Water consumption in meat- and plant-based diets

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Research Idea

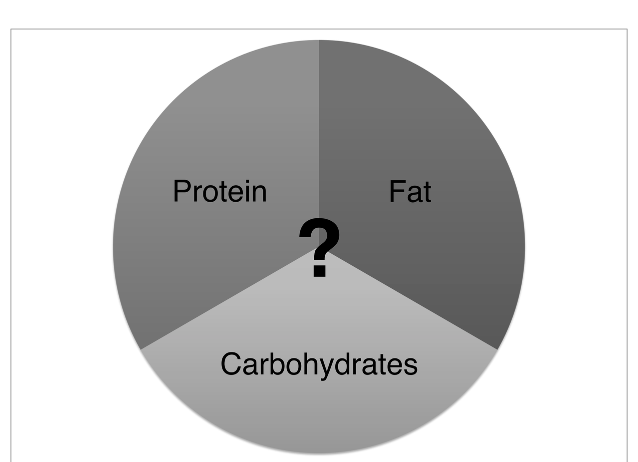
The environmental cost of human diets has recently been topic in various scientific studies and papers (Eshel et al., 2014; Westhoek et al., 2014; Steinfeld et al., 2006). Climate change and population growth might lead to a decline in per capita availability of natural resources for human consumption and potential dietary changes are proposed to mitigate such negative effects. A reduction of animal products such as meat, eggs and dairy in the Western countries is commonly suggested as a possible way towards higher food security over the next decades. Seemingly left out of this debate is a profound discussion of potential consequences for human health as a transition from animal to more plant foods may also lead to a decline in available macro- and micro-nutrients that are essential for our well-being. Studies typically approach this topic from a caloric point of view, assuming calories in human diets are arbitrarily interchangeable. Some studies also take into account the protein content of certain food item as a way of a more useful approach for comparing different food sources, though then lack a proper analysis of the varying digestibility of these foods.

Such an approach can lead to an underestimation of the resource intensity of plant foods. Picking one particular resource, water, we propose a more refined method to estimate the environmental cost of different food sources for human nutrition. Assuming that protein, and hence the availability of certain amounts of essential amino acids, form the basis of a balanced diet, **we investigate the efficiency of the production of animal and plant protein sources with regard to their respective water requirements**. Additionally, we discuss the relevance of essential micro-nutrient contents of the various analyzed protein sources.

Methods

Defining a balanced human diet

There is a great number of definitions when it comes to a healthy or balanced human diet. Some concepts are based on very recent human dietary patterns (USDA, 2010), while others chose to approach this topic from an evolutionary and observational historic perspective (Cordain et al., 2000; Eaton 2006; Frasetto et al., 2009). Here, we define a balanced diet as a diet that provides sufficient, nutritious and safe food to meet the dietary needs of an active and healthy human being. Consequently, when discussing the environmental consequences of our diets, the normative goal in food security debates should additionally incorporate a nutritional perspective on future food supply.



We take the protein content as basis for defining human diet, complemented by essential fatty acids, minerals, vitamins, and other dietary fats and carbohydrates as building blocks and fuel sources. This approach makes it necessary to account for the protein quality of certain foods. Given that all methods have their own advantages and disadvantages, we choose to take an average factor for comparing plant with animal protein sources of 1.5, i.e. to meet the same protein needs with plant instead of animal protein one has to consume on average 50% more plant protein. Further, we will test this assumption in form of a sensitivity analysis (Friedman 1996; Sarwar 1996; Schaafsma, 2000; Tomé, 2012).

For comparing animal and plant protein sources we created a potential mix of food groups for each category - a combination of meats and eggs as default animal protein mix, and a combination of grains and legumes as default plant protein mix according to shares from FAO's food supply data (see table).

Default plant and animal protein mixes

Plant protein mix	Animal protein mix*
Wheat (45%)	Beef (incl. offal) (21%)
Rice (37%)	Pork (35%)
Corn (12%)	Chicken (32%)
Rye	Goat
Oats	Turkey
Millet	
Sorghum	Eggs
Beans and legume flours (39%)	
Peas (11%)	
Lentils (50%)	

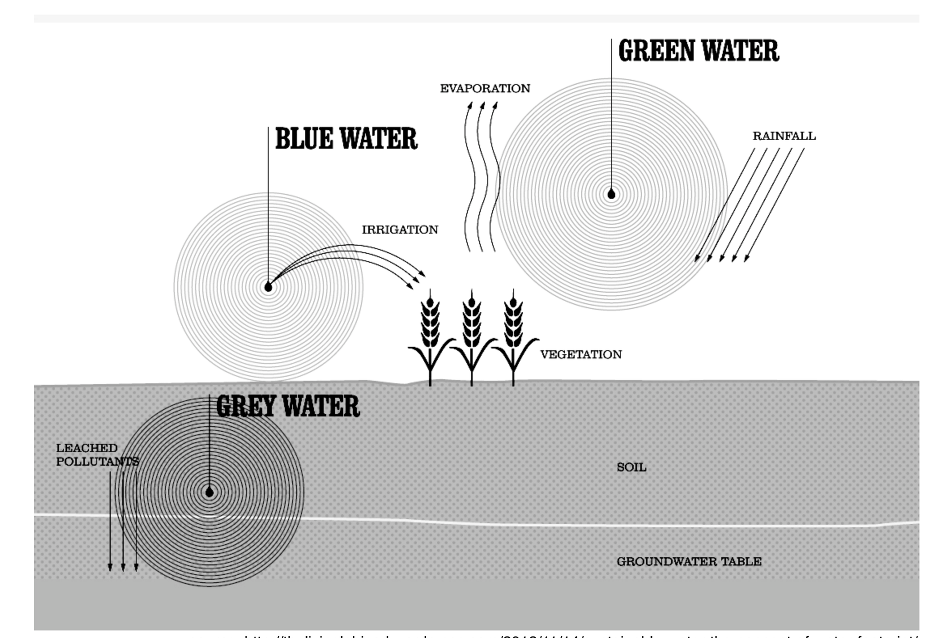
*no nutritional data for sheep available

In a second step we analyze the micro-nutrient content of each plant and animal protein source using data from the USDA National Nutrient Database for Standard Reference (USDA, 2014). Micro-nutrients considered in this study are the vitamin A, thiamin, riboflavin, niacin, B6, folate and B12. Minerals included are calcium, iron, magnesium, potassium and zinc. We compare their specific nutrient content on a cooked 100g basis with reference to the daily Dietary Reference Intakes (DRIs) from the Food and Nutrition Board.

Water consumption in food production

The Water Footprint forms an often applied approach to assess the water consumption that occurs when producing a certain good (Mekonnen and Hoekstra, 2011 and 2012). It is defined as the volume of freshwater appropriated to produce a product, taking into account the volumes of water consumed and polluted in the different steps of the supply chain. Regarding agricultural products, the database lists the average blue, grey and green water consumption by product on a sub-national level, calculated using the global CROPWAT model (Hoekstra et al., 2011). Blue water is defined as the fresh surface and groundwater. Grey water is water that is required to dilute pollutants to such an extent that the quality of the water remains above agreed water quality standards. Green water is the precipitation on land that does not run off or re-charge the groundwater but is stored in the soil or temporarily stays on top of the soil or vegetation. Eventually, this part of precipitation evaporates or transpires through plants (see graph). For this analysis we chose to focus on to the blue and grey water demand of different agricultural products. Green water demand will be discussed separately as the amount of embedded rainwater could not be used for other products or services.

Types of water in the Water Footprint assessment



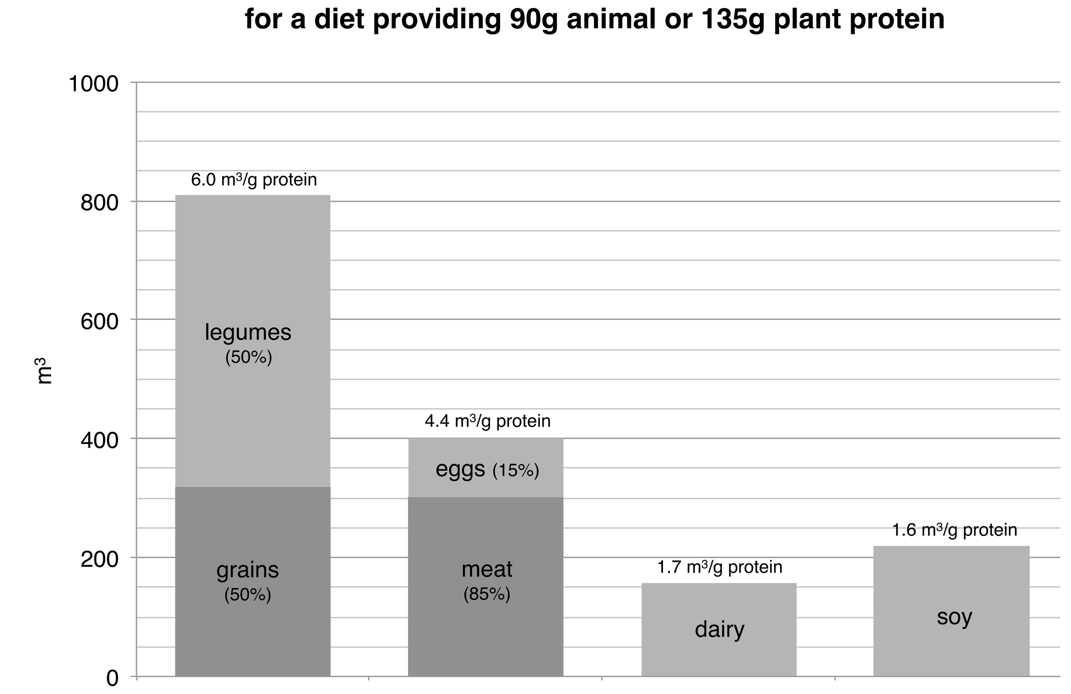
source: http://thelivinglabiesd.wordpress.com/2012/11/14/sustainable-water-the-concept-of-water-footprint/

Results (preliminary)

Applying global average water consumption data from the Water Footprint database, adding up blue and grey water demand, correcting plant protein sources with an average digestibility factor of 1.5, and using average protein contents of foods in an equal mix of grains and legumes, **we estimate a water use intensity about two times as high for the plant protein mix as for the animal protein mix** - providing 90g of protein (animal, roughly 15% of energy in an average 2,200 kcal/day diet) or 135g (plant) daily for an average adult (Walpole et al., 2012; Elango et al., 2009). (Note: meeting entire protein needs with such a grain-legume mix would roughly provide 4,000 kcal, while the meat-egg mix provides about 500 kcal). These numbers represent hypothetical food groups, while realistically most diets contain food items from both protein mixes. However, **this comparison helps to illustrate the consequences with regard to water when shifting from one protein source to another**.

Further, we calculated the water use intensity for meeting daily dietary protein needs with a mix of dairy and soy foods in two separate categories. Both food groups show lower water intensities expressed in m^3/g protein but realistically can only be consumed in limited amounts.

Water consumption in m^3/cap/day for a diet providing 90g animal or 135g plant protein



Discussion

Several points are not yet addressed or still need clarification:

1) Differences in the supply of micro-nutrients from different protein sources (availability, quality, amount)

2) What are the effects from shifts of protein sources within each protein mix (e.g. certain types of meat or legumes)?

3) How sensitive are the results regarding higher or lower protein digestibility factors?

4) How do the results relate to an average human diet? Role of carbohydrate load etc.

5) What about nuts or fish as potential protein sources?

6) The role of the green grey water demand

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