Assessing the Environmental Impact of Sustainable Food Systems

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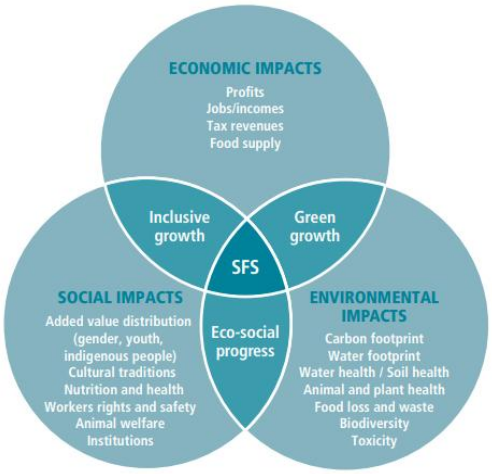
Introduction

Human health and the environment are intricately connected, with a healthy environment significantly boosting physical, mental, and social well-being. Climate change poses a major threat to human health, as highlighted by the World Health Organization (WHO), which reports that 3.6 billion people live in areas highly vulnerable to climate change. Human activities are major drivers of climate change, global warming, greenhouse gas emissions, biodiversity loss, and land degradation. To achieve environmental sustainability, it is crucial to operate within planetary boundaries—environmental limits within which human activities should remain. Common discussions about reducing environmental impacts often focus on practices like using reusable bags, driving electric vehicles, or switching to clean energy. However, the impact of food choices on carbon footprints is less frequently addressed. Recent scrutiny, driven by the Sustainable Development Goals (SDGs), has increasingly focused on the carbon emissions associated with food and food-related products.

The carbon footprint (CF) of a food product measures the greenhouse gases emitted directly or indirectly through its production (Wicki et al., 2020). CF is closely linked to climate change, which in turn affects environmental issues and food security globally. The rising global population and increased demand for resources have intensified food and energy crises, leading to greater environmental pressures due to higher food consumption.

Animal agriculture contributes 18% of greenhouse gas emissions. As shown in figure 1, meat and dairy products produce significantly more greenhouse gases compared to plant-based foods. Beef, lamb, and mutton are particularly high emitters, while plant-based foods such as potatoes, bananas, and wheat have much lower greenhouse gas emissions.

A sustainable food system (SFS), according to the Food and Agriculture Organization (FAO), is one that ensures food security and nutrition for all without compromising the economic, social, and environmental foundations needed to support future generations. Sustainable food system development takes a holistic approach, requiring positive outcomes across three dimensions: economic, social, and environmental (Figure 1). Economically, a food system is sustainable if its activities are commercially or fiscally viable. Social sustainability involves equitable distribution of economic value, considering vulnerable groups by gender, age, race, etc. Environmentally, a food system is sustainable if its activities have neutral or positive impacts on the natural environment, including factors like biodiversity, water, soil, plant and animal health, carbon and water footprints, food loss and waste, and toxicity.



Source: Adapted from FAO, 2014.

Fig 1. Three dimensions of sustainable Food Systems.

The "water footprint" (WF) measures the volume of water used in producing food items, categorized by source. The blue water footprint (Fig. 2) refers to water from surface or groundwater used for irrigation, industrial, and domestic purposes. The green water footprint (Fig 3) refers to precipitation stored in the soil's root zone, which evaporates, is transpired, or is incorporated into a product. This type of water is particularly relevant for agricultural, horticultural, and forestry production.

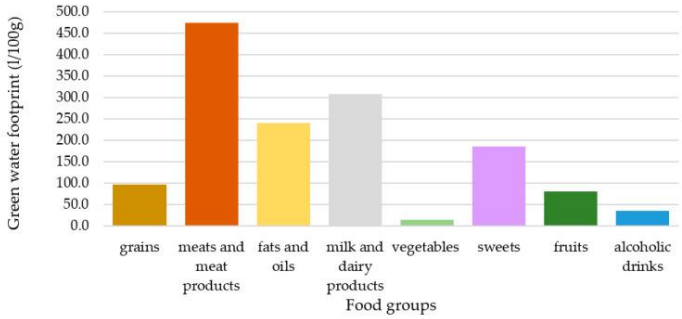


Fig 2. Blue water foot print of food commodities.

Environment foot prints of animal based diets

As the environmental impact of the current food system—especially from animal-based food production—becomes increasingly evident, there is growing momentum among food industry leaders, climate activists, and policymakers to advocate for diets that emphasize plant-sourced foods (Tziva et al., 2020). Research highlights that the current levels of animal production are unsustainable, leading to excessive use of natural resources and significant environmental damage (Jarmul et al., 2020). The EAT-Lancet

Commission has estimated that animal-derived food production, particularly red meat, contributes substantially to greenhouse gas emissions (GHGEs) in the food system, including carbon dioxide, methane, and nitrous oxide (Willett et al., 2019). Approximately 88% of emissions from animal products occur on the farm, with only 12% coming from post-production activities such as processing, refrigeration, transport, retail, and waste. Major sources of these emissions include feed crop production, which involves synthetic fertilizers, poor land and soil management, and non-renewable energy use (Vibart et al., 2021). Livestock rearing also produces significant on-farm emissions from enteric fermentation and manure management, accounting for 14–51% of total anthropogenic GHGEs.

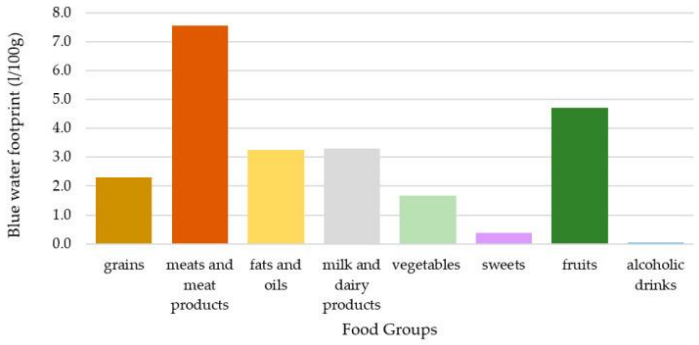


Fig 3. Green water footprint of food commodities

Animal products, particularly dairy, animal fats, and meats, have large ecological footprints. Estimates indicate that 0.85 hectares per person (8,500 square meters) are needed annually to support an average global diet, with animal products consuming up to 87% of land use. Meat and fish alone contribute nearly half (44%) to land degradation, largely due to the extensive terrestrial feed crop production required for livestock and aquaculture operations. The intense land use for animal feed leads to significant soil erosion and degradation, with about 90% of cropland losing soil at a rate 13 times faster than sustainable levels. Furthermore, land used for staple crops and feed results in carbon stock loss, with deforestation contributing approximately 2.9 gigatonnes of CO2 emissions globally each year (Food and Agriculture Organization of the United Nations, 2021).

Water use for producing various foods and forage crops ranges from 500 to 2,000 liters per kilogram of food, with animal protein production requiring about 100 times more water than grain production. Although livestock watering accounts for only 1.3% of total agricultural water use, the water needed for producing feed and forage crops substantially increases overall water requirements. Studies suggest that shifting from animal products to plant-based foods could raise freshwater use by up to 16% due to the high water demands of certain crops, such as legumes, vegetables, and fruits. Specific foods, like nuts, have a higher scarcity-weighted water use compared to dairy, eggs, processed meats, and fish (Clark et al., 2019).

Environment foot print of plant-based diet

Diet composition plays a crucial role in environmental impact through food systems, which are major contributors to climate change and are expected to have increasing effects due to population growth (Aleksandrowicz et al., 2018). As a result, nutrient-balanced diets that focus on plant-based foods may be essential in bridging human health and environmental sustainability. For instance, the EAT-Lancet Commission Panel in 2019 proposed the Planetary Diet, which primarily consists of vegetables, fruits, whole grains, legumes, nuts, and unsaturated fats, with moderate or minimal amounts of fish and poultry, and little to no red meat, highly processed foods, processed meats, added sugars, refined cereals, and starchy vegetables. This diet could potentially meet global targets for environmental sustainability, nutrition, and health (EAT-Lancet Commission).

Aleksandrowicz et al. (2016) reviewed the environmental impacts of various plant-based diets, including pescatarian, Mediterranean, healthy dietary guidelines, vegetarian, and vegan diets. They found that greenhouse gas emissions (GHGEs), land use, and water use were reduced by 22%, 28%, and 18% respectively across all plant-based diet types. Vegan diets showed the greatest reductions in GHGEs (−51%) and land use (−45%), while the lowest reductions were observed in diets with balanced energy intake or partial meat replacement with dairy products. Vegetarian diets showed the most significant benefit for water use (−37%), although vegan diets exhibited an increase in water use, which was controversial due to limited studies on the vegan diet's impact on water use (Zucchinelli et al., 2021).

Chaudhary et al. (2018) analyzed the nutrition and environmental outcomes of dietary changes across 156 countries under three scenarios: global healthy eating guidelines, vegan diets, and vegetarian diets. The results indicated that shifting towards lower animal product consumption and more plant-based foods improved nutrient intake and reduced GHGEs and freshwater use in North America and Europe. However, in high-income countries, achieving adequate nutrient intake in regions like South Asia required increased GHGEs and freshwater use. Thus, dietary changes did not always produce both nutritional and environmental benefits across all countries.

Behavioural Interventions to Encourage Plant-Based Eating

Behavioural intervention strategies can be powerful tools for encouraging consumers to choose plant-based foods. For instance, a study conducted in three university cafeterias found that increasing the proportion of vegetarian meals offered led to a 41% to 79% rise in their sales, suggesting that making plant-based options more available and substituting them for other choices can effectively boost their consumption. Additionally, research in a university cafeteria showed that labelling vegetables with a focus on taste

increased their consumption by 39%, compared to health-focused labelling of the same items. This evidence supports the idea that menu design and labelling strategies can significantly influence consumer preferences. These findings highlight that enhancing the variety and availability of vegetarian dishes, along with using appealing flavour-focused messaging, could be effective strategies for increasing plant-based food consumption in schools and other food service environments (Epsiona et al., 2022).

Conclusion

In summary, plant-based diets (PBDs) have the potential to be nutritionally sufficient, healthy, culturally suitable, cost-effective, and environmentally friendly. However, to facilitate a shift from current eating habits to these sustainable plant-based diets, it is important to address and overcome existing obstacles. Key measures could involve updating and widely distributing food-based dietary guidelines (FDBGs), establishing and promoting urban gardens and farms, fortifying foods, innovating plant-based alternatives using local ingredients, and implementing taxes on unhealthy food products.

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