frontiers in Sustainable Food Systems

PERSPECTIVE
published: 20 December 2018
doi: 10.3389/fsufs.2018.00088

# Implications of the Western Diet for Agricultural Production, Health and Climate Change

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Our current eating habits affect not only our health but also the environment and agricultural production. Previous studies have shown the relationship between our eating habits and each of these three topics independently. Here we analyzed the links between health, agricultural production and environmental data together, using global databases. We found the Western diet—dominated by processed foods, refined sugar, fats and flours—has negative implications for all three. Increased production and consumption of sugar and refined grains over the last 40 years correlates with negative human health outcomes globally: an alarming increase in diseases such as diabetes, overweight and obesity. In addition to these health effects, the Western diet relies on methods of agricultural production that negatively impact ecosystems, increase the use of fossil fuels and boost greenhouse gas emissions (GHGe). Ancestral communities around the world consume a greater variety of plant and animal species (including insects) than Western urban populations, with positive health and environmental outcomes. Processed food, on the other hand, comes at a high environmental cost: it generates high GHGe, accelerates land-use change to support agriculture and intensive livestock activities, and requires huge amounts of water and agrochemicals. Changing the Western diet could substantially reduce diabetes, obesity, and GHGe. Consuming insects and a wider variety of plant species could improve health outcomes and reduce some of the environmental impacts of agricultural production.

**Keywords: edible insect, Western diet feeding, agricultural production and development, Greenhouse gases emissions, diabetes**

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***Edited by:***
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***Specialty section:***
*This article was submitted to Nutrition and Environmental Sustainability, a section of the journal Frontiers in Sustainable Food Systems*

***Received:*** *31 August 2018*
***Accepted:*** *05 December 2018*
***Published:*** *20 December 2018*

***Citation:***
*Vega Mejía N, Ponce Reyes R, Martinez Y, Carrasco O and Cerritos R (2018) Implications of the Western Diet for Agricultural Production, Health and Climate Change. Front. Sustain. Food Syst. 2:88. doi: 10.3389/fsufs.2018.00088*

A number of studies have shown an association between diet and pandemic diseases such as diabetes and obesity (Guigliano et al., 2018). Our current eating habits affect not only our health but also the environment, clearing extensive natural areas and producing large amounts of GHGe. Here, we investigate how the actual Western diet, dominated by low-cost, highly processed food, is a driver for changes throughout the agricultural sector and how these changes increase the incidence of nutritional and metabolic diseases and greenhouse gases emissions. Here we reviewed three databases spanning from 1975 to 2015: (1) environmental, obtained from the Food and Agriculture Organization (FAO) (FAOSTAT, 2018), (2) health, obtained from the World Health Organization (WHO) (WHO database, 2018), and (3) agricultural production (FAOSTAT, 2018). We carried out a multiple correlation analysis using these databases and the expected population growth data (in urban and rural settings) at a global scale. To eliminate the possibility that these correlations are only associated with the demographic behavior we included population growth in the analysis.

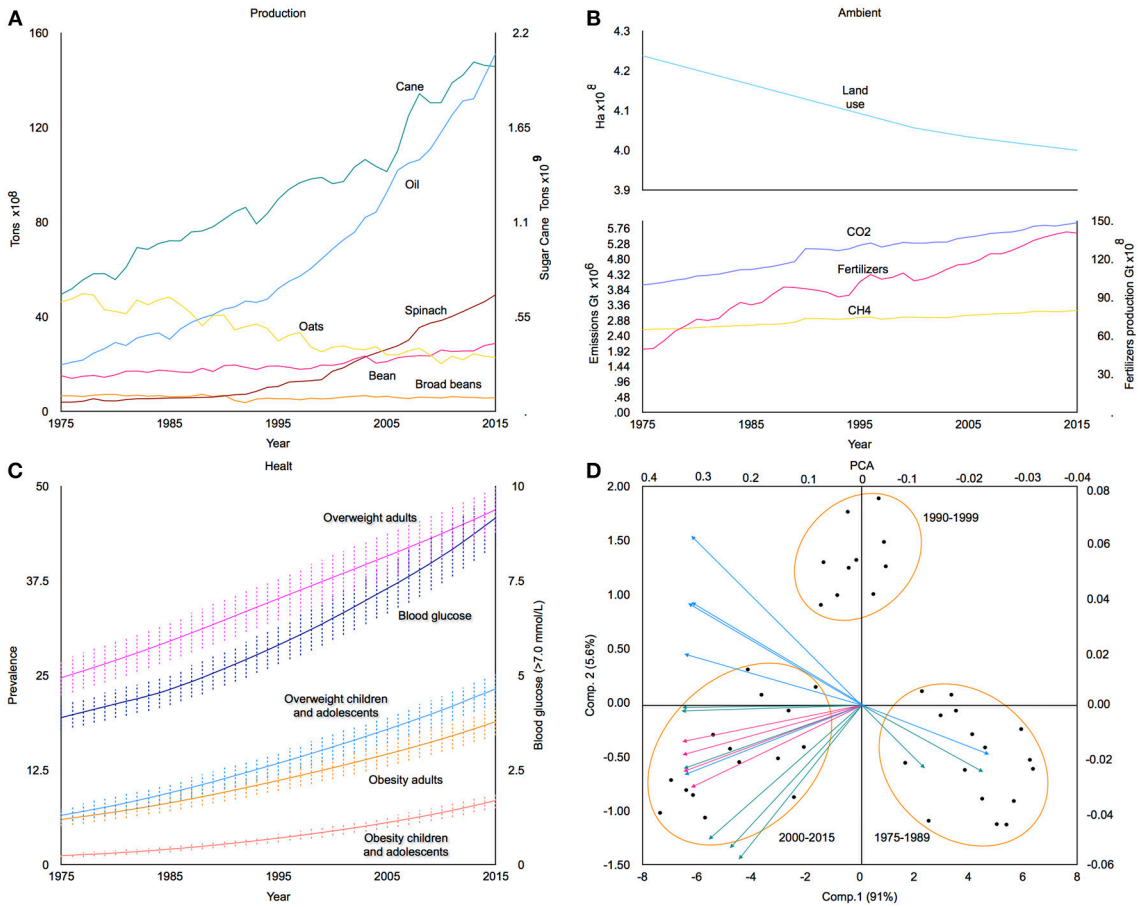


**FIGURE 1 |** Worldwide health, environmental, and agricultural production data in a 40-year period and the correlation between them. **(A)** The agricultural production tendency indicates that sugarcane and oil are the main products supplied to the food industry. **(B)** Environmental data represented by land-use change as natural areas are reduced in size while agricultural land coverage and $CO_2$ and $CH_4$ emissions increase. **(C)** The rise in the prevalence of overweight and obesity in adults and children, and diabetes, measured by the amount of blood glucose. **(D)** Principal component analysis (PCA) of 15 variables and worldwide demography data. Health variables: (1) Overweight adults, (2) blood glucose, (3) overweight children and adolescents, (4) obesity adults, (5) obesity children and adolescents; Agricultural produce variables: (6) Sugarcane, (7) oats, (8) bean, (9) oil, (10) spinach, (11) broad beans; Environmental variables: (12) land use-change, (13) $CO_2$, (14) fertilizers, (15) $CH_4$. PCA reveals a strong relation between health problems associated with diet trends and with sugarcane production and the use of fertilizers.

**TABLE 1 |** Variances and variance proportion of the first three components in the comparison between environmental, health and agricultural production data.

| Component | 1 | 2 | 3 |
|---|---|---|---|
| Variances | 17.3 | 1.8 | 0.34 |
| Variance proportion | 0.913 | 0.056 | 0.016 |

In the last five decades, sugar consumption has tripled worldwide (Lustig et al., 2012). During this time, the production of sweeteners and oils, two basic ingredients of the Western diet, has risen, in some cases, by an order of magnitude (FAOSTAT, 2018). For example, in case of the sweeteners, sugarcane production has increased by 294% ($2.0 \times 10^9$ tons in 2015 from $6.8 \times 10^8$ tons in 1975) (**Figure 1A**). Corn production has also increased 310% ($1.0 \times 10^9$ tons in 2016 from $6.8 \times 10^8$ tons in 1975) from which, at least in the USA a considerable proportion goes to the production of high-fructose corn syrup (Parker et al., 2010). A great amount of energy is required to produce these commodities (mostly from burning of fossil fuels), which produces $CO_2$ and $CH_4$. In the past 40 years the amount of $CO_2$ produced by agricultural activities has increased 1.5 times from 3.9 to 5.9 $\times 10^6$ gigagrams, while land-use change has decreased natural areas globally to expand agricultural areas (**Figure 1B**). Combined with environmental and food security issues, several regions of the planet are suffering of a widespread diet-related health crisis, characterized by nutritional diseases including malnutrition, overweight, and obesity, as well as nutrient-related metabolic disorders such as type 2 diabetes, cardiovascular disease, hypertension, and cancer (WHO database, 2018). The prevalence of obesity in children worldwide has increased from 1% in 1975 to 7% in 2015, while diabetes, measured by the mean level of glucose in blood (mmol/L), has increased from 3.8 to 8.4 in the same period of time (**Figure 1C**). These pandemics have economic and environmental consequences. The public health

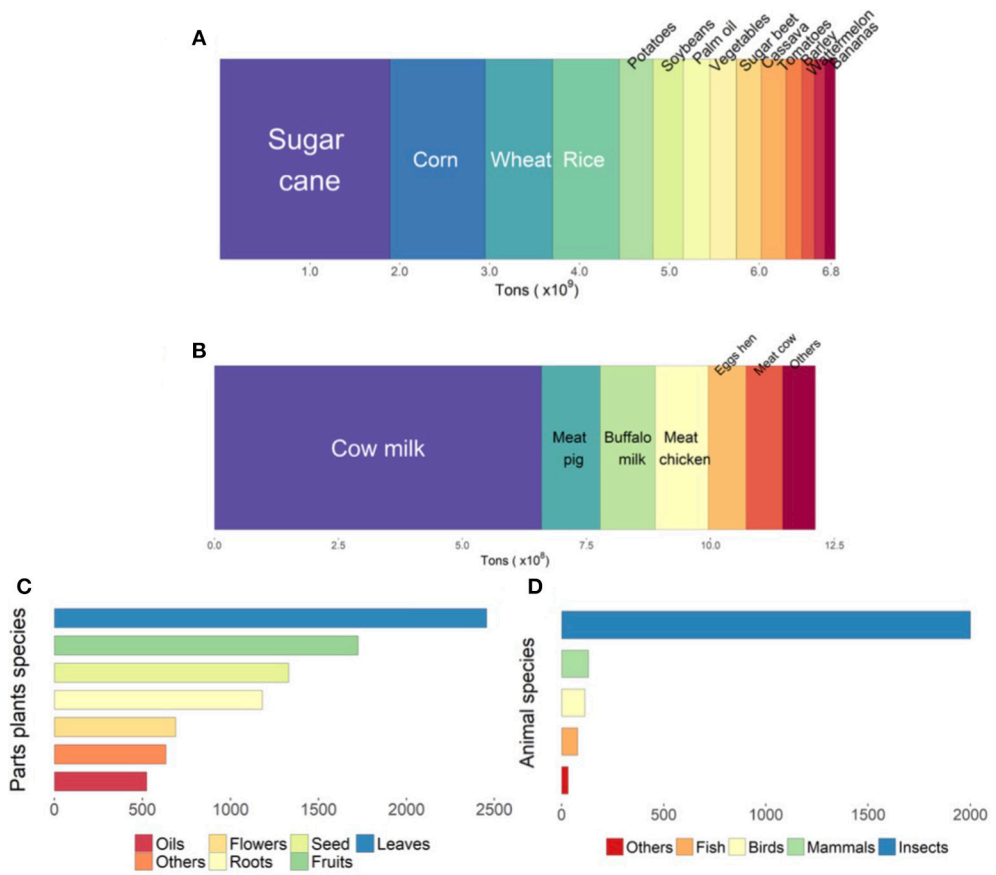


**FIGURE 2 |** Plants and animals making up the highest human consumption rates in 2016 and the potential species that can be consumed locally. **(A)** Sugarcane is the most produced agricultural product with almost 2 × $10^9$ tons/year, followed by corn, wheat, and rice. **(B)** Cow's milk and meat, along with pork and chicken, are currently the main animal protein sources for the human population. **(C)** Several plants' parts can be used from thousands of species for human consumption, including leaves, fruits, seeds and roots (Guil and Torija, 2002; Shaheen et al., 2017). **(D)** Animals that could be consumed as part of the human diet, the insect group could have the highest extraction potential due to its diversity and population density (Van Huis, 2013).

system of some countries have collapsed due to a lack of resources to treat these diseases that are driven, mainly, by their citizens' lifestyles (WHO database, 2018).

Based in Principal Component Analysis, our results showed a clear positive relation and same growth rate between health issues such as overweight, obesity, and diabetes with some environmental variables and its inputs (synthetic fertilizers) (**Table 1**). The increase in sugarcane production worldwide is almost directly proportional to the accumulation of sugar in the blood (**Figure 1D** and although it is not the sole contributor to the myriad of metabolic diseases, refined sugar (produced from sugarcane) has been associated with metabolic diseases (Goran et al., 2013; Maccdonald, 2016). Some environmental variables have the same growth rate as those related to health and production, specifically sugarcane and synthetic fertilizers. On the other hand, products of high nutritional value such as oats, broad beans, beans, and spinach tend to have an inverse relation with health variables (**Table 1**). A decline in broad bean production over the past 40 years took place when the production of flours and sugars increased, in order to mass produce processed foods, such as refined pastas and high sugar content drinks, consumed by urban populations. Examining the correlation between GHGe and agricultural activities, we didn't observe a proportional growth behavior with respect to health and production variables. This could be because the emission of GHGe might only be a small fraction of a larger total of the production chain and we may need to include another fraction, in addition to the one related to agriculture that accounts for processing, transportation, and packing food.

World sugar production is mostly destined to produce beverages with a high percentage of processed sugar. In the US, multiple studies have shown that the consumption of these drinks is associated with health issues such as overweight, obesity, and diabetes (CDC database, 2018). This trend becomes concerning when research shows that adults and young people consume between 143 and 145 calories per day from these products (CDC database, 2018). But the consumption habits of sugary drinks are not the only problems that affect the population in terms of health and environment. Ruminant production for meat consumption has been increasing significantly for more than 50

years, along with $CO_2$ and $CH_4$ emissions and land-use change due to this activity (Ripple et al., 2013). Most wheat, corn, and rice produced worldwide is largely used in the production of highly processed foods (Indexmundi database, 2018). The production of processed foods, such as instant soups, has been maintained from 2012 to present at 100 billion rations annually (WINA database, 2018). This type of food represents the urban way of life and has unfortunately spread to rural areas of Latin American and Asian countries. These highly processed foods not only contain high sodium amounts but also various types of sugars, which besides the aforementioned health problems, are associated with cardiometabolic risk factors (Huh et al., 2017).

It is estimated that at a global level, we could consume a total of almost 10,000 plant species and at least 2,500 animal species (**Figure 2**), along with a great variety of fungi, algae, and lichens. However, 75% of the world's food comes from only 12 plant species and less than five animal species (FAO, 1999), forming the basis of the current feeding habits in urban areas (**Figures 2A, B**). Whereas in rural populations, namely in those where ancestral ethnic groups still live, diets widen in terms of the number of species eaten and are seasonally structured (Shaheen et al., 2017). Recent research has evaluated not only the nutritional value of the diets but also their impacts in terms of carbon footprints (Behrens et al., 2017). For example, in a recent study, Vázquez-Rowe et al. (2017) showed that the traditional Peruvian diet, based on native foods, produces lower environmental impacts and lower health risks, than those diets that follow the Western diet model (e.g., increasing beef consumption). Several studies have shown that in terms of health and carbon footprint, it is more beneficial to include insects and other forms of protein, carbohydrates, vitamins, and minerals in our diet (Van Huis, 2013). Consuming insects could reduce these environmental and health problems, including the advantages of acquiring high quality proteins and reduce environmental detrimental effects due to their abundance (**Figure 2D**), including about 2,000 edible species worldwide (Wegier et al., 2017).

To mitigate health and environmental problems simultaneously a potential solution would be to enact public policies at a national level encouraging the development (and implementation) of national diet recommendations. Regardless of how these policies are enacted, it is essential that each country includes urban areas in their policies and to design a diet enriched with a higher variety of local animal and plant species (Guil and Torija, 2002). These types of diets have the potential to significantly reduce health, environment, and agricultural production problems.

It has recently been observed in the USA that the increase in temperatures as a consequence of global climate change, could deactivate certain metabolic processes of brown adipose tissue leading to insulin resistance and trigger an increase in the prevalence of diabetes (Blauw et al., 2017). Currently, there are more than 400 million adults who suffer from type 2 diabetes, which caused 1.5 million deaths in 2012 with 20-year projections indicating an increase of more than 30% (WHO, 2016). This percentage might be higher if we consider deaths caused by obesity and cardiovascular diseases. These are consequences of our diet trends, which increase GHGe and temperatures and in turn create a surge in the number of diabetes cases.

It is clear that our actual diets cause a drastic acceleration of GHGe production, a marked increase of obesity and diabetes prevalence, and an expansion of land-use change in order to satisfy the demand to produce highly processed food products and sugary drinks. Research shows that a viable solution to this problem is to modify our diet and, where feasible, return to the consumption of local products with high nutritional value and lower energy expenses to produce them.

## AUTHOR CONTRIBUTIONS

NV, find data base, analysis of data and its interpretation, drafted the manuscript. RC participated in study design, data analysis and interpretation, and were major contributors in writing the manuscript. RP, YM, and OC drafted the manuscript. All authors read and approved the final manuscript.

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**Conflict of Interest Statement:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.