

Opportunities and challenges for a Bioeconomy-driven transformation of food system

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ABOUT THIS STUDY

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Table of contents

Executive Summary	5
1. Introduction	7
2. Opportunities for bioeconomic innovations	9
2.1. Bio-inputs	9
2.2. Bio-fortified crops	9
2.3. Plant-based meat	11
2.4. Biofuels	12
3. Challenges for upscaling	13
4. The (potential) fallacy of equitable livelihoods	16
5. References	17

Executive Summary

The UN Food System Summit proposed five action tracks (ATs) towards food system transformation. This short brief delves into the role of bioeconomic innovations in catalyzing synergies between the five ATs, and offers recommendations related to their adoption and knowledge gaps. In particular, we focus on four innovations: bio-inputs for agricultural production, bio-fortified crops, plant-based meat substitutes, and biofuels.

Bio-inputs are a nature-based alternative to synthetic agricultural inputs that can contribute to the production of safe food (AT1), potentially increasing household income through the reduction of production costs (AT4), and improve resilience against agricultural inputs' shocks (AT5) while reducing environmental impact (AT3). **Bio-fortified crops** containing larger amounts of specific nutrients can improve nutrition and tackle malnutrition (AT1), while contributing to healthier dietary choices (AT2) and potentially reducing the need for large quantities of pesticides (AT4). **Plant-based meat substitutes** have a lower environmental impact than meat while maintaining the same micronutrient content, which contributes to food security (AT1) and to shifting consumption patterns (AT2), while creating more economic opportunities (AT4). Lastly, **biofuels** can increase energy security (AT5), and make food more affordable (AT1) if the cost of transportation and energy is reduced. Integration with agroforestry and other sustainable land management practices could promote a nature-positive production (AT3), while creating jobs and regional economic opportunities (AT4).

Despite the potential of bioeconomic innovations to transform food systems, their adoption is still low. We highlight three points that could support the development and wide-scale adoption of bioeconomic innovations. First, clear and coherent regulatory frameworks can boost investments and facilitate the access to these technologies by lowering costs. Second, although some of these potential benefits of bioeconomic innovations are supported by scientific evidence, others remain anecdotal. Building a more solid body of research on the impacts of these technologies in “real-life” scenarios could help raise public support. Third, changing consumer preferences for more sustainable food items will likely require the implementation of consumption



policies such as increasing value-added tax on red meat or introducing climate-related excise taxes. We conclude by emphasizing that processes of technological change are not neutral and could result in increased inequalities if vulnerable groups cannot access these innovations or if they cannot benefit from the new business opportunities brought by the process of technological change.

1. Introduction

Food systems are complex entities that exist at various scales – global, regional, national, and local – and relate to the wide range of actors and activities involved in the production, processing, transportation, and consumption of food products, and thus encompasses multiple interrelated sectors. On one hand, they contribute not only to diets and human health but also to economic growth, with agri-food systems contributing to 73% of all employment in low-income countries (Berdegué et al., 2023). On the other hand, food systems are a major contributor to and are affected by climate change and environmental degradation. It has been estimated that food systems contribute to around one-third of all anthropogenic greenhouse gas (GHG) emissions (Crippa et al., 2021) and agriculture alone threatens around 86% of all species at risk of extinction, as documented by the IUCN (Benton et al., 2021). These are the result of the conversion of natural habitats into crop- and pasturelands, and the unsustainable intensification of production, leading to the depletion of freshwater resources, and pollution of aquatic and terrestrial ecosystems. Without a deep transformation of global food systems, it is unlikely that we will achieve the goals of the 2030 Agenda for Sustainable Development.

In September 2021, the first UN Food System Summit took place with the goal to generate strategies for transforming food systems to be more sustainable, equitable, and resilient and thus make progress towards the SDGs. In order to set an action-oriented agenda for food system transformation, five action tracks have established (Box). Each of these encompasses different aspects, challenges, and opportunities related to food systems, but, to avoid inefficient solutions, they should not be pursued in isolation. The multidimensional concept of Bioeconomy was highlighted during the Summit for its potential and opportunities to be employed as a new development paradigm that could be used to tie the links between the five action tracks, thus contributing to increased coherence and synergies between initiatives (Trigo et al., 2021; Von Braun et al., 2023).

New and systemic technological innovations are essential for the profound transformation that food systems require, ranging from improvements in agricultural production and reductions in GHG emissions to improvements in dietary options and waste management (Herrero et al., 2021, 2020). It has been estimated that without technological change and dedicated supporting policies, the environmental effects of food systems could increase

by 50-90% (Springmann et al., 2018). Despite competing definitions of Bioeconomy, at its core it represents a restructuring of our production systems driven by technological innovations that make use of sustainably produced and procured biological resources. This includes not only utilizing these biological resources to reduce our reliance on fossil resources, but also adhering to circularity principles and developing new bio-based products that can contribute to economic growth. Therefore, in this short brief we present some of the bioeconomic innovations that could contribute to the five action tracks and highlight some of the caveats related to their adoption and knowledge gaps.

Five Action tracks of the UN Food Systems Summit

AT1. Ensuring access to safe and nutritious food for all: enabling all people to be well-nourished and healthy;

AT2. Shifting to sustainable consumption patterns: promoting and creating demand for healthy and sustainable diets, reducing waste;

AT3. Boosting nature-positive production at sufficient scale: acting on climate change, reducing emissions and increasing carbon capture, regenerating and protecting critical ecosystems and reducing food loss and energy usage, without undermining health or nutritious diets;

AT4. Advancing equitable livelihoods and value distribution: raising incomes, distributing risk, expanding inclusion, creating jobs;

AT5. Building resilience to vulnerabilities, shocks and stresses: ensuring the continued functionality of healthy and sustainable food systems.

Source: von Braun et al. (2023).

2. Opportunities for bioeconomic innovations

2.1. Bio-inputs

The success of the Bioeconomy and its contributions to food systems depend on biomass being produced sustainably. For the past decades, we have seen a sharp increase in the quantities of synthetic inputs used per hectare of cropland, with Brazil and Argentina being the top users of pesticides. Bio-inputs (i.e. biofertilizers, biopesticides and biostimulants) are often promoted as a promising and more sustainable alternative to synthetic inputs, and as such they are well-aligned with the UN Food Systems Summit's action tracks. By enhancing crop yields while reducing reliance on agrochemicals, bio-inputs contribute to the production of safe food (AT1) and have the potential to reduce production costs—especially when the bio-inputs are produced on-farm —, thus increasing household income (AT4). The use bio-inputs is a clear example of a nature-positive approach in food production (AT3), as it reduces the environmental impact of agriculture by decreasing chemical runoff and the impacts on biodiversity. The recent Russia–Ukraine war, which caused a decline in trade of fertilizers and grains, increasing the price of food worldwide, has shown how susceptible food systems can be to shocks to the supply of agricultural inputs (Ben Hassen and El Bilali, 2022). Investments in locally produced bio-inputs could increase the resilience of food systems to these shocks (AT5).

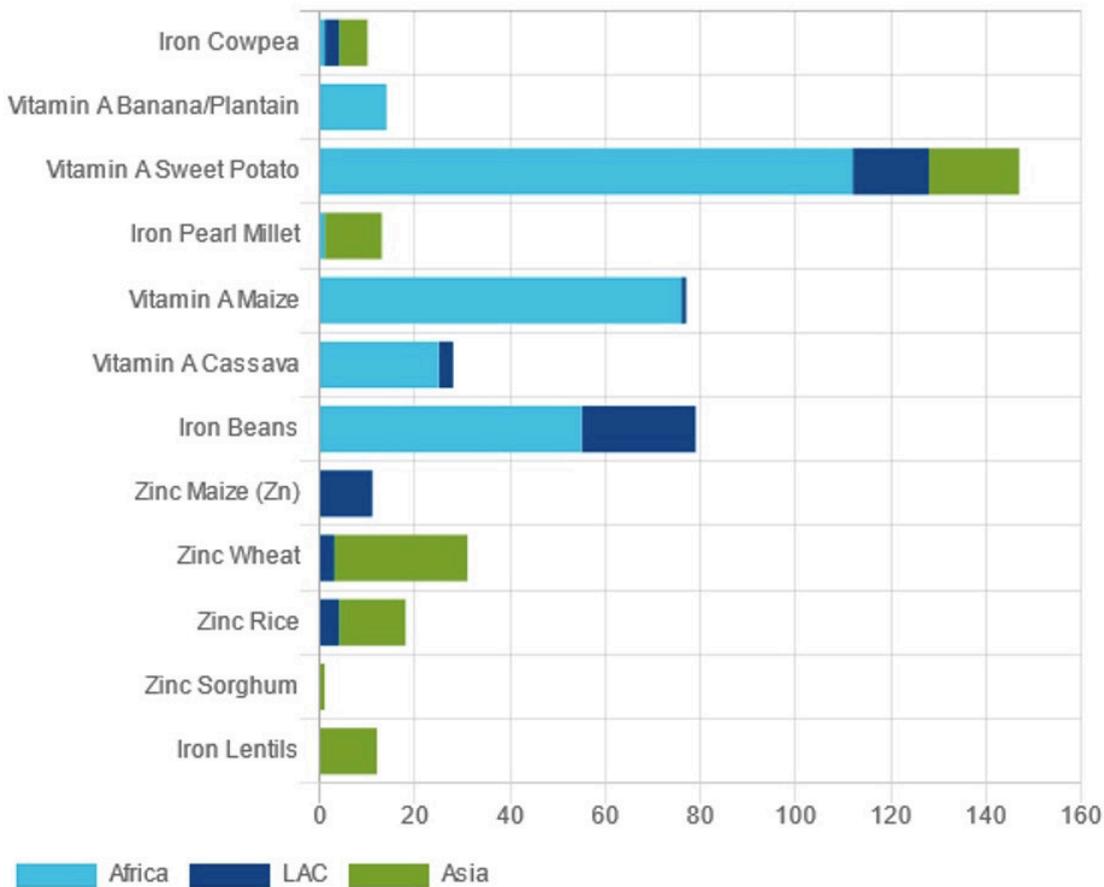
2.2. Bio-fortified crops

Despite advances in the SDG2 indicators during the last decades, it is estimated that around 10% of the people in the world are undernourished. Malnutrition, i.e. the lack of essential vitamins and minerals required by the body for proper growth and development, is also prevalent in many parts of the world, with an estimated 2 billion people suffering from it. This can have serious health implications, such as poor physical and mental development in children, anemia, blindness and general losses in productivity. Bio-fortified crops, developed either through conventional or genetic breeding techniques, are a key

innovation for addressing this issue, especially in contexts where people have limited access to diverse diets (Van Der Straeten et al., 2020).

Biofortification has been spearheaded by the CGIAR research program HarvestPlus, who has developed several biofortified varieties of staple crops in Latin America, Africa, and Asia (Figure 1). It is estimated that HarvestPlus has benefited over 86 million people in farming households, who grow its more than 290 varieties of biofortified staple crops (Bouis and Saltzman, 2017; HarvestPlus, 2023). These crops are a direct solution to improving nutrition and tackling malnutrition in vulnerable populations (AT1). Moreover, bio-fortified crops play a role in shifting consumption patterns. By promoting healthier dietary choices and increasing the availability of nutrient-dense foods, they can reduce the demand for resource-intensive food sources, supporting a transition to more sustainable consumption patterns (AT2). Furthermore, bio-fortified crops can be bred to be more resistant to some pests and diseases, thus reducing the need for large quantities of pesticides, contributing to more sustainable practices (AT4).

Figure 1 – Number of biofortified varieties by region.

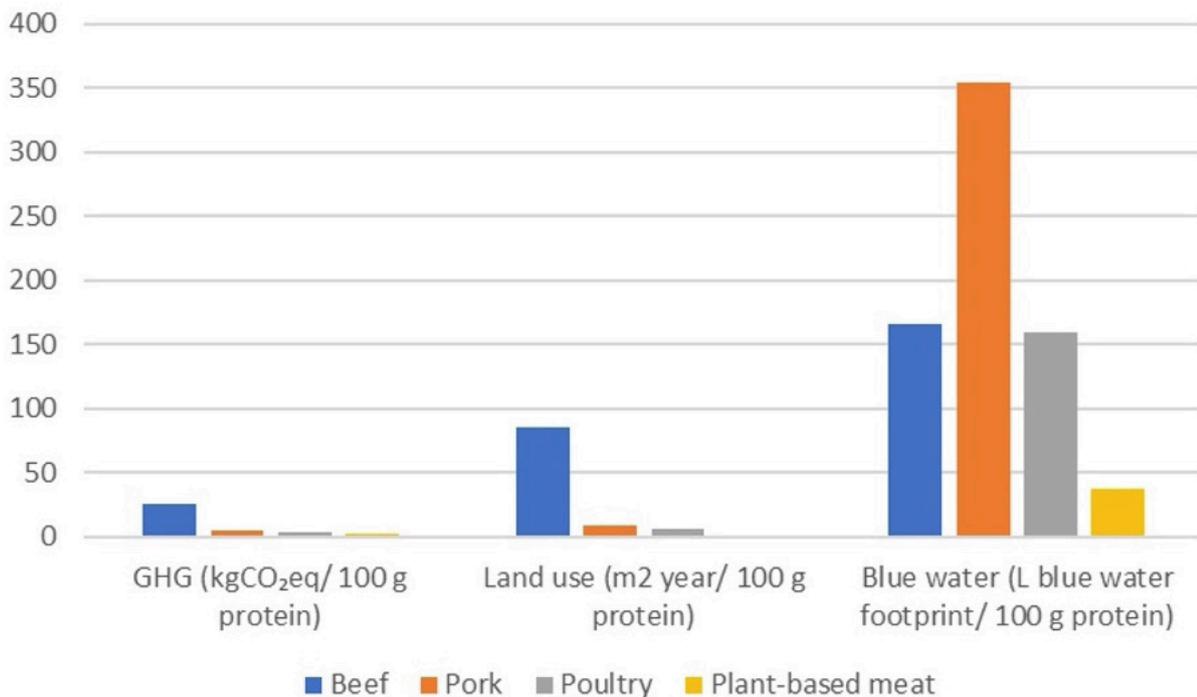


Source: HarvestPlus (2023).

2.3. Plant-based meat

The emergence of plant-based meat substitutes offers a range of benefits across the action tracks. Compared to beef, pork, and poultry, plant-based meat has significantly lower environmental impacts (Figure 2). Despite some concerns that plant-based meat might lack the nutritional content found in animal products, recent research has shown that this is not the case and that the main products currently available in the markets have a micronutrient content comparable to beef (Pingali et al., 2023). Therefore, these products can provide safe and nutritious option for consumers at a much lower environmental footprint, contributing both to food security by diversifying protein sources (AT1) and to shifting consumption patterns (AT2). As consumers opt for plant-based alternatives, they contribute to a more sustainable and eco-conscious food system. Moreover, the reduced demand for traditional meat products alleviates the pressure on natural resources, including land, water, and biodiversity. Lastly, the growth of the plant-based meat industry generates job opportunities and encourages innovation in agriculture and the food sector, supporting more equitable livelihoods and economic opportunities (AT4).

Figure 2 – Environmental impacts of plant-based meat.



Source: Own elaboration with data from Pingali et al. (2023).

2.4. Biofuels

Since the energy sector is a major contributor to global GHG emissions, reducing our reliance on fossil energy sources is an important component towards decarbonizing our food systems. Biofuels have the potential to reduce the cost of transportation and energy, making food distribution more accessible and affordable. This cost reduction can benefit both producers and consumers, ensuring wider access to safe and nutritious food (AT1). The cultivation of biomass for biofuels could be integrated with agroforestry and sustainable land management practices. This integration promotes a nature-positive approach by sequestering carbon, enhancing soil health, and supporting biodiversity (AT3). Biofuel production can also contribute to the creation of jobs in rural areas, providing economic opportunities and supporting equitable livelihoods, particularly in regions where agricultural production plays a crucial role in the local economy (AT4). Furthermore, by reducing reliance on fossil fuels, which are subject to price volatility and supply disruptions, biofuels can enhance energy security and resilience. This, in turn, contributes to the overall resilience of the food system by ensuring the consistent availability of fuel for transportation and energy needs (AT5). Still, past biofuel policies have been criticized for contributing to food price spikes and deforestation as undesirable secondary effects (Havlík et al., 2011; Zilberman et al., 2013). It is thus important to ensure that feedstock for biofuel production is sourced from sustainable production systems and biomass flows (including second and third-generation technologies) that do not compete with food production.

3. Challenges for upscaling

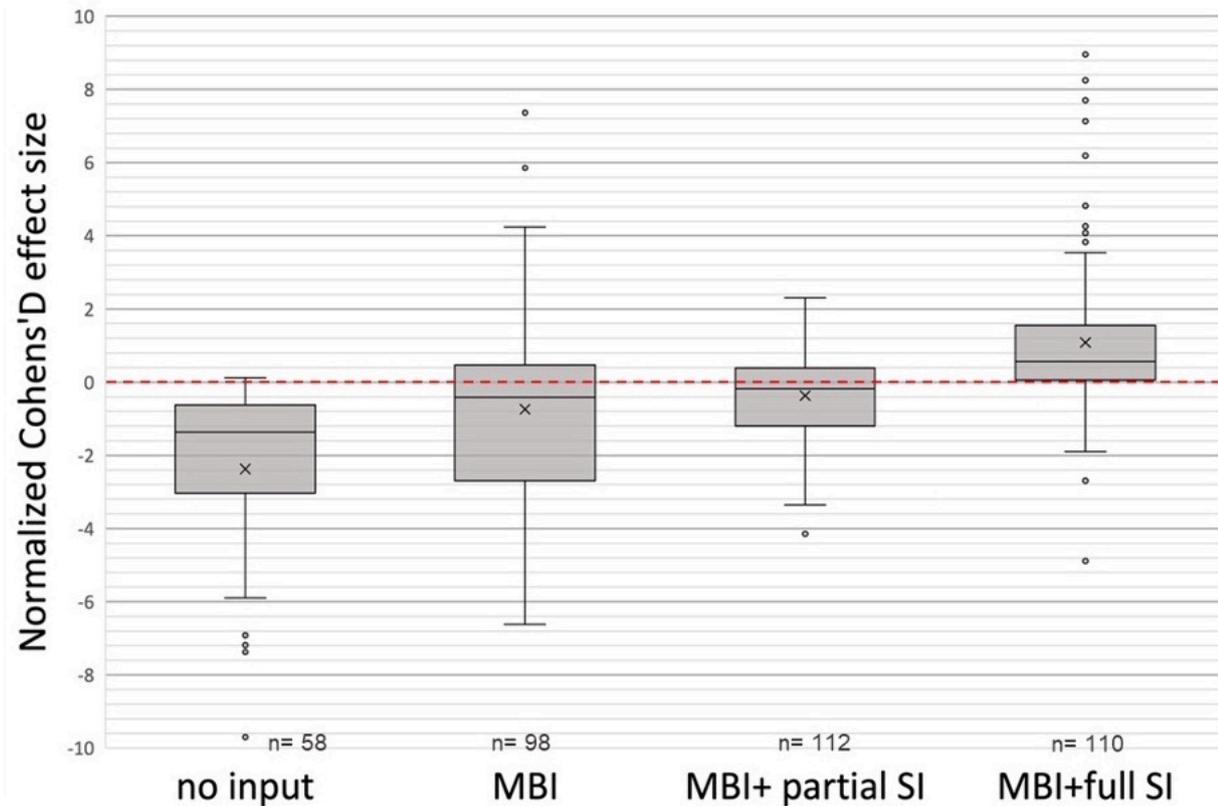
Despite the potential of these bioeconomic innovations to contribute to sustainable food systems, their adoption is still overall low. For example, in 2019, biofuels still accounted for only 0.7% of all energy consumed globally and bio-inputs represent only a fraction of the global market for agricultural inputs. Although each technology has its particularities and reasons for lagging behind, we want to highlight three important factors.

First, some of these technologies still lack the necessary regulatory frameworks to support their development, registration, quality control, commercialization, and use. Clearly defined regulations can reduce some of the uncertainties that entrepreneurs face and clarify issues related to intellectual property and benefit sharing, which is especially important when new technologies are based on traditional knowledge and local biodiversity (Martinelli and Sellare, 2022). This can result in higher investments in these innovations, which might ultimately lead to cheaper and more effective solutions, thus increasing consumers' acceptance and adoption. However, regulatory frameworks designed on the basis of political ideologies can have the exact opposite effect, increasing costs and sometimes outright banning some technologies. This is often debated in the context of genetically modified crops (Van Der Straeten et al., 2020; Wu et al., 2021).

Second, if for some bioeconomic innovations we do already have decades of scientific evidence that support their effectiveness, for others the evidence is much thinner and often lack rigor. This is clearly in the case of agricultural bio-inputs. Although there are several studies that analyze the benefits of specific bio-inputs on productivity, soil nutrients, and plant health, these are often based on greenhouse experiments or controlled field trials. Studies conducted in “real life” settings that focus on socioeconomic benefits are still missing. There is still a large knowledge gap about the effects of bio-inputs in “real-life” settings (Scherer, 2023). This knowledge gap notwithstanding, the evidence that we do have available is rather mixed. For example, Figure 3 shows that, when compared to traditional agricultural systems that use synthetic inputs (SI), microbiome-based inputs (MBI) do not have a significant effect on maize yields, neither when used on their own nor when combined with synthetic inputs. This Figure also highlights the large variation in the effect sizes found in the literature. This uncertainty and the lack of sufficient knowledge on the social and economic performance of MBIs has been identified as one of the main reasons for low adoption rates (Plohl et al., 2022). Furthermore, it is

important to highlight that, for some technologies, we still have knowledge gaps regarding how they affect some of the actions tracks identified above. For example, despite the potential benefits of biofuels to create employment opportunities in rural areas, much of the evidence on this is anecdotal (Bosch and Zeller, 2019).

Figure 3 – Effects of microbiome-based inputs on maize yields.



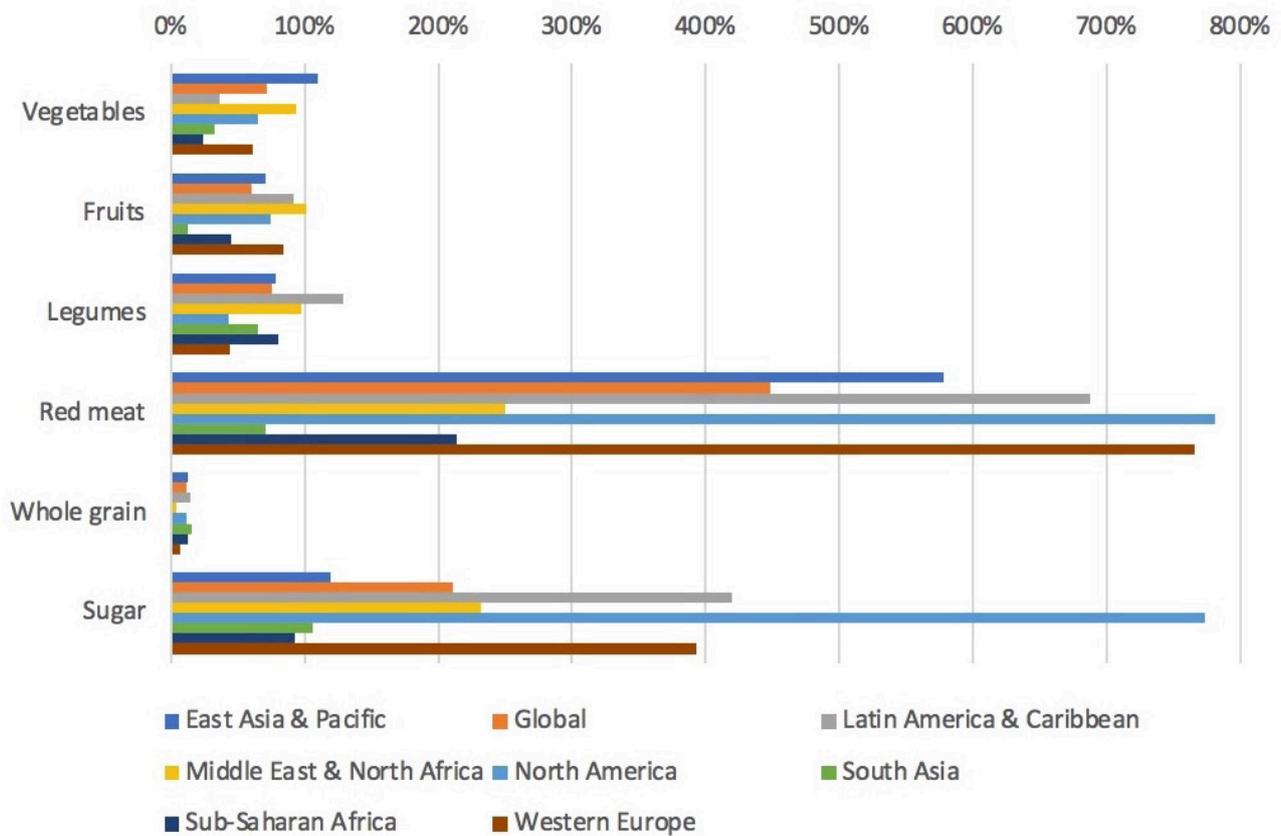
Note: Data points represent the effect sizes found in 40 experimental studies.

Source: Scherer (2023).

A third challenge for upscaling the adoption of some bioeconomic innovations relates to consumer preferences. Although biofortification of staple crops can have an important role in reducing micronutrient deficiencies and plant-based meat provides low-impact alternatives to animal products, a healthy diet that provides the necessary caloric and micronutrient intake should be comprised of several food groups. However, we observe that the global consumption of fresh fruits and vegetables, legumes, and whole grain is below a reference diet proposed by the EAT-Lancet Commission (Willett et al., 2019), while red meat and sugar is overconsumed in most regions of the world (Figure 4). Dietary change is often mentioned a key requirement for reducing the negative environmental and health impacts of food systems, and yet it doing so remains a huge challenge, as food

consumption is deeply rooted in culture. Therefore, innovations in food items must be accompanied by initiatives that support the consumption of more varied and nutritious items, such as awareness campaigns, procurement contracts with public schools, and eventually also targeted tax policies (Cawley et al., 2019). However, it is important to note that public support for taxing meat is still low and that tax policies could have a negative impact on the welfare of low-income households if they are not designed properly (Klenert et al., 2023; Perino and Schwickert, 2023).

Figure 4 – Diet gap between dietary patterns in 2019 and reference diet intakes of food.



Note: Reference dietary intakes are taken from Willett et al. (2019).

Source: Own elaboration based on data from Global Burden of Disease Collaborative Network (2021).

4. The (potential) fallacy of equitable livelihoods

Much has been said about how the Bioeconomy can create many opportunities to improve the livelihoods of people in the Global South. However, to what extent can bioeconomic innovations contribute to more equitable livelihoods by raising incomes, distributing risk, expanding inclusion, and creating jobs remains an open question. Technological innovation is not neutral; i.e., the process of technical change can be capital biased, skill biased, and labor augmenting, which benefits different segments of the population (Acemoglu, 2002).

In the context of the Bioeconomy and the transformation of food systems, increasing demand for technologies that rely on high-volume and low-value biomass might at first create new marketing opportunities for farmers without them having to make significant adaptations to their production systems. This is the case for first and even second-generation biofuels. However, as we move towards a fully upgraded Bioeconomy, where there is widespread adoption of complex processes and technologies based on low-volume and high-value biomass, the opportunities for farmers as biomass suppliers become more limited. Changes in the organizational structure of value chains induced by the introduction of these new technologies can have important consequences for welfare (re)distribution (Mac Clay and Sellare, 2022). For example, we do not know how a (hypothetical) widespread adoption of plant-based meat would impact the various actors involved in the beef industry (Pingali et al., 2023) and it is still unclear whether growing concentration in the global seed and biotech industries will lead to higher prices (Deconinck, 2020). All this might have important consequences for whether the most vulnerable groups will have access to these bioeconomic innovations and whether they will be able to enjoy the new business opportunities that arise from the process of technological change.

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