Agricultural Systems 136 (2015) 14–29

Contents lists available at ScienceDirect

Agricultural Systems

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

Possible implications of dietary changes on nutrient fluxes, environment and land use in Austria

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ARTICLE INFO

Article history:
Received 7 August 2012
Received in revised form 4 January 2015
Accepted 27 January 2015
Available online 25 February 2015

Keywords:
Diet change
Land use
MONERIS
MFA
Nitrogen
Phosphorus

ABSTRACT

Health recommendations clearly show that in Austria and other highly developed countries less animal and more plant based food should be consumed. A meat based diet is held responsible for a number of environmental problems. We explore the impacts on nutrient fluxes (nitrogen and phosphorus) and land use as the result of a change from a meat based diet to a healthier balanced diet consisting of less animal based products and more plant based food in Austria. We use a detailed material flow analysis and the nutrient emissions model MONERIS in combination with scenarios. The scenarios address differing farming methods, varying trade options and different use of potentially available agricultural area. Our findings show that overall, a shift to a healthy balanced diet leads to less land being used for agricultural production (–30%), less resource consumption (20% to 25% less phosphorus) and lower transfer of nutrients from agriculture into the environment compared to the reference situation. Total emissions of nitrogen and phosphorus into water decrease (between 15% and 11% for nitrogen and by 5% to 6% for phosphorus) and nitrogen concentrations in groundwater change substantially depending on the intensity of farming assumed by different scenarios.

1. Introduction

Agriculture requires vast resource inputs and impacts waters, climate and soils. In 2008, agriculture contributed 8.8% to the total Austrian CO_2 equivalent (62% for CH_4, 72% for N_2O) emissions (Anderl et al., 2010). Emissions into the atmosphere are of particular interest for different reasons. Mainly climate active gases (e.g. N_2O) receive attention in the ongoing discussions on agriculture and climate change. Yet, there are other impacts of non-climate active nitrous gases from agriculture on the environment (Jefferies and Maron, 1997; Vitousek et al., 1997).

Impacts on water are another challenge for agricultural activities. Especially the eutrophication potential of emitted phosphorus and nitrogen are a matter of concern (Bennett et al., 2001; Smith et al., 1999). Eighty percent of all Austrian nitrogen (N) emissions into waters stem from diffuse sources, with the highest proportion coming from agriculture (Schilling et al., 2011; Zessner et al., 2011b). An important step in implementing the European Water Framework Directive 2000/60/EC was the publication of the National River Basin Management Plan (NGP). Eleven percent of all Austrian water bodies were described as at risk of not reaching a good status for chemical or physical parameters by 2015. The NGP 2009 (BMLFUW, 2009) requests the implementation of measures to achieve the good status in all water bodies. In this context, it becomes particularly relevant to explore how nitrate concentrations in groundwater would change applying different agricultural scenarios. Nutrient emissions (especially N) from the agricultural sector are identified as main pressure on the Danube river basin and expected to rise in the future without appropriate management objectives (ICPDR, 2009).

The importance of the link between human diet and health is well known (Friel et al., 2009). Federal and non-governmental organizations often attempt to raise awareness to the benefits of healthy nutrition and to support dietary change, though obesity and other health related diseases continue to increase (WHO, 2003). Another topic gaining increasing attention is the link between diet, resources consumption and environmental pollution. Animal husbandry is often associated with contributing to climate change and depleting resources (Smil, 2002; Steinfeld et al., 2006).

A predicted global shift to a meat based diet will further exacerbate the challenge of feeding a growing population of an expected 9 billion people in 2050 (UN, 2011). It will not be possible to solve this challenge solely by increasing the area of land under agricultural production. At present, more than 1.5 billion hectares of land are used worldwide for crop production (arable land and land under permanent crops) with little scope for further expansion (FAO, 2012).

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http://dx.doi.org/10.1016/j.agsy.2015.01.006
0308-521X/

Minimizing food wastage and intensifying agricultural production on existing arable land are options for addressing the challenge of increased demand. However, agricultural intensification leads to further nitrogen losses into the environment (Eickhout et al., 2006). This sharpens the effect of nitrogen pollution in aquatic ecosystems such as acidification and eutrophication (Camargo and Alonso, 2006; Carpenter et al., 1998). Furthermore agricultural intensification requires an increase in other resource inputs. Some of them, like mineral phosphorus (Cooper et al., 2011), appear to be limited in the long run (some hundred years). Thus, a demand driven strategy to raise food security in the future is a dietary shift from a meat to a plant based diet (Godfray et al., 2010).

Meanwhile, a number of authors deal with the relationship of human diet patterns and their impact on the environment. Some of them examine the impact of human diet on farmers and agricultural markets (e.g. Arnoult et al., 2010; Rickard and Gonsalves, 2008), others cover the influence on water consumption. (e.g. Renault and Wallender, 2000). Material flow analyses have been calculated by varying authors for different regions showing the relationship between food production and/or food consumption and the resulting nutrient fluxes (e.g. Bleken and Bakken, 1997; Risku-Norja and Mäenpää, 2007; Zessner and Lampert, 2002; Zessner et al., 2010). However, the change in nutrient fluxes caused by a change in human diet patterns have not been investigated so far. Although some literature exists on the relationship between the land demand of different diets (P. W. Gerbens-Leenes et al., 2002; Gerbens-Leenes and Nonhebel, 2005; Meier et al., 2014) and their impacts on the environment (Meier and Christen, 2013), all of these studies use conversion factors, transferring different food types into land use, based on an agricultural production system. The innovative aspect of our study is that required land use of a balanced diet is linked to the agricultural production potential and the nutrient requirements (nitrogen and phosphor) of agriculture in a reference period (2001–2006). By linking this nutrient supply to nutrient emissions into water, the impacts of a balanced diet on the aquatic system can be estimated. To deal with questions arising from changes in demand of agricultural products, production (conventional and organic farming) and agricultural trade, scenarios have been defined. Several scenarios are based on the relationship between diet, agricultural production, nutrient management and environmental impacts of the reference period. Based on the current knowledge of the authors, no holistically observed studies investigating the relationships between human nutrition, land and nutrient resources and impacts on the aquatic environment on a country wide scale exist so far. This paper intents to close this gap in providing a sufficient methodology and applying it for Austria as a case study.

2. Materials and methods

The first step of the investigation covered the quantification of the relationship between nutrition, agricultural production, consumption of resources and environmental impacts in Austria in the period 2001 to 2006 (the reference period). In a second step scenarios were defined to describe alternative diets along with aspects of production. This allowed the quantification of changes in resource consumption and environmental pollution for this alternative diet. In the final step, the differences between different scenarios and the reference period were calculated for comparison.

2.1. Investigating the reference period

2.1.1. Functional unit and system boundaries

The area specific system boundary was set to the national territory of Austria. The space specific system boundary, important for the material flow analysis, includes the troposphere and the groundwater. Due to data availability aspects, the average for the years 2001–2006 (the reference period) was used as the temporal dimension. One average Austrian citizen (cap) is used as the functional unit. Absolute values are related to the total population of Austria (mean population for the years 2001–2006: 8,130,515 inhabitants (Statistik Austria, 2009a)). As the number of incoming foreign tourists almost balances with outgoing Austrians, tourism was neglected (Statistik Austria, 2009b, 2010a, 2010b). For the Austrian agricultural system four different branches were identified: husbandry, crop farming, fruit-growing and vegetable gardening. There was no further differentiation between these branches. However, it was differentiated between production of animal based (including fodder production) and production of plant based food. It was assumed that manure from husbandry is transported to areas where there is a lack of nutrients.

2.1.2. Food chain system

To determine the fluxes between food production and consumption, different data from different sources are required. The production intensity data provide average agricultural production in Austria. Additionally, information on the amount of imported and exported goods (food and agricultural products) is needed to determine the total amount of products used in Austria. Different utilizations of goods (food, feed, industry, seed and energy) have to be distinguished too. Losses occurring during processing and preparation of goods must be considered as well as the amount of food wasted in private households. Finally the average mass of food consumed needs to be determined. Supply balances for agricultural products (Statistik Austria, 2007), official Austrian agricultural reports (BMLFUW, 2008) and nutrition reports (Elmadfa et al., 1998, 2009) were the main data sources used for the investigations. The food chain system of the reference situation describes the fate of food from field to fork.

2.1.3. Agricultural land use

Land use and the agricultural production intensity for the reference period were derived from the official land use and harvest statistics (BMLFUW, 2008). The agricultural production intensity is defined according to Shriar (2000) by yields per unit time and land. Imports and exports of goods (e.g. milk, beef, feedstuff, and tropical fruits) were converted to the agricultural area needed to produce these foods. Main imports, such as soya and rice were linked to the yields of the origin country according to FAO (FAO, 2009).

2.1.4. Material flow analysis

A material flow analysis (MFA) (Baccini and Brunner, 1991) was performed for nitrogen (N) and phosphorus (P). Based on mass flows and corresponding N and P concentrations, complex relationships of nutrient flows were clearly expressed in “processes” and “fluxes”. A MFA-system developed by Thaler et al. (2011) was used as a basic tool for further investigation of nutrient resource consumption and nutrient losses into the environment (Fig. 1). It comprises the processes “animal husbandry”, “plant production and agricultural soil”, “aquatic system”, “troposphere”, “waste and wastewater treatment” and “industry”. “Plant production” is divided into production of fodder, production of plant based food and production of raw materials for industrial use. The process “industry” contains several branches such as processing agricultural products or supporting agriculture with fertilizer, seed and feedstuff. Emissions into air were calculated using the methods from IPCC (Houghton et al., 1997) and EMEP/CORINAIR (EEA, 2006) with factors for Austria derived from the Austrian National Inventory Reports (UBA, 2008; Anderl et al., 2010). Deposition of N was linked to the sources (Anderl et al., 2010). Detailed descriptions of several processes and data sources are published in Thaler et al. (2011) (supplementary material of Thaler et al. (2014) and Zessner et al. (2011c). The MFA models are constructed using the software STAN (Cencic and Rechberger, 2008), a