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Diversity of Mexican diets and agricultural systems and their impact on the land requirements for food

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ABSTRACT

Mexico is a megadiverse country with large agroclimatic diversity and socioeconomic inequality. These two factors result in strong diversity in diets and agricultural systems within the country. In this paper, we assess the impact of Mexican diets and production systems on the per capita land requirements for food. We estimate it for the extremes: from the very basic diet of the poorest share of the population to the affluent diet of the richest share of the population; and for extensive and intensive systems, with irrigation as the indicator of the intensity of the system. We show that the basic diet produced in rainfed systems requires 1620 m^2/cap/yr and produced in irrigate systems requires 700 m^2/cap/yr. The affluent diet produced in rainfed systems requires 2540 m^2/cap/yr and produced in irrigated systems requires 1230 m^2/cap/yr. Hence, differences in diets result in a requirement for 80% or 60% more land for an affluent diet; and differences in production systems result in more than twice the amount of land for extensive than for intensive systems. In 2050, it would be possible to feed the entire population with affluent diets only if all the present area of crop land had the productivity of intensive systems. In contrast, it would be possible to feed all people with a basic diet even if all present crop land area had only the productivity of extensive systems.

1. Introduction

Arable land for crop production is limited. Future global population growth and dietary changes will increase the demand for arable land for food production, especially in developing countries (Davis et al., 2016; Godfray et al., 2010; Kastner et al., 2012). Estimates of the land required for food per person (Kastner and Nonhebel, 2010; Kastner et al., 2012; Peters et al., 2016; de Ruiter et al., 2014) have shown that basic diets in low-income countries require less land than affluent diets in high-income countries which are rich in animal products. For instance, an average person in Southeast Asia with a basic diet requires 1200 m^2/yr in comparison with an average person in southern Europe with an affluent diet rich in animal products who requires 3000 m^2/yr (Kastner et al., 2012). However, climate, type of soil, management practices and use of crop yield-related inputs strongly influence agricultural production and hence the amount of land required per person. For instance, an average person in West Africa, also with a very basic diet, requires 2500 m^2/yr, more than twice the requirement in Southeast Asia where crop yields are higher owing to climate conditions, use of yield-related inputs, and management practices.

Most studies of land requirements for food (Kastner and Nonhebel, 2010; Kastner et al., 2012) use national-level data and do not account for differences in diets and production systems within the country. However, some have analysed differences within countries (Peters et al., 2016; de Ruiter et al., 2014). An analysis of several European countries (de Ruiter et al., 2014) found that differences in the level of education within a country resulted in dietary differences and, therefore, in differences in land requirements for food.

Differences in diets and production systems can be strong within countries, especially in transition countries with large income inequality, such as Mexico. The Gini Index measures income distribution within a country, with 0 being equality (income is the same for all people) and 1 being complete inequality (only one person has all the income). In 2014, Mexico had a Gini index of 0.48 (World Bank, 2016), ranking it the 24th country with the largest income inequality. In Mexico, diets are changing rapidly owing to urbanization and increased income (Rivera et al., 2004), and food consumption patterns are widely diverse. Only 14% of the Mexican population has healthy nutritional habits, and the rest are malnourished or overweight, or have other nutritional problems (del Castillo Negrete, 2013). Dietary patterns depend on income level (Martínez Jasso and Villezca Becerra, 2003) and demographics, with urban and rural populations having different diets (Navarro-Meza et al., 2014).

Wide diversity in Mexican agricultural systems is reflected in the

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heterogeneity of productivity (SIAP, 2016) arising from local variations in agro-climatic, socioeconomic, historical and cultural conditions. Mexico is a megadiverse country with optimal conditions for several types of crops (Sarukhan et al., 2010). Management practices vary from small-scale farms with low input to large-scale farms with high input (González Estrada, 2010).

This wide diversity of diets and agricultural systems motivated the analysis of the impact of these differences on the per capita Land Requirements for Food (LRF). We focus on cropland and do not include pasture land. The aim of this paper is to estimate the LRF per person for the extremes of the spectrum of diets and production systems of Mexico: for the most basic and the most affluent diets; and for extensive and intensive agricultural production systems (using irrigation as the indicator of the degree of intensity of the system). This will indicate the impact of diets and production systems on the attainment of food self-sufficiency for Mexico.

2. Methods

Our approach is based on the methodology of Kastner and Nonhebel (2010), who linked production data (crop yields) and consumption data (food supply) to calculate the arable land needed per person in the Philippines and to identify the relative influence of technological improvements, of population growth or of dietary changes on land use change. However, unlike Kastner and Nonhebel (2010), we do this for different diets within Mexico (based on the socioeconomic development of the population), and for different production systems (irrigated and rainfed). We do this for the years 1980 and 2014 to discuss changes in production systems assuming no changes in diets.

The land used for food for any country consists of the land that was used to produce the food within the country, and the land used to produce imported food. However, since we are assessing the impact of differences in production systems in Mexico, we do not consider the role of food imports. This is discussed in Section 6.2.3.

2.1. Food consumption data

We used national per capita food supply data (FAO, 2013) to illustrate the average Mexican dietary pattern. We used the data for the main food categories of the Mexican diet: cereals, pulses, roots, sugars, vegetable oils, fruits, green vegetables, stimulants, alcoholic beverages and animal products. The food supply data include food losses throughout the food chain, and a more accurate indication of the actual diets is a household-level survey. Nevertheless, our aim is to determine the agricultural land used to produce the food of the Mexican population, and this should include the land for food losses. Furthermore, Gerbens-Leenes et al. (2010) compared food supply data with household-level surveys and showed that food supply data give a good estimate of diets.

A study of dietary patterns in relation to income level in the Mexican population (Martínez Jasso and Villezca Becerra, 2003) used 1998 data from ENIGH, the Mexican National Survey of Household Income and Spending. Food consumption for the Mexican population was divided into 10 groups of equal size (decil I to X) based on income, where decil I had the lowest income and decil X had the highest. We used data from Martínez Jasso and Villezca Becerra (2003) to estimate the differences in food patterns between the poorest and the richest groups of the population (see Appendix 1 of Supplementary Material). We calculated, for each food category, the ratio between decil I and the Mexican average, and between decil X and the Mexican average. Then we combined these ratios with the food supply data of the FAO (2013) to estimate the food supply data in kcal/cap/day and in kg/cap/yr for each decil group.

To determine the dietary differences within the country due to the socioeconomic development of the population, we compared the average food supply data in kcal/cap/day (FAO, 2013) with the food supply for the poorest 10% of the population (decil I) and the richest 10% of the population (decil X) (see Fig. 2).

2.2. Crops production data

We used data from the Agrofood and Fisheries Information Service of the Mexican government, SIAP (2016), for planted area, harvested area and production per crop for 1980 and for 2014. The SIAP database distinguishes between irrigated and rainfed agriculture. We class irrigated systems as intensive and rainfed systems as extensive; We selected irrigation as indicator because, in Mexico, it is the yield-related input that has the strongest impact on crop yields (Appendix 4 of Supplementary Material).

The FAO (2013) data give, for each food category, a product designated "others", for instance "Cereals, others" (see Table A2.1). Since it is not possible to link these consumption data with the production data, we used one crop to represent each food category of the crop-based components of the diet, this being the crop that is most consumed in each food category (Appendix 2 of Supplementary Material).

To calculate the per capita use of arable land, we used the national average data of crop yields for irrigated and rainfed systems and every year.

2.3. Calculation of the land requirements for food (LRF)

For all crop-based food categories of the diet (cereals, pulses, roots, sugars, vegetable oils, vegetables, fruits, stimulants and alcoholic beverages), we used conversion factors from Kastner and Nonhebel (2010) (Appendix A of Supplementary Material) to convert the food consumption data into the crop equivalent. Only the following needed to be converted: sugars into sugar cane (Fig. 1), vegetable oil into soybeans and beer into barley. By dividing this value by the yield in ton/ha of the crop representing the food category (see Appendix 2 of Supplementary Material for the crops of each food category), we obtained the per capita LRF in m^2/cap/yr. This involved conversion of tons into kilograms and hectares into square meters.

Calculation of the LRF for the animal products used the Kastner and Nonhebel (2010) assumption that 3 times more land is needed to produce one kilocalorie of animal-based food than one kilocalorie of crop-based food (Fig. 2).

3. Diets: impact of socioeconomic development

The average Mexican food supply is 3000 kcal/cap/day (FAO, 2013). The daily caloric intake of the poorest share of the population

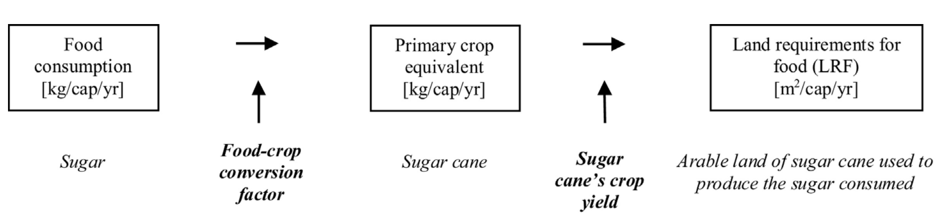

Fig. 1. Illustration of our approach to calculate the land requirements for food (LRF) based on Kastner and Nonhebel (2010). See text for details.