



## Plant-based school meals as levers of sustainable food transitions: A narrative review and conceptual framework

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### ARTICLE INFO

#### Keywords:

School meals  
Sustainability  
Plant-based diets  
Food consumption  
Food systems

### ABSTRACT

Current food systems face immediate and complex challenges in feeding a growing global population. It is necessary to mitigate the environmental impact of food systems while ensuring food security across the globe. Drawing on the example of recent multi-sectoral approaches which focus on the interconnections between public health and the environment, this work offers a narrative review and broader conceptual framework advancing two propositions. The first is that school meals systems have the potential to help enable sustainable food transitions. The second is that favoring well-planned plant-based meals in schools may strengthen this potential. The review and resulting framework highlight the relevance of seeking transdisciplinary dialogue and considering diverse sectors of society, such as public health, the environment, social protection, economic development, and community welfare. We review possible health benefits as well as possible economic and environmental outcomes, especially if school meals are sourced mainly from local communities and eco-friendly agricultural practices. Cross-sectoral implications related to social protection and community welfare are also identified and discussed, as well as potential pathways for materializing sustainable food transitions in schools.

### 1. Introduction

Global threats to the stability of the Earth's ecosystems are increasing and call for urgent action [1–3]. The starting point for transformation is troubling: the soil is increasingly degraded [4–7], access to clean water is becoming more compromised [8,9], the air is increasingly polluted [4,10–12], biodiversity is declining [8,13], and food insecurity is still a reality [14].

Sustainability is the bridge that conciliates the conservation of ecosystems with human progress and wellbeing [15,16]. Regeneration can be a tool to achieve sustainability. For example, regeneration may help promote water retention and aquifer recharge increase, biodiversity growth, food security of high nutritional value, carbon sequestration from the atmosphere and storage in the organic matter in the soil – the second largest active store after the oceans (i.e., 1500 billion tones worldwide) [5,17]. Against this backdrop, recent and influential multi-sectoral approaches (e.g., One Health, [18]; Planetary Health Diet

[3]) have emerged as a response to the complex challenges associated with food sustainability [19]. These approaches have primarily focused on two main sectors: public health and the environment. Drawing on their example, as well as on previous models focused on the creation of sustainable communities (i.e., Egan Wheel [20]) and sustainable development (i.e., Doughnut Economics [21]), the present work offers a narrative review and broader conceptual framework advancing the proposition that school meals systems may help enable sustainability transitions, via synergies that harness the multi-sectoral impact of school meals systems on public health, environment, economic, social protection and community welfare domains. We present a multi-sectoral framework for food sustainability transitions applied to school meals systems, which extends beyond the intersections between public health and the environment (e.g., One Health, [18]; Planetary Health Diet [3]). This extension and application adds value to the agenda of sustainable development due to its potential to cross disciplinary boundaries, the widespread prevalence of school meals systems – which reach children

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and communities from different socioeconomic backgrounds –, and the global economic investment made in school feeding programmes worldwide [22].

Our main objective is threefold: encourage transdisciplinary dialogue in the context of sustainable food transitions, identify opportunities for expanding systemic conceptual frameworks in this context, and ultimately help inform the design and implementation of sustainability programmes, research, and policy. To achieve our objective, we used a narrative review as an exploratory and descriptive first step toward identifying and discussing recent developments across disciplinary fields [23]. This also provided an opportunity to identify key concepts and gaps in research, as well as emerging transdisciplinary tendencies which can then be analyzed via more systematic and resource-intensive methodologies, such as systematic or scoping reviews [23–25]. Systematic reviews tend to be driven by specific research questions and follow predefined criteria on all stages of the review process, including search, selection, evaluation, synthesis, and reporting. Scoping reviews tend to be driven by broader research questions but still use a systematic protocol to search and select relevant studies, often with the aim of clarifying concepts, definitions, and developments in the literature. Narrative reviews do not follow a structured a priori protocol and comprehensive data search procedures like systematic and scoping reviews [23] but can be useful to introduce an overview of developments on a given topic, especially when it has not been extensively reviewed before [26,27], and as a first step to enabling discussion and considering requirements for subsequent research and reviews on the topic [28]. The search strategy for this narrative review comprised three stages. First, we defined broad key search terms related to: (i) school-meals systems (e.g., school-meals, school-meal programmes, school feeding); (ii) plant-based eating (e.g., plant-based diets, plant-based food); and (iii) cross-sectoral areas of activity and development proposed by integrative models such as the Planetary Health Diet [29], the Egan Wheel [20], and the Doughnut Economics model [21] (e.g., sustainability, environment, regeneration, public health, disease prevention, food security, human rights, economy, community). Then, we conducted an iterative search with different combinations of these keywords on scientific databases (Scopus, Web of Science), Google Scholar as a broad-scope platform, and ascendancy and pendancy approaches [30] to identify additional peer-reviewed publications conceptually and empirically relevant for the topic. As a result, we considered a total of 189 publications and selected those that fell within the aim of this work (N = 114), which are included in the narrative review and discussion presented here.

## 2. The potential of school meals systems to help enable sustainable food transitions

School meal programmes are widespread across the globe. According to the first State of School Feeding Worldwide report, published in 2013 by the United Nations World Food Programme [31], in collaboration with the World Bank (WB) and the Partnership for Child Development (PCD), school meal programmes are ubiquitous in high-, middle- and low-income countries, with approximately 368 million children (about 1 out of every 5) receiving a school meal daily [31], reaching around 370 million children in recent years [22]. The estimated global investment in these programs is around US\$75 billion a year [31]. In many cases, most funding comes from governmental budgets, as authorities acknowledge school feeding as an important response to hunger and poverty in vulnerable households with school-aged children. School feeding serves as a protective and strategically targeted platform, from which further interventions can be staged and expanded during crises [31–36].

School feeding services can also seek to promote favorable health and nutritional outcomes, support education, increase social protection, advance economic and agricultural development, and foster environmental sustainability [32,37–41]. Furthermore, school meals systems offer a platform from which nutrition interventions can be put in motion at a local or national scale, targeting both food and nutrition education

components, which may have a combined effect on reinforcing healthy eating habits in children, and potentially their families and communities [33,42,43].

### 2.1. School meals systems and public health

Dietary problems and malnutrition, ranging from undernourishment to excessive weight or obesity, combined with micronutrient deficiencies, are still prevalent in low-, middle- and high-income countries [44]. Child obesity is associated with a higher risk for several harmful health outcomes (e.g., cardiovascular disease [45], insulin resistance [46], asthma [47], depression [48]) and a higher likelihood of adult obesity [49]. A growing body of research also links better nutritional intake with higher academic performance [50] and school attendance [38] in school-aged children.

School meals systems have the potential to promote healthier diets by improving the quality of students' meals in preschool, primary, middle school, and secondary school-aged children and adolescents [41, 44]. This can be addressed by promoting the availability of a variety of foods and ensuring the adequate intake of vegetables and legumes, fruit, nuts, foods high in fiber (i.e., whole grains) in school meals, and limiting the serving, advertising, and sale of unhealthy foods [29]. Schools can also potentially reduce the number of children starting school already malnourished [34] by providing micronutrient supplementation or fortified meals [51,52]. School meals systems can also address children's malnutrition through combined food and nutrition education efforts, which have shown positive effects on the prevention of child obesity [53]. On the one hand, meals should be produced according to high standards and national dietary guidelines, local food availability, cultural preferences, and the needs of vulnerable groups (e.g., those suffering from macro or micronutrient deficiencies). On the other hand, implementing school nutrition activities with educational value can also encourage and empower students to be agents of change within their families and communities [41].

### 2.2. School meals systems, economic development, and social protection

School meals systems can impact the economy by reducing healthcare costs related to obesity [54] and strengthening local food systems [41]. The impact of obesity on the global economy has been estimated to be around USD 2.0 trillion and 2–7% of all healthcare expenses in developing countries [55]. Nearly 30% of the population has been classified as overweight or obese, and almost half of the adult population in the world (41%) may suffer from excessive weight by 2030 [55]. School meals have the potential to help reduce the staggering healthcare-related costs associated with obesity, by raising the quality of the food served to higher standards in terms of nutritional value and food safety [56,57]. The economic outcomes can also be potentially strengthened by favoring links with local food producers, local markets, and proximity distribution systems within the national and local communities [41,58–60]. Hence, school meals can help support the development of local economies, help create job opportunities (particularly for low-skilled and/or rural women and youths) and bolster agricultural development [32]. These links can energize local economies and small-to medium-sized food-production, processing, and distribution businesses, and potentially support more diversified agroecological systems [37,39,61,62].

School meals systems can also help ensure the “right to education” [63] and the “right to adequate food” [64], especially in more vulnerable groups such as students from low-income households. Additionally, school meals can increase families' food security [33] through take-home portions that can benefit other members of the household as well. Higher food security has been linked to enhanced cognitive, academic, and psychosocial development, namely, increased learning abilities [65], higher social cooperation, and lower suspension, grade retention and dropout rates [56].

### 2.3. School meals systems and community welfare

School meals can influence the broader community by offering nutrition education experiences that promote children's and their families' lifelong healthy-eating habits, increase their exposure and preference for a variety of healthier food choices (e.g., fruits and vegetables) [66], and transfer knowledge (e.g., nutritional literacy) to the rest of the community [42,43,67,68]. School meals can also help reinforce and celebrate tradition, cultural diversity, and a sense of community among students, school staff, families, and local producers [69,70]. School gardens are an educational platform linked to school meals that can further promote the local community's social, physical, and environmental well-being [69,71]. School gardens can be integrated into the nutritional and educational strategy of schools to offer enjoyable learning opportunities by developing students' skills on how to grow, manage, harvest, and cook seasonal produce, as well as promoting students' involvement in food preparation at home [69,71]. Furthermore, they offer opportunities for increased exposure to food items and cooking traditions from ethnic minorities to prevent social exclusion and prejudice, and to promote meaningful social and cultural exchanges around meals [72].

### 2.4. School meals systems and the environment

The intensification and oversimplification of agricultural systems are increasingly impacting ecosystems worldwide and contributing to concerning trends for climate change [1,4,13]. Some of these concerns include soil acidification [6], exhaustion of freshwater resources, water eutrophication [73], biodiversity loss [8], and a sequence of effects (e.g., nitrogen cascade [4,13]), which disrupt the environment. One way to minimize environmental impacts of the food system is shifting toward lower-impact, plant-based food consumption (e.g., [74–76]) and transitioning from conventional resource-extracting farming systems toward regenerative and less intensive approaches [1,75,77,78]. Public procurement in school meals systems can be a lever for strengthening and supporting less harmful supply chains [40,77], prioritizing local and agroecological synergies over highly intensive approaches that focus only on yield quantity at the expense of other (community- and environment-oriented) metrics.

### 3. Plant-based school meals for sustainable food transitions

The current scientific consensus is that progressing toward more sustainable food systems requires both production- and consumption-side measures [79]. One of the consumption-side measures with the highest potential to help mitigate climate change and biodiversity loss is favoring plant-based over animal-sourced food products and meals [3, 5]. The school meals system can help promote these changes by strengthening known drivers and tackling known barriers to increased plant-based eating (e.g., [80–82]). The potential for large-scale plant-based dietary shifts through school meals interventions is also strengthened in light of evidence that parents may be motivated by their children's food tastes and desires when making food purchase choices for the family [83], and often adapt to their children's preferences [84]. The current review and resulting integrative framework address the proposition that increased plant-based eating in schools may help promote sustainable food transitions with potential cross-sectoral implications for public health, social protection, economic development, community welfare, and the environment.

Regarding health, increasing evidence suggests that following a well-planned plant-based diet – characterized by an abundance of grains, nuts, legumes, leafy greens, starchy and cruciferous vegetables and fruits, with limited consumption of animal products, highly refined grains, added sugars and oils – is associated with multiple health benefits (e.g., [85,86]). Some of these benefits include, for example, reduced all-cause mortality [87] and cardiovascular protective effects [88,89]. A

lower incidence of obesity and type 2 diabetes is also associated with various types of plant-based diets, especially when compared to diets higher in animal-sourced foods [90,91].

Furthermore, well-planned plant-based diets also tend to be richer in phytonutrients, which are linked with a lower presence of inflammatory biomarkers [92] and lower risks of several noncommunicable diseases [93–95]. According to a recent umbrella review of systematic reviews and meta-analyses, plant-based diets are associated with a reduced risk of diabetes, ischemic heart disease, and cancer [96]. Taken as a whole, this suggests that the potential health benefits of school meals systems may be bolstered by enabling access to – and increasing familiarity with – nutritionally balanced plant-based meals. This can help promote healthier and more sustainable life-long food preferences and eating habits where plant-based eating is increasingly normalized, through exposure to diverse, balanced, and appetizing plant-based meals during school years, in addition to the animal-based meals which currently dominate Western and Westernized representations of what constitutes a 'proper meal' [97–99].

Strengthening the role of healthy plant-based meals in school meals systems can potentially yield indirect long-term outcomes for the economy and community welfare. Efforts to prevent and tackle Non-communicable Diseases (NCDs; e.g., cardiovascular diseases, cancer, diabetes) are seen as a vital investment [100], since NCDs are responsible for the death of more than 36 million people a year, with a global economic impact estimated to reach \$47 trillion by 2030 [101]. Additionally, obesity substantially burdens the global economy in terms of direct healthcare-related costs, lower productivity due to lost workdays, permanent disability, and premature mortality [54,55]. Favoring healthy plant-based meals in school meals systems may carry further economic opportunities due to the contrasting resource requirements in conventional production systems and supply chains of animal (vs. plant-based) food products. Animal-sourced foods tend to be less efficient in land use, water irrigation, and reactive nitrogen emissions than plant-based foods [102]. Favoring partial replacements of major animal food categories (i.e., beef, pork, dairy, poultry, eggs) with plant-based sources of protein can create conditions for producing more food per unit of cropland [76], as well as reducing anthropogenic suffering and improving animal welfare [103]. Emerging evidence also suggests that the (monetized) health and environmental co-benefits of plant-forward transitions may mitigate potential economic losses in the agri-food sector in Europe [104]. Furthermore, sustainable dietary patterns, which are typically characterized by plant-rich diets, were recently identified as lower in cost than current diets in most high-income and many middle-income countries when considering different socioeconomic scenarios up to 2050 [105]. Calculating the real (short-, mid-, and long-term) economic costs and benefits of large-scale dietary shifts is a complex endeavor, especially with the likely aggravation of the climate crisis. Nevertheless, these emerging findings raise the hypothesis that the potential economic benefits of optimizing the school meals systems can be strengthened by favoring an increased reliance on plant-based meals.

Lastly, there are also relevant potential environmental outcomes associated with large-scale transitions toward increased plant-based eating in school meals systems. Evidence suggests that following whole-food plant-based diets is important for maintaining proposed sustainable food production parameters at desirable levels [1,76,106]. Plant-based foods tend to have lower environmental impacts (i.e., GHGs, land use, fossil fuel energy use, eutrophication and acidification potential) compared to animal-sourced products [102,106]. For example, a recent modeling study of 85 countries revealed that the adoption of dietary guidelines recommending the limited consumption of red meat and dairy in favor of plant-based foods, was associated with significant reductions in greenhouse gas emissions and progress in attaining global environmental targets [107]. Similarly, a systematic review of environmental impacts of dietary change in 49 dietary scenarios highlighted the potential to reduce total per capita GHG emissions through a

transition to plant-based diets and healthy diets with limited intake of ruminant meat [108]. It is also estimated that the future per capita land demand would be reduced very substantially with plant-based diets and healthy diets with restricted intake of ruminant meat [108,109]. Recently, a comparative life-cycle assessment of plant and beef-based patties has shown that plant-based options have a much lower impact on climate change than their animal-sourced counterparts [110]. These overall findings are particularly relevant in the context of ‘food away from home’ catering services. On the one hand, the school meals system shows the highest greenhouse gas emissions compared to other ‘food away from home’ settings, particularly during the food production phases [111]. On the other hand, meat-free school meals have shown lower environmental impacts during the same life-cycle assessment phase [112]. Taken as a whole, these dietary shifts may have significant environmental benefits, especially if implemented within the school-meals system, where around 370 million children receive a school meal a day worldwide [22].

#### 4. Conclusions and future directions

The current review advances the proposition that school meals systems may help enable sustainable food transitions. Additionally, it proposes that favoring healthy plant-based meals in schools has the potential to strengthen positive outcomes of these transitions across multiple sectors. The review and the proposed integrative framework illustrate the interconnectedness between major societal domains and the potential for new advances in planning and policymaking based on concerted efforts from stakeholders across sectors – with a focus on school meals systems (Systemic Regeneration Wheel, Fig. 1). This reinforces previous calls for integrated, cross-sectoral efforts to enable sustainable food transitions [5,81,113,114].

The current framework offers a first step for additional efforts to expand and consolidate these propositions and cross-sectoral approaches. Narrative reviews - such as the one presented here - are not guided by predefined, protocol-based search methods which usually also include some form of data extraction and synthesis (e.g., PRISMA [115]). This means that narrative reviews are not equipped to minimize selection biases, unlike systematic, scoping, or umbrella-reviews and meta-analyses, and should not be taken as self-standing summaries of the available evidence on a given topic. The aim here was to encourage transdisciplinary dialogue in the context of school meals, plant-based eating and sustainable food transitions, and advance toward more integrative conceptual frameworks applied to this topic, which may ultimately inform the design and implementation of sustainability programmes, research, and policy. This should be regarded as complementary to further research and subsequent reviews that ensure standardized, controlled procedures to collect, synthesize, and communicate research findings [24,25], as well as challenges in the implementation of the framework.

We suggest as a priority that future efforts to enable sustainable food transitions in schools seek opportunities for interdisciplinary dialogue across the sectors highlighted in this review. For example, acknowledging the systemic nature and potential of healthy plant-based school meals for food sustainability transitions may inform modeling studies (e.g., [105,107]) and multi-criteria evaluation and life-cycle analyses [116] that go beyond conventional (field-specific) metrics and indicators. The SRW can help guide, develop, and assess cross-sectoral strategies and trajectories to identify pitfalls, trade-offs, and opportunities to promote healthy and sustainable plant-based meals in school environments, which favor shorter supply chains and environment-friendly agricultural techniques. The SRW can also inform extensions of research on provision- and consumption-focused pathways to enable sustainable food transitions in schools, such as strengthening ethical and environmentally beneficial consumption orientations, increasing and improving the offer of plant-based meals, and mobilizing local communities and society [98]. This is important to set concrete,

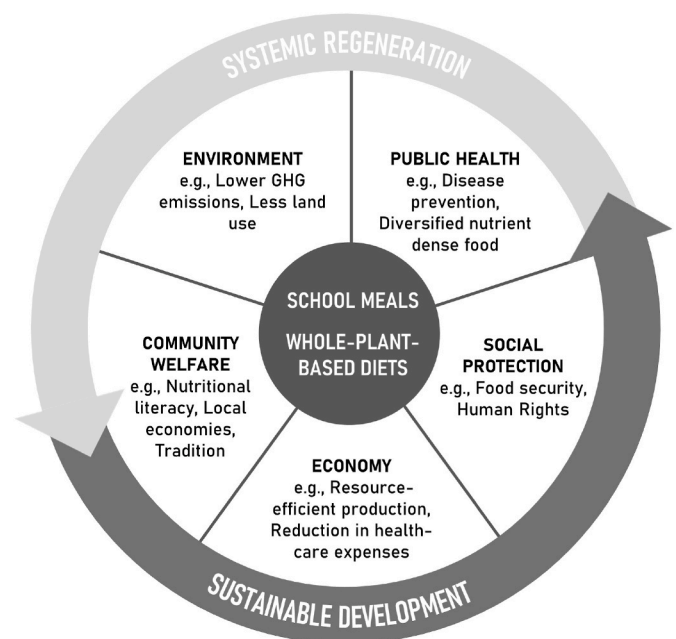


Fig. 1. Systemic Regeneration Wheel (SRW): Plant-based school meals as levers of sustainability transitions with potential outcomes across sectors of society.

context-specific action plans that anticipate possible attrition and implementation challenges of shifting from meat-centric toward more flexitarian school food environments (e.g., [98,117–120]). In addition, the SRW applied to the school meals system can act as a frame from which different pathways for food transformation can be envisioned and implemented, namely those proposed by influential multi-sectoral approaches and international guidelines (e.g., Planetary Health Diet [3]). These pathways include: 1) strengthening long-lasting and multi-level (i.e., global, regional, local) partnerships between governing bodies and actors of the private sector and civil society; 2) fostering international, national, and local commitments to dietary shifts; 3) re-aligning the food production system’s goals and values from yield quantity to nutrient-dense and diversified food offered to students; 4) promoting eco-centric governance of land use; and 5) intensifying the demand for nutritionally dense food, with lower environmental impact, by school-aged children, their families, and their communities. Hence, actors, stakeholders, and decision-makers within the school meals system that place sustainable food transitions on their agendas and favor healthy plant-based eating in school environments are potentially at the forefront of creating a positive impact on our current and future societies.

#### Funding/Acknowledgements

This work was supported by Programa Lisboa 2020, Portugal 2020 and the European Regional Development Fund (Lisboa-01-0145-FEDER-029348), and by the state budget through the Portuguese Foundation for Science and Technology (PTDC/PSI-GER/29348/2017).

#### Declaration of competing interest

None.

#### Data availability

No data was used for the research described in the article.

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