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Healthy diets for sustainable food systems: a narrative review

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To face the challenge of feeding a growing population that changes its lifestyles and diets while trying to conserve natural resources and to protect biodiversity, there are three main strategies to achieve such sustainability goals: (1) changing current agricultural practices, (2) reducing losses and waste throughout the food production and processing chain, and (3) promoting healthy and sustainable diets. Strategies (1) and (2) are important and they are part of the academic, government and industrial agenda, but strategy (3) has been given little attention so far. However, increasing the efficiency of the production, processing and distribution of foods (strategies 1 and 2) may trigger unexpected rebound effects that could offset the gains. Hence, addressing the demand-side by promoting (and facilitating) healthy and sustainable food choices is a valuable tool to contribute to the sustainability of food systems. In this narrative review we (1) explored the environmental impacts of the global food system; (2) reviewed the role of efficiency improvement in agricultural activities to mitigate the environmental impact of food production; (3) summarized the limitations related to technical and technological changes due to the rebound effect; and (4) reviewed what healthy eating is and why it is the central piece of a sustainable food system.

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Environmental significance

Food systems are at the center of ecological collapse due to their considerable impact on multiple dimensions of the terrestrial biosphere. Several strategies have been proposed to address the great challenge of feeding a growing population that changes its lifestyle and diet while trying to conserve natural resources and to protect biodiversity. Most of these initiatives were related to improving agricultural systems, but potential negative consequences could arise when increasing efficiency due to the rebound effect. The adoption of healthy diets has emerged in the last decade as a critical tool to address both public health issues and food system sustainability through changes in food demand, which could modify the natural resources used and the environmental degradation.

1. Introduction

Since the middle of the 20th century, the accelerated increase in the global population, as well as the consumption per capita, has driven an exponential growth in the production of goods and services. As a consequence, humanity's impact on Earth's systems followed the same trend.[1] At present, human activities have exceeded the planet's capacity to provide the resources we are using and the ability to absorb our waste, which have generated a series of biophysical changes at a rate never witnessed in Earth's history.[2]

Such biophysical changes are occurring at least in six dimensions: (1) alteration of the global climate system, (2) widespread pollution of air, water and soil, (3) accelerated loss of biodiversity, (4) reconfiguration of the biogeochemical cycles of carbon, nitrogen and phosphorus, (5) changes in land use and land cover, and (6) depletion of resources, including freshwater and arable land.[3] Each of these dimensions interacts with the others in a complex and dynamic way, disrupting basic conditions for human health: it worsens the quality of the air we breathe and the water we drink, it decreases the nutritional density of the food we produce, it increases our exposure to infectious diseases and to natural phenomena such as heat waves, droughts, fires and tropical storms, among others.[4] Therefore, the well-being of humanity and the degradation of the biosphere cannot remain disconnected for much longer.[5–7]

In addition, such imbalances in the Earth's systems increase the vulnerability of human societies to the contemporary global health challenges, such as emerging and re-emerging infectious diseases, as shown by the coronavirus disease 2019 (COVID-19) pandemic, antimicrobial resistance, and the increasing burden of non-communicable diseases (NCDs).[8] This becomes even more critical by the interplay of these issues, scaling up the complexity of the challenges we face.[9] For instance, people with one or more NCDs were at higher risk of death from a COVID-19 infection.[10] While fossil fuel use, industrial contamination,

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smoking and sedentarism (among others) are factors that need to be addressed, there is no piece of the puzzle as important as food: food production and consumption play a major role in the deterioration of both the environment and public health.[11,12] Given the magnitude of the challenge around food and the need to radically change the way we produce and consume it, it has been called the "Great Food Transformation".[13]

In order to face the great challenge of feeding a growing population that changes its diets and lifestyles, while conserving natural resources and protecting biodiversity, multiple actions have been proposed to achieve food system sustainability.[14] However, the actions that have historically dominated the academic and productive debates can be classified in two groups of strategies: (1) change how food is produced at farms in order to increase the efficiency of agricultural systems (crop and livestock); and (2) reduce losses and waste in the food chain. While both strategies are important to achieve food systems that are capable of supplying food in a sufficient quantity and adequate quality, they are not enough.[15,16]

Firstly, increasing the efficiency of the production, processing and distribution of foods may trigger unexpected rebound effects that could offset the gains. Although there are several cases of rebound effect in the history of agriculture (*i.e.*: deforestation besides yield increases), it is not usually considered in food system thinking and it's poorly understood.[17] Secondly, it is uncommon to consider the role of the end-users of food systems: the consumers who eat the food. Consumer choices may ultimately determine the demand for food and, consequently, the use of natural resources and environmental degradation.[18,19] In addition, dietary choices also affect human health significantly and, together with other components of lifestyle, are largely responsible for the current (and increasing) high prevalence of NCDs.[20] Thirdly, improving the efficiency in the supply-side may have negative impacts on the demand-side, such as unhealthy eating due to changes in food availability and food prices. In this sense, an integrative analysis of these topics is missing.

In this narrative review we (1) explored the environmental impacts of the global food system; (2) reviewed the role of efficiency improvement in agricultural activities to mitigate the environmental impact of food production; (3) summarized the limitations related to technical and technological changes due to the rebound effect; and (4) reviewed what healthy eating is and why it is the central piece of a sustainable food system.

2. Global food system and its environmental impacts

As famines were left behind during the 20th century, agriculture became one of the human activities with the largest impact on the structure and functioning of the biosphere.[11,21] In order to supply food, fiber and bioenergy to a continuously growing global population, humanity uses almost half of the Earth's ice-free land area:[22] 3203 million hectares (Mha) of pastures (about 26% of Earth's ice-free land), and 1557 Mha of cropland (about 12% of Earth's ice-free land), of which 56% are for direct human consumption (food hereafter), 32% for animal consumption (feed hereafter), 9% for biofuels, and 2% for fiber and 1% for other uses.[23] This appropriation of land has occurred at the expense of the conversion of hundreds of millions of hectares of natural ecosystems, which have released 512 Gt CO_2-eq to the atmosphere between 1961 and 2017, the equivalent to 10 years of current emissions.[24] At present, land-use use and land-use change emissions represent 32% of the 18 Gt CO_2-eq emitted by the global food system, which correspond to one-third of total anthropogenic greenhouse gas (GHG) emissions.[25] At the same time, the expansion of the agricultural frontier has caused an alarming reduction in biodiversity.[26]

Agriculture and livestock farming have radically altered the biogeochemical cycles of nitrogen and phosphorus.[27] In rich nations from Europe and North America, the excessive fertilizer application has led to water pollution through eutrophication. But in less developed nations from Africa and Latin America, fertilization was not enough to meet the nutrient needs of crops, causing a depletion of nutrients and jeopardizing the soil's natural capital.[28] While nitrogen is an abundant element in the atmosphere that can be transformed into fertilizer through the Haber–Bosch process, phosphorus is a scarce input because it is obtained through rock mining.[29] Some scholars have pointed out that the world's phosphorus reserves are running low, endangering global food security.[30]

Likewise, the excessive application of pesticides has also led to soil and water contamination, and to a reduction in the population of pollinators and other insects on which agriculture depends.[31] Pesticides have also caused damage to human health and ecosystems in general.[32] Even so, highly toxic pesticides are still in widespread use internationally and constitute a substantial challenge to human health.[33]

Regarding water, in most regions of the world, 92% of freshwater is used for agriculture, which is obtained by pumping it from groundwater, aquifers, rivers and lakes.[34] At the global scale, approximately 360 Mha are under irrigation which represents nearly 40% of the total area used for agricultural production.[35] While this is associated with important agricultural production, it also leads to water reserves depletion and soil salinization.[36,37] Nearly 12% of the global consumption of groundwater and surface water for irrigation is for feed, not for food, fibers or other crop products.[38]

But problems are not limited to terrestrial ecosystems. The production of blue foods (defined as all edible aquatic organisms, including fish, shellfish and algae from marine and freshwater production systems) has quadrupled in the last 50 years, and the exploitation of marine resources has led to saturate or exceed fishing capacity in 90% of the world's fishing grounds.[39] Although, at present half of the fish meat is provided by fish farms, while the other half is provided by deep-sea fishing.[40] In this regard, the most common practice of deep-sea fishing is trawling, which acts as a giant harvester of the seabed, keeping what it is of interest and discarding what it is not: often turtles, dolphins, sharks and other emblematic species that are thrown back to the sea without life.[41]

Regarding indirect consequences, food systems require facilities and machinery such as ports, ships, tractors, harvesters, wire fences and silos, which are made of metals, wood, plastics and other inputs of industrial origin that use fossil fuels for their manufacture.[42] In addition, a wide diversity of chemicals are utilized, including antibiotics and others to promote growth in domestic animals and to prevent and treat diseases when they are raised under confinement conditions.[43,44] The misuse of these compounds contaminates water and soil, and contributes to the alarming growth of antimicrobial resistance.[45]

Projections indicated that by 2050 the global population will reach nearly 10 billion, and the demand for food will increase by 35% to 56% compared to 2010.[46] If the environmental impact of the global food system is not addressed, it is highly likely to get worse.[47] For instance, it was estimated that in a business as usual scenario, for 2050 (compared to 2010) the crop area will increase from 12 to 21 million km^2, annual GHG emissions from 5.2 to 9.9 Gt CO_2-eq, annual freshwater withdrawal from 1800 to 2970 km^3, while fertilizer application will be 51% and 54% higher for nitrogen and phosphorus, respectively.[48]

Some authors argue that the current food production is enough to feed the world, and even the projected human population by 2050, because one third of global food production is wasted or lost, and 35% of grains are devoted to livestock.[49,50] While calories and macronutrients are necessary to avoid hunger and undernutrition, in order to have good health it is necessary to consume the micronutrients present in some foods that are produced in quantities that are insufficient to meet current demands (such as fruits and vegetables).[51] In addition, the environmental problems caused by current crop and livestock systems, jeopardize our ability to produce the food we need tomorrow.[21]

3. Improving efficiency to reduce the environmental impact of food systems

Industrial agriculture is based on farming systems that use modern technologies and economies of scale in order to maximize yields relative to land use and production costs (*i.e.* costs of labor, technology, seeds, fertilizers, and pesticides). While industrial agriculture aims to increase agricultural efficiency and so, as a side-effect, reduces environmental impacts per unit of output, due to its often-large scale, homogeneous landscapes, low crop-diversity, and high use of pesticides, it can result paradoxically in a rise of the environmental impacts per unit of area.[52]

One of the most known approaches to achieve a decoupling between economic/productive growth and environmental degradation is sustainable intensification, which aims to increase food production on existing lands and reduce its environmental impact through the rational use of inputs.[53] Although sustainable intensification designates a goal for the development of agricultural systems (cero deforestation plus lowering environmental impact), it does not favor any particular agronomic route to achieve it.[54] Some examples of sustainable intensification include the application of fertilizers in the right quantities to avoid soil impoverishment and to prevent soil and water contamination; the improvement of irrigation technology to reduce water use; the use of cover crops to increase soil fertility and reduce weeds; and reduce tillage to prevent soil erosion.

Despite being a promising alternative with great potential to contribute to climate change mitigation and the reduction of the ecological footprint associated with food production, sustainable intensification faces critics. Since industrial agriculture and the food industry have shaped each other, sustainable intensification practices have been developed primarily for major crops used as commodities, particularly those used as animal fodder, as inputs to produce ultra-processed foods and as raw material for biofuel production (*i.e.* soybean, palm oil, maize).[55] Although there are many efforts around the world to sustainably intensify the production in small farming systems, the farmers who have benefited the most were those who are highly capitalized and have the capacity to access trade networks and new technologies, mostly private software and hardware.[56] For this reason, some authors have suggested that sustainable intensification is a Trojan horse driven by biotech companies and international trade organizations, whose mission is to deepen the industrial agriculture model while disguising it as green.[57] In this sense, in order to avoid a further deepening of inequality, it is necessary to design public policies that facilitate the adoption of technologies for all farmers.[58]

As an alternative to sustainable intensification, agroecology and other forms of agriculture have been proposed, such as ecological intensification and conservation agriculture, among others.[59] These forms of agricultural production are based on the application of ecological principles for the design of multifunctional landscapes that provide food and fiber, but also ecosystem services.[60] Because ecosystem services are the contributions of ecosystems to human wellbeing (such as carbon sequestration, regulation of the hydrological cycle, pollination, food and medicines), fostering landscapes that restore such processes is crucial for building a more resilient agriculture.[61] Some agroecological or ecological intensification practices have been tested and systematized in the last decade, such as crop diversification and rotation, cover crops, beetle banks, wildflower strips, erosion management, which have proven to be critical for reducing yield gaps with conventional farming systems.[62,63] This suggests that it might be feasible to produce enough food to feed the planet from sustainable farming systems. However, the adoption of agroecology practices in large-scale farming systems (*i.e.* highly mechanized, commercial farms that take place in privately owned or rented land) remains a challenge.[64]

However, feeding the planet through agroecology, ecological intensification, or sustainable intensification is a contested debate that goes beyond food availability.[55,64] While food availability is an important dimension of food security, it is not the only one, and focusing only on it can be tricky and simplistic.[65] Doing so implies that a complex problem (such as world hunger) can be solved just by changing the way food is produced, as if prices, waste, unequal distribution of resources and lack of opportunities do not matter. Certainly, increasing food production will be a necessary strategy to achieve food security.[48] However, greater focus should be on the efficiency and equity of the overall food systems rather than on the efficiency of agricultural productivity alone. Instead of "How do we grow more?", we should ask "What should we grow, in what quantities, for which purposes, and for whom?". That means to account for the other dimensions of food security, such as use and access.[66] For this to happen, it is necessary to value food beyond its monetary price and cost which also implies moving beyond simplistic productive (*e.g.* yields per hectare) and financial (*e.g.* price per ton) metrics for describing food systems.[67]

Regardless of which method of agriculture is chosen, there will always be inevitable conflicts between the protection of biodiversity and human needs.[68] Hence, we should use the best tools at our disposal and avoid ideological biases, in order to meet multiple objectives while minimizing risks. But food production would not have to change homogeneously around the world in order to achieve sustainability.[69] While in some regions increasing production will be desirable, in others decreasing it will be necessary, especially in those regions where hunger is not a concern or where there are important habitats for biodiversity conservation.[70,71] Indeed, in some areas it may even be preferable to avoid human activities at all in order to leave space for nature.[72] In this sense, the environmental impact of food production must be reduced to ensure human well-being and prosperity, for which all forms of agriculture must be considered without prejudice.

4. The rebound effect in food production

While increasing productive efficiency in agriculture may sound as the best way to reduce the environmental impact of food systems, it is not that simple. Increasing the efficiency of the production process also affects the producer–consumer system. For instance, reducing the price of a product due to a better use of inputs can generate changes in the behavior that partially or fully offset the expected resource savings.[73] This phenomenon is known as the Rebound Effect, and was originally described in England during the mid-19th century by William Jevons. This economist observed that the improvements in the efficiency of coal-steam engines led to an increase in the total use of coal instead of maintaining or reducing it. Increasing the efficiency of the use of coal caused a reduction in its price, and as a consequence the coal was used on a larger scale because more coal-based industries were opened.[74,75]

There are multiple well-documented examples in industry where the increase in technological efficiency was accompanied by a rebound effect, being most notably in the aluminum, iron and power generation industries.[76] The transport industry represents a paradigmatic example that allows us to understand the complexity of the rebound effect. Modern cars are the most efficient in history, but at the same time (and partly because of this) they travel more distance than ever before, which has led to an increase in total fuel use.[77,78]

The agricultural sector has not been immune to this phenomenon.[79] Since 1960, the scientific and technological advancement of the Green Revolution caused a dramatic increase in crop yields and agricultural production. As a result, the prevalence of hunger was reduced as never seen before, life expectancy increased, the infant mortality rate declined significantly and extreme poverty decreased.[80] The new varieties of crops were more efficient, but because they were planted over large areas, the demand for nutrients and water rose substantially, so synthetic fertilizers and irrigation systems were used at large scale. In addition, huge quantities of pesticides were applied to combat pests due to the low-diverse and homogenous new landscapes. Together, the intensive use of these inputs has caused diverse environmental and health problems which were never predicted.[81]

Something similar occurs with land. Norman Borlaug, father of the Green Revolution, predicted that as yields increased, the cultivated agricultural area would decrease and deforestation would be avoided, a hypothesis known as land sparing.[82] Besides that this idea has gained popularity in the last two decades as a strategy for saving natural areas where biodiversity can be left intact, the evidence shows that the area occupied by most of the crops benefited by the Green Revolution has increased substantially on a global scale, causing deforestation in many regions of the world, particularly in South America, sub-Saharan Africa and South and East Asia.[83,84] As occurs in other sectors of the economy, the increase in productive efficiency reduces the production costs, which generally motivates producers to expand if they have conditions that allow growth, such as land, labor and capital.[79] Still, Norman Borlaug was not completely wrong: thanks to the increases in crop yield, 18–27 million hectares were saved (at least relative to what was expected from population growth pressure).[85]

It is noteworthy to mention that the technical and technological innovations of the Green Revolution did not reach equally to all crops. Fruits, vegetables, nuts and most whole grains and legumes, were not included in the wave of the Green Revolution. Instead, most crop productivity growth occurred in a handful of crops that were promoted by the food industry: corn, rice, wheat, soybeans, sunflower, palm, sugarcane, barley, rye, oats, potatoes and cassava.[80] These crops were chosen mostly because they are relatively easy to store and transport,[86] and because they are suitable for multiple purposes such as human food, livestock feed, biofuel and alcohol production, and others.[87] With some exceptions (such as rice, potato and cassava), almost all of these crops are transformed into other products before reaching the final consumer, either into foods easily identifiable with the raw material (such as flours, meats, dairy and eggs), or also into components of ultra-processed foods. Something similar has occurred with domesticated animals: from the 8800 livestock breeds of 38 different species in the world, only a few of them were exploited during the last century for meat, milk and egg production.[88] At present, cattle, pigs and broilers represent the largest share of mammal and bird biomass worldwide.[89] Besides that the amount of calories has increased globally, the high availability of staple crops and animal products has caused another unexpected rebound effect: a global dietary shift towards unhealthy diets rich in animal products (particularly red meat) and ultra-processed foods (defined as hyperpalatable ready-to-eat products that contain flavors, colors and cosmetic additives, and which have been produced and conveniently packaged in a factory).[90,91] More about it is discussed in the next section.

The Green Revolution, which was beneficial in ensuring food security, has unexpected harmful consequences on agriculture and human health.[92] Due to the lack of regulation in the agricultural sector and, particularly on agricultural biotechnology companies, the current industrialized food systems are premised on economies of scale that reduce prices, incentivize the externalization of costs, and create growth in consumption and demand. This vicious cycle (supply creating demand leading to intensification of supply) is a classic rebound effect and, in turn, creates a greater need for land and intensifies competition for water, energy, and inputs.[93] Although in most cases the rebound effect is not large enough to cause a net increase in resource use, any trade-off of savings has important implications for natural resource use planning in a finite world.[94] Therefore, quantifying potential rebound effects and market regulation should be a key requirement when evaluating realistic scenarios for global food supply at a reasonable environmental cost.[79]

5. Food, nutrition and health

The accelerated urbanization, the reduction in the habit of eating homemade meals, the increase in per capita income, and the wide availability of animal products and ultra-processed food gradually pushed societies towards hypercaloric and unhealthy diets known as "western diets".[95] This dietary pattern is characterized by a high consumption of refined grains (flours), sugar, salt and added fats (oils), as well as animal foods (often also ultra-processed, such as bacon, ham and chicken nuggets), and a low intake of fruits, vegetables, legumes and whole grains.[96] While this trend is observed across the entire population, the most strongly affected are the poorest (as is often the case in many other aspects of inequality), which resulted in a scenario of fat poor and skinny rich in most high- and middle-income countries, as well in some low-income countries.[97,98]

According to the Global Burden of Diseases (GBD) study, nearly 70% of all premature deaths worldwide are caused by NCDs, such as cardiovascular and pulmonary diseases, cancer, type 2 diabetes and renal failure.[99] Unhealthy diets are responsible for 11 million premature deaths annually, killing many people as tobacco smoke.[12] Therefore, the consequences the above-mentioned dietary pattern (western diet) has on public health, people's quality of life, labor productivity and health costs, are enormous.[100] In fact, it has been estimated that NCDs will cause a cumulative loss of output of $47 trillion between 2011 and 2030.[101]

The role of food consumption in maintaining and restoring health has been widely underestimated by the medical community, but in recent years healthy eating was positioned as one of the most powerful and cost-effective tools to promote wellness and improve public health.[102] Until a few decades ago, the focus of human nutrition science was on preventing dietary deficiencies and achieving the recommended intake of calories and protein, leading to recommendations based on the Four Basic Food Groups of a healthy diet, as established by the US Department of Agriculture in 1956: (1) meats, (2) dairy, (3) grains, and (4) fruits and vegetables.[103] Epidemiological studies and randomized clinical trials have expanded the knowledge and shed light on the role that different food groups have on long-term health, indicating that reducing or eliminating some foods while increasing the intake of others, can contribute significantly to prevent most NCDs (and even treat and reverse them), as well as reduce premature deaths.[104] Gradually, the encouragement of the adoption of healthy diets became a national policy in many countries. In 1992, the Food and Agriculture Organization of the World (FAO) and the World Health Organization (WHO) suggested that each country should develop its own dietary recommendations to guide the population and health professionals, giving birth to the National Dietary Guidelines (NGDs).[105]

The concept of "healthy diet" has evolved to focus on the optimization of long-term health, considering health issues due to deficiencies as well as excesses.[106] Therefore, the old vision focused on nutrient intake (the reductionist ideology of nutritionism) gradually changed to one focused on the encouragement in the consumption of health-protective food groups, and limiting the intake of detrimental food groups.[107] At present, the most important dietary risk factors are considered to be the low consumption of fruits, vegetables, legumes, whole grains and nuts, and the high consumption of red and processed meats, sugary and alcoholic beverages, salt and ultra-processed foods.[108,109] Hence, a healthy diet is rich in fruits, vegetables, legumes, whole grains, nuts and seeds, and low in red and processed meats, sugary and alcoholic beverages, salt and ultra-processed foods, while it may contain moderate amounts of milk, poultry meat and fish.[110] The current scientific consensus on healthy eating can be summarized in a single sentence expressed by the writer Michael Pollan: "Eat food, not too much, mostly plants".[111]

6. Win–win: human and environmental health

In the same way as the nutritional sciences, the environmental sciences also have developed a variety of methodologies to investigate the impact of food production on the environment. The most common methodology applied consist in the quantification of natural resources use (*i.e.* land, water, energy, and fertilizer) and the emissions of pollutants (*i.e.* CO_2, CH_4, NO_x, SO_4^{-2} and PO_3^{-3}) across the life cycle of foods.[112] This kind of analysis can be performed throughout the whole food life cycle (from farm to fork) or at some stage of the food chain, using a specific unit as a reference for comparison (*e.g.*, per kg of weight, per kg of protein or per 1000 calories).[113] Besides that the vast majority of food products' life cycle studies have focused on some mainstream environmental indicators such as GHG emissions, energy consumption, land occupation or freshwater use, there are other less commonly used indicators such as the emissions of eutrophying and acidifying substances, or the impact on biodiversity.[114]

In general lines, the research has showed that plant-based foods (such as grains, fruits and vegetables) have a lower environmental impact per unit of weight, per unit of nutrient or serving than animal foods in all the indicators analyzed.[19,115] Because animals belong to a higher trophic level of the food chain compared with plants, they require a larger amount of energy and resources for their growth and development. In addition, big animals require a long breastfeeding and rearing phase, and consequently consume more energy and resources. For instance, depending on the productive model, beef cattle need 10–12 kg of dry matter per day for 12 to 24 months; but chicken consumes 4–5 kg of feed during its entire and short life. For these reasons, it is estimated that beef meat has an impact 20 to 200 fold higher than plant-based foods (such as legumes or whole grains), and an impact 2 to 25 fold higher compared with other animal products such as milk, eggs, pork, chicken and fish.[115] For these reasons, animal products provide only 18% of our calories while occupying 83% of our agricultural land and are responsible for 56% of GHG emissions from the food sector.[19,116]

Since food choices determine food demand, it is easy to understand why reducing animal products in human diets could decrease the environmental impact of food systems.[117] Modeling studies that have examined the potential effect of a global transition towards a healthy plant-based diet (such as a flexitarian diet), indicates that GHG emissions from food systems could be cut by half, mainly due to a reduction in CH_4 emissions from livestock and CO_2 emissions from deforestation.[48,118,119] Furthermore, by adopting a healthy flexitarian diet the land requirement would be only a quarter of the land we use now to feed the world population.[120] This means that the remaining land could be used for the restoration of ecosystems that are highly valuable for biodiversity conservation, such as forests, woodlands, wetlands and natural grasslands.[121] The possibility of reducing agricultural area is an option that should not be underestimated, as allowing nature to recover is one of the most powerful strategies to simultaneously remove CO_2 from the atmosphere and protect biodiversity.[122,123] Restoring 15% of converted lands in priority areas could avoid 60% of expected extinctions while sequestering 299 Gt CO_2-eq.[124] A recent study has estimated that a global adoption of a plant-based diet (with small amounts of meat, milk and eggs) could free up to 613 Mha of cropland (40% of today's cropland, or twice the area of India) and 2713 Mha of pastureland (85% of today's pastureland, almost the same size of the African continent), in which 332–547 Gt CO_2-eq could be sequestered over 35 years (10–15 Gt CO_2-eq per year).[125]

Although the above-mentioned studies are based on the modeling of a global adoption of plant-based diets, they represent very useful exercises to explore the potential contribution of dietary changes.[126] From these studies we also learned that it is not necessary to eliminate the consumption of animal products in order to obtain such benefits, since even small changes towards a plant-based diet would represent a better scenario than the one we are in now.[127] In addition, they have shown that the replacement of beef by other meats with lower environmental impact (such as pork and chicken), without reducing the total amount of meat consumed, can generate significant improvements. However, a considerable amount of grains and croplands will still be devoted to animal production.

Certainly, modifying the food demand through dietary changes is an effective tool to reduce the (unsustainable) ecological footprint of what we eat, and should be immediately included in the toolbox to combat climate change and ecological collapse.[5,7] Shifting consumption towards plant-based diets, even with moderate amounts of animal products, is key to meeting the Paris Agreement. One recent study has shown that, when compared to other strategies such as increasing production efficiency and reducing losses and waste, dietary change towards plant-rich diets has a greater GHG emission reduction potential in the global food system.[119] In fact, if the people living in the world's 54 richest countries (17% of the global population) switched to a plant-based diet, agricultural emissions would be reduced by 61%, nearly 98 Gt CO_2-eq.[128] However, dietary changes do not replace the other strategies, but rather enhance their impact through synergistic effects.

Interestingly, there is an association between the environmental impact of food groups and its effects on health: in general, those foods with low environmental impact also improve health, and *vice versa*.[129] This finding is strengthened by the fact that, in general, those foods that reduce the risk of mortality associated with one NCD also do so with other NCDs, and those that present lower values of environmental impact for one aspect also do so for others.[129] This means that the same plant-based diet that generates the environmental benefits mentioned above, even with moderate amounts of animal products (a flexitarian diet), has the potential to prevent 1 in 4 premature deaths from NCDs.[130] Therefore, increasing the dietary share of fruits, vegetables and whole grains (legumes, cereals, nuts and seeds), and decreasing the share of some animal products (particularly red meat and processed meats), can generate important benefits for people by reducing the incidence of and mortality from NCDs, and for nature by reducing the environmental impact of the food system.[118] Hence, healthy diets have the attribute of being (also) sustainable.

Although the benefits of adopting a healthy diet are very clear, it remains a great challenge.[131] Dietary patterns are a reflection of the context in which people live, such as the availability of food in the market, the cultural and social norms that shaped food choices, the economic situation in which they find themselves, and the food environments they experience, among others. Hence, a substantial change in the structure and function of the food systems is required, for which a widespread, multi-sector, multi-level action to change what food is eaten, how it is produced, and its effects on the environment and health is needed.[118] Because of the scale of change needed, it is unlikely to be successful if left to the individual or the whim of consumer choice. Informing and educating the public on what eating healthy is (through the NDGs or front-of-pack labeling), is important but not enough.[90] Such "soft" policies place most responsibility on the individual consumer, with which industry is often more comfortable. The effectiveness of such policies on behavior change overall and in specific population subgroups has been variable and they may have smaller effects in marginalized groups.[132] Hence, harder policies to guide the choices are needed, such as subsidies to encourage some food products or taxes to disincentivize others. In any case, the regulatory participation of the government is crucial.[133]

7. Conclusion

Food has always been a challenge for humanity, but now more than ever before: we have to feed a growing population in the context of climate change and ecological collapse. We also face a situation where the global food system plays a major role in the environmental degradation: it has a negative impact on the climate, as well as on terrestrial and aquatic ecosystems, being the main driver of biodiversity loss, alteration of the biogeochemical cycles of nitrogen and phosphorus, and depletion of water resources.

Fortunately, there is a wide range of options for improving agricultural systems and reducing the environmental impact of food production. We also know the best strategies to avoid food loss and waste along the agrifood chain. However, in the absence of incentives and disincentives to lead the way, we should not lose sight of the possible negative consequences associated with increased efficiency (rebound effect).

Dietary shifts towards healthy diets have great potential to improve food system sustainability through changes in food demand, and hence, natural resource uses and environmental pollution. Replacing beef with lower-impact animal proteins (pork, chicken, fish or cultured meat) or plant-based proteins (such as legumes, whole grains and nuts), is one of the most effective strategies for reducing GHG emissions. However, the largest benefits will come from diets that are more based on plants. This pathway also offers the potential to require considerably less land than today's heavily animal-based diets, opening the door to the possibility of using the freed-up land to sequester carbon dioxide by restoring ecosystems and landscapes that are critical to climate change adaptation and biodiversity conservation. But to achieve improvements in public health, these changes should also be accompanied by an increase in the consumption of fruits and vegetables, and a reduction in the intake of ultra-processed foods. Although replacing meat with plants (partially or totally) is a logistical and cultural challenge, it offers improvements in multiple dimensions that no other strategy can provide. This huge challenge requires changes from everyone, from individual consumers, to national governments, companies, and international multilateral organizations.

Conflicts of interest

There are no conflicts to declare.

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