. Acad. Sci. U. S. A. 109, 3232–3237. http://dx.doi.org/10.1073/pnas.1109936109.

Hoekstra, A.Y., Wiedmann, T.O., 2014. Humanity's unsustainable environmental footprint. Science 344, 1114–1117. http://dx.doi.org/10.1126/science.1248365.

Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M., Mekonnen, M.M., 2011. The Water Footprint Assessment Manual: Setting the Global Standard. Earthscan, London, UK.

Hoekstra, A.Y., Mekonnen, M.M., Chapagain, A.K., Mathews, R.E., Richter, B.D., 2012. Global monthly water scarcity: blue water footprints versus blue water availability. PLoS ONE 7, e32688. http://dx.doi.org/10.1371/journal.pone.0032688.

Jalava, M., Kummu, M., Porkka, M., Siebert, S., Varis, O., 2014. Diet change—a solution to reduce water use? Environ. Res. Lett. 9, 074016. http://dx.doi.org/10.1088/1748-9326/9/7/074016.

Koop, S.H.A., Van Leeuwen, C.J., 2015. Application of the Improved City Blueprint Framework in 45 municipalities and regions. Water Resour. Manag. 29, 4629–4647. http://dx.doi.org/10.1007/s11269-015-1079-7.

Koop, S.H.A., van Leeuwen, C.J., 2016. The challenges of water, waste and climate change in cities. Environ. Dev. Sustain. 1–34. http://dx.doi.org/10.1007/s10668-016-9760-4.

Liu, J., Savenije, H.H.G., 2008. Food consumption patterns and their effect on water requirement in China. Hydrol. Earth Syst. Sci. 12, 887–898. http://dx.doi.org/10.5194/hess-12-887-2008.

Liu, J., Lundqvist, J., Weinberg, J., Gustafsson, J., 2013. Food losses and waste in China and their implication for water and land. Environ. Sci. Technol. 47, 10137–10144. http://dx.doi.org/10.1021/es401426b.

Luan, I.O.B., 2010. Singapore water management policies and practices. Int. J. Water Resour. D. 26, 65–80. http://dx.doi.org/10.1080/07900620903392190.

Mekonnen, M.M., Hoekstra, A.Y., 2016. Four billion people facing severe water scarcity. Science Advances. http://dx.doi.org/10.1126/sciadv.1500323.

National Institute for Public Health and the Environment, 2016. Dutch National Food Consumption Survey. http://www.rivm.nl/en/Topics/D/Dutch_National_Food_Consumption_Survey.

OECD, 2016. Water governance in cities. OECD Studies on Water. OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264251090-en.

Pahlow, M., van Oel, P.R., Mekonnen, M.M., Hoekstra, A.Y., 2015. Increasing pressure on freshwater resources due to terrestrial feed ingredients for aquaculture production. Sci. Total Environ. 536, 847–857. http://dx.doi.org/10.1016/j.scitotenv.2015.07.124.

PVE, PPE, 2013. Vee, vlees en eieren in Nederland - Kengetallen 2012 (Cattle, meat and eggs in the Netherlands - Key numbers 2012). Productschap Vee en Vlees en het Productschap Pluimvee en Eieren.

Rees, W., Wackernagel, M., 2008. Urban ecological footprints: why cities cannot be sustainable—and why they are a key to sustainability. In: Marzluff, J.M., Shulenberger, E., Endlicher, W., Alberti, M., Bradley, G., Ryan, C., et al. (Eds.), Urban Ecology: An International Perspective on the Interaction Between Humans and Nature. Springer US, Boston, MA, pp. 537–555.

Rockstrom, J., Steffen, W., Noone, K., Persson, A., Chapin, F.S., Lambin, E.F., et al., 2009. A safe operating space for humanity. Nature 461, 472–475.

Rosario-Ortiz, F., Rose, J., Speight, V., Uv, G., Schnoor, J., 2016. How do you like your tap water? Science 351, 912–914. http://dx.doi.org/10.1126/science.aaf0953.

Schyns, J.F., Hoekstra, A.Y., Booij, M.J., 2015. Review and classification of indicators of green water availability and scarcity. Hydrol. Earth Syst. Sci. 19, 4581–4608. http://dx.doi.org/10.5194/hess-19-4581-2015.

Statistics Netherlands, 2016. Statline, electronic database. http://statline.cbs.nl.

UN, 2014. World Urbanization Prospects: The 2014 Revision, Highlights.

Unit EI, Siemens, 2009. European Green City Index - Assessing the Environmental Impact of Europe's Major Cities, Munich.

van der Hoek, J.P., Struker, A., de Danschutter, J.E.M., 2015. Amsterdam as a sustainable European metropolis: integration of water, energy and material flows. Urban Water J. 1-8. http://dx.doi.org/10.1080/1573062X.2015.1076858.

van Ittersum, M.K., Cassman, K.G., Grassini, P., Wolf, J., Tittonell, P., Hochman, Z., 2013. Yield gap analysis with local to global relevance—a review. Field Crop Res. 143, 4–17. http://dx.doi.org/10.1016/j.fcr.2012.09.009.

Van Leeuwen, C.J., Sjerps, R.M.A., 2015. The City Blueprint of Amsterdam: an assessment of integrated water resources management in the capital of the Netherlands. Wa. Sci. Technol. 15, 404–410. http://dx.doi.org/10.2166/ws.2014.127.

Van Rossum, C., Fransen, H., Verkaik-Kloosterman, J., Buurma-Rethans, E., Ocké, M., 2011. Dutch National Food Consumption Survey 2007–2010: Diet of Children and Adults Aged 7 to 69 Years. RIVM, Bilthoven.

van Thiel L. Watergebruik Thuis 2013 (Water use at home). Commissioned by VEWIN, 2013.

Vanham, D., 2013. The water footprint of Austria for different diets. Water Sci. Technol. 67, 824–830. http://dx.doi.org/10.2166/wst.2012.623.
Vanham, D., 2016. Does the water footprint concept provide relevant information to address the water–food–energy–ecosystem nexus? Ecosystem Services 17, 298–307. http://dx.doi.org/10.1016/j.ecoser.2015.08.003.
Vanham, D., Bidoglio, G., 2013. A review on the indicator water footprint for the EU28. Ecol. Indic. 26, 61–75. http://dx.doi.org/10.1016/j.ecolind.2012.10.021.
Vanham, D., Hoekstra, A.Y., Bidoglio, G., 2013a. Potential water saving through changes in European diets. Environ. Int. 61, 45–56. http://dx.doi.org/10.1016/j.envint.2013.09.011.
Vanham, D., Mekonnen, M.M., Hoekstra, A.Y., 2013b. The water footprint of the EU for different diets. Ecol. Indic. 32, 1–8. http://dx.doi.org/10.1016/j.ecolind.2013.02.020.
Vanham, D., Bouraoui, F., Leip, A., Grizzetti, B., Bidoglio, G., 2015. Lost water and nitrogen resources due to EU consumer food waste. Environ. Res. Lett. 10, 084008. http://dx.doi.org/10.1088/1748-9326/10/8/084008.
Verdegem, M.C.J., Bosma, R.H., Verreth, J.A.J., 2006. Reducing water use for animal production through aquaculture. Int. J. Water Resour. D. 22, 101–113. http://dx.doi.org/10.1080/07900620500405544.
VEWIN, 2015. Drinkwaterstatistieken 2015 (Drinking water statistics 2015). VEWIN - Vereniging van waterbedrijven in Nederland (Association of water companies in the Netherlands).
Voedingscentrum. Richtlijnen voedselkeuze, 2011.
Westhoek, H., Rood, T., van den Berg, M., Nijdam, D., Reudink, M., Stehfest, E., 2011. The Protein Puzzle. The Consumption and Production of Meat, Dairy and Fish in the European Union. PBL Netherlands Environmental Assessment Agency, The Hague.
Zhang, X., Dagevos, H., He, Y., van der Lans, I., Zhai, F., 2008. Consumption and corpulence in China: a consumer segmentation study based on the food perspective. Food Policy 33, 37–47. http://dx.doi.org/10.1016/j.foodpol.2007.06.002.