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Sustainable Food Security and Nutritional Challenges

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Abstract: Food security is an immensely complex issue connected to global food production and supply systems. One of the key challenges is to provide sufficient, safe, and nutritionally balanced food for everyone on the planet. It is closely linked to many factors including population growth, poverty, economic stability, and environmental sustainability. Currently, the world population is growing at an unprecedented rate, placing immense pressure on food production systems. Thus, meeting the increasing demand for food presents a significant challenge for the current global agriculture and food systems. The World Food Program reported that over 345 million people faced high levels of food insecurity in 2023. Additionally, 2 billion people are living with micronutrient deficiencies (such as vitamin A, iron, and iodine). Over time, a severely restricted food intake can cause malnutrition and reduce the lifespan. On the other hand, nearly 2 billion adults worldwide are overweight or obese. Global emergencies such as the COVID-19 pandemic and war zones have complicated the situation and resulted in increased hunger, lower immunity, increased infectious disease, and increased rates of early mortality. Furthermore, climate changes are disrupting traditional growing seasons, increasing the frequency of extreme weather events, and posing a serious threat to crop yields. This scenario warrants adaptation of sustainable and resilient agriculture and food systems is crucial for improved and sustainable food security.

Keywords: food security; hunger; malnutrition; nutritionally balanced; sustainable; climate change; food production system; triple burden; SDG

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1. Introduction

Global population growth over the past century has led to a substantial increase in demand for food and this trend is set to continue. Based on the United Nations report [1], the world's population will surpass 9.7 billion people by the year 2050, and this number is projected to climb well over 11 billion by the year 2100. If these numbers were compared to the global population nearly a decade ago (2015), there would be 53% more people requiring food and water supply in addition to medication, shelter, and education [2]. Furthermore, the demographic areas that significantly contribute to this rapid growth include the regions of Africa and South Asia, particularly individuals aged between 15 and 24 and aging populations (65 and over). Consequently, this may result in different food consumption patterns that may affect the increase in requirements for several food items (cereals, fruit, vegetables, animal proteins) [1]. Therefore, it is evident that consumer behavior and the increase in the number of people living on the planet significantly influence the prospects of food and agriculture.

This increase in the overall population also presents an increase in two very polarized sub-population extremes that contribute to further health and well-being challenges. In one extreme, we are faced with an increased share of the undernourished population. In this context, we can expect negative health consequences resulting in hunger, lower immunity, increased infections disease, and increased rates of early mortality. In addition to the consequences of the global pandemic due to the SARS-CoV-2 pandemic, in 2021 it was estimated that nearly 1 billion people across 93 countries do not have enough food to eat, making it one of the worst years for world hunger [3]. On the other side of the spectrum, we are faced with increased rates of obesity with nearly 2 billion adults classified as being overweight and more than 35% of this population being obese [4,5]. Among many factors contributing to the current food insecurity situation include challenges in supplying nutritious and safe foods when the consumers' food purchasing powers are limited [6,7]. Therefore, it is plausible to propose that this double burden of malnutrition will lead to an increase in adverse cardiometabolic and psycho-cardiological health effects (among other health issues) associated with inadequate nutrition, and obesity and overweight.

A report published by EAT [8] described the current global food system as the single largest human pressure on earth, threatening local ecosystems, driving a sixth mass extinction of species, and impacting the stability of the entire earth system. The problem for people not getting enough food is because of unsustainable and unjust mechanisms of production, consumption, and distribution of food. The concerns about rapid climate changes and the growing global population have stimulated efforts to explore more sustainable food production systems [9]. This can be seen in the so-called protein transition, wherein plant-based proteins are replacing animal-based proteins. Helland and Sörbö [10] elaborated that sustainable food security requires (a) availability of food or sufficient food production, (b) access to food and ability to purchase food, (c) sufficiency in terms of nutrition including energy, proteins, and micronutrients as well as safety, and (d) the stability and foreseeability of these conditions. There are logical reasons to shift food consumption patterns to more plant-based diets as half of the world's cereal production ends up as animal feed leaving only around one-third for human nutrition [11]. Another example of sustainable intensification and source reduction could be intensifying the harvest of vegetable crops to double the output with the same footprint [12]. Therefore, changing the current global food system in a sustainable direction will improve global food security and make it more resilient [13].

With such a bleak picture of the global population and food systems, in addition to the non-viral consequences of the pandemic, food science and human nutrition as well as food innovations are proposed to be the most influential areas for the management of future population demands. This includes rapid advancements in areas of agri-food technologies, food supply, health, therapeutics, and several other overall life areas wherever the food is the focus point. This article discusses the importance and availability of nutritionally balanced food for sustainable food security and highlights the challenges in meeting sustainable development goals (SDGs) in the future.

2. Functions of Food

Food is important for life, all living things (including human beings) need food and water to survive. It is an essential need of humans to meet certain fundamental conditions for survival. Food has many functions in the human body including: (a) it helps to stay alive, be active, move, and work, (b) it builds new cells and tissues for growth, (c) it is needed to maintain health and heal, and (d) it prevents and fights infections [14]. Human basic nutritional requirements consist of adequate intake of macronutrients, micronutrients, and water. Macronutrients (carbohydrates, fat, and protein) are the nutritive components of food that provide energy and maintain the body's structure and systems. Micronutrients (vitamins and minerals) are equally important for the body's function but are consumed in very small amounts in comparison to macronutrients. These can be further divided into macro minerals, trace minerals, and water- and fat-soluble vitamins. Vitamins play a role in energy production, immune function, blood clotting, and many other functions whereas minerals are needed for normal growth, bone health, fluid balance, and several other processes [15]. A 'balanced diet' generally contains adequate amounts of micronutrients. Water has a key role in many of the body's functions such as nutrient metabolism, getting rid of wastes, protecting joints and organs, and maintaining body temperature. All nutrients (macro and micro) and water are needed for an active and healthy life.

It is clearly explained that food and water are basic needs of the human body as food sources provide energy and water keeps it hydrated to function properly. Experts are not able to establish exactly how long a person can live without food, but there are records of people surviving without food or drink between 8 and 21 days [16]. The unavailability of food could lead to a condition known as starvation (when a person's body does not receive enough energy-providing nutrients to carry out its usual life-supporting functions). The length of time that the body can survive without food is determined by many different factors and this period significantly varies among individuals. An individual's age, sex, body size, fitness, general health, and activity level all play a role and influence survival period. Table 1 provides an overview of the survival periods when food or water or both are not available and examples of the effects on the body's functions [16–18].

Table 1. Unavailability of food and water—survival period and effects on the body [16–18].

Food Availability Situation	Survival	Effects on the Body's Functions
With water only, no food	1–3 weeks (most cases) (In some exceptional cases, up to 2–3 months)	Starvation affects many vital processes including: Cardiovascular system (drop of pulse and blood pressure) Gastrointestinal system (bloating, stomach pain, vomiting, nausea, fluctuations in blood sugar levels, bacterial infections) Central nervous system (lack of brain energy, difficulty concentrating, sleep issues) Endocrine system (menstruation becomes irregular or stops altogether, bones weaken, metabolic rate drops, and core body temperature drops leading to hypothermia)
With food only, no water	2–3 weeks (Adults can survive for a few weeks but infants can die within hours)	The unavailability of water causes dehydration. Moderate dehydration symptoms • Dry mouth and tongue • Restlessness and irritability • Sunken eyes • Feeling thirsty • Urinating less Severe dehydration symptoms • Lethargy • Unconsciousness • Weak or absent pulse • Very dry mouth and tongue • Low blood pressure • Passing very little or no urine at all

Table 1. *Cont.*

Food Availability Situation	Survival	Effects on the Body's Functions
No food, no water	4 days (Maximum one week)	Starvation and unavailability of water are more dangerous and lead to • Loss of weight • Metabolic rate drops • Multiple health problems (stunting, wasting, reduced immune system function, micronutrient deficiency) • Dehydration

Basically, food is a carrier of nutrients aiming to maintain the body. The main challenge is ensuring the availability of a nutritionally balanced diet for the growing world population and not kilograms or even calories.

3. Food Availability for Sustainable Food Security

Availability of food from production and distribution to exchange is one of the most fundamental pillars of food security [10,19,20] (Figure 1). This pillar has evolved from the sufficiency of food amount to that of energy and nutrients in the food supply, in addition to food safety [13].

The importance of sustainability as a long-term time dimension of food security (Figure 1) has been highlighted [21], in response to various challenges to the current food and nutrition system such as climate changes and health concerns for a growing population [13,19,22]. Sustainability has been elaborated to encompass all existing food security pillars [21]. Each pillar can be measured by several indicators at a different level, availability at regional and national levels, accessibility at the household level, utilization at the individual level, and stability at the exposure/shock or vulnerability levels. A suite of indicators also has been proposed to measure sustainability at each of those levels. For example, nutrition and health indicators have been nominated to measure sustainability at the individual level, namely that of the utilization pillar of food security. Intakes of fruit and vegetables, dietary diversity score, measures of food insecurity/security status of vulnerable groups, and diet-related non-communicable diseases (NCDs) and mortality are a few such indicators.

The close inter-relations between food availability, nutrition (and thus utilization), and sustainability are further illustrated by findings of a recent systematic literature review [23]. The authors elaborated on nine domains of sustainable food security. Two such domains have been identified as 'sufficient food' and 'balanced and diversified diet', corresponding to food availability and utilization, respectively. Some even view availability as an essential prerequisite to addressing under-nutrition issues in a socio-economically sustainable manner [24]. As such, the influence of the sustainability dimension of food security on population health is mediated by multiple other dimensions such as food production (availability), malnutrition, and dietary behaviors (utilization) [25].

3.1. Balanced Diet and Health Outcomes

In the case of food security, when sustainability and all four pillars such as availability and utilization of food are in optimal states, physical and mental well-being can be more easily achieved (Figure 1), even during times of major population health challenges [26]. This applies to population wellbeing in response to diseases, as well as the attainment of Sustainable Development Goals (SDGs). In fact, 12 or more of the 17 SDGs contain indicators for or affected by malnutrition, particularly those related to health and wellbeing [27]. The pivotal role of a balanced diet, as a result of food security, for optimal health is reflected by findings of a recent ecologic study that explored the relationship between under-nutrition, dimensions of food security, and socio-economical development at the global level [28]. The analysis highlighted that the availability of food and nutrients per capita, particularly protein in food supply appeared to have impacted the prevalence of under-nutrition more than the level of socio-economic development. At the population level, food and nutrient availability data (food balance) are commonly used to estimate dietary trends, in the absence of actual intake data [29]. Therefore, it is plausible that a balanced diet characterized by appropriate quantities and proportions of specific types of food and nutrients may influence health outcomes such as nutritional status [30].

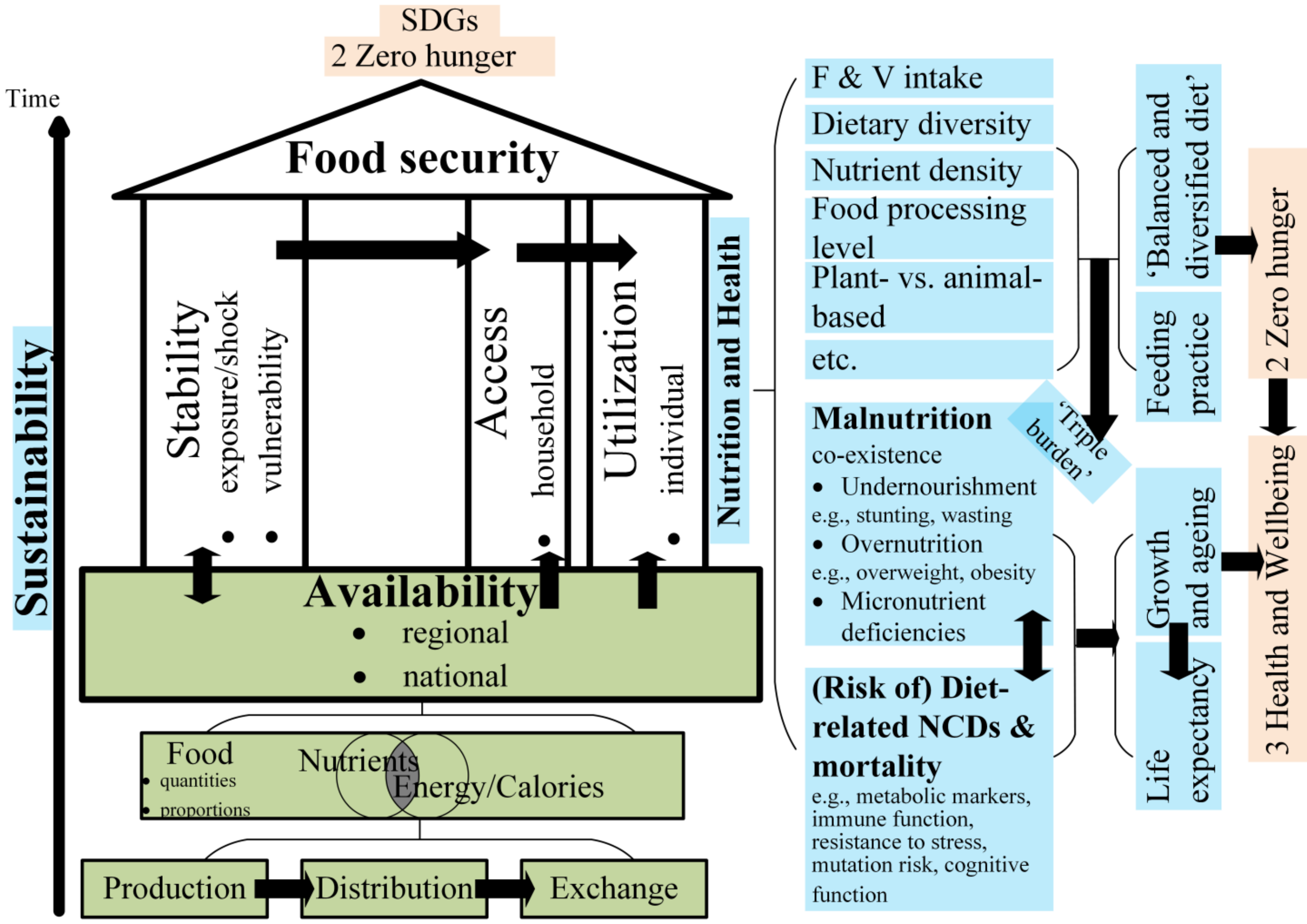

Figure 1. Schematic representation of relationships between sustainable food security, food availability, and nutrition and health outcomes. F & V = fruit and vegetable; NCD = non-communicable disease; SDGs = sustainable development goals. Apricot text boxes refer to SDGs.Blue text boxes represent components of the 'Uitlization' pillar to which indicators of sustainability are applied. Green text boxes represent components of the 'Availability' pillar, the basis of food security. Arrows indicate direction of contribution when variation in sustainability indicators occur. The time axis on the left represents the time dimension of food security.

In addition to the quantities of foods and nutrients, overall dietary quality, as measured by dietary diversity may help to improve dietary behavior. For example, household dietary diversity has been reported to correlate with improvement in mothers' infant feeding practices [30,31]. Optimal infant feeding practice has been shown to lower the risk of infection and mortality in early life and corresponds to improved metabolic markers in later life [32,33]. A balanced diet, also characterized by an abundance of plant-based foods, lower intakes of meat, higher intakes of dietary fiber, and minimal consumption of ultra-processed foods, in comparison with a typical 'western' dietary pattern, has consistently demonstrated improved metabolic profile, immune function, resistance to stress and lower risk for genetic mutations, all clinical features associated with healthy aging [34–36]. A long-term shift of diet from unhealthy to healthy aging-associated patterns could increase population life expectancy from a few years to over a decade [37]. Thus, a balanced diet, enabled by optimal food and nutrient availability as part of sustainable food security, appears to help improve nutritional status, certain dietary behaviors, key clinical outcomes during growth and aging, and thus plausibly life expectancy [31–36]. Attainment of these outcomes may then contribute to that of SDGs.

On the other hand, when the pre-requisite of sustainable food security, the availability of nutritious food is diminished, attainment of a balanced diet becomes less stable or likely or even impossible, triple burden of malnutrition and hence the associated longer-term health outcomes may emerge in the case of non-transitory food insecurity [38,39]. These three broad groups of malnutrition include undernutrition, micronutrient-related malnutrition, and overweight and obesity, and the associated diet-related NCDs [38,39]. What warrants the common root cause of all three forms to be addressed is the emerging co-existence of them in many socio-economically disadvantaged populations and sometimes within single families [40].

3.2. Undernutrition

Undernutrition is commonly manifested as muscle wasting (insufficient weight-for-height), stunting (insufficient height-for-age), and being underweight (insufficient weight-for-age) [39]. While a balanced diet, more likely achieved during food security can positively influence dietary behavior and health outcomes, food insecurity has been consistently reported to impede the adoption of healthy dietary behavior and many health outcomes [30,40]. The severity of food insecurity can also be measured by the prevalence of undernourishment, as an indicator of the extent of dietary energy available compared with the estimated population requirement in a region.

Recent global data indicates that increased food insecurity severity is associated with a general lack of consumption of all food groups, and increased odds of adhering to unhealthy dietary practices [30]. For example, higher severity of food insecurity was associated with lower dietary diversity in women within the age group 15–49 years. This was reflected in the higher prevalence of no consumption of fruit or vegetable and animal-source food and lower odds of adopting diets protecting against NCDs, albeit also with lower odds of consuming diets linked to NCDs. These associations are alarming as they were based on data from a group of mostly low- to middle-income countries (LMICs), generally more vulnerable to the consequences of undernutrition [40]. Among the stagnant prevalence of undernourishment and moderate to severe food insecurity at the global level, those that worsened were among the LMICs and disproportionally affected the least developed countries (LDCs).

Higher prevalence of stunting in those aged five years and below and anemia among women aged 15–49 years were reported in LDCs than the world average [30]. Evidence from high-income countries indicates a similar trend. For example, a US cross-sectional study of the 2007–2010 NHANES data reported moderate to high household food insecurity correlated with lower odds of household availability of healthy foods, including fruits, dark green vegetables, and fat-free or low-fat milk, albeit also with lower odds of availability of salty snacks [41]. In that study home food availability was a surrogate measure for household food choices. Individuals with food insecurity demonstrated more severe binge-eating behaviors [42–44], with higher consumption of dietary energy, fat, and carbohydrates in experimental settings with the unrestrictive supply of processed and ultra-processed food [42,44].

The most recent surveillance of nutritional status around the world indicated an increased prevalence of obesity in adults, in addition to anemia among women of the age range of 15–49 years [30]. Stagnant progress in alleviating low birth weight, wasting, and overweight among children aged five years and under was also reported. A projection of 6.8% globally will still experience chronic undernourishment by 2030 based on current trends, leading to a daunting outlook for the achievement of SDG2 (zero hunger). In addition to overall nutritional status and anemia, recent evidence alerts us to the widespread risk of inadequacies of many micronutrients, despite regional variations [45]. More than 65% of the world's population has been estimated to be at risk of inadequacies in iodine, vitamin E, calcium, and iron. Even the micronutrient least of concern in that study, niacin, may be at risk of insufficiency in approximately 22% of the global population. Thiamin and magnesium are next, with approximately 30% of the population at risk. Folate, riboflavin, pyridoxine, cobalamin, niacin, and selenium were of particular concern in specific regions.

The wider spread of risks appears among women than men for those 12 nutrients mentioned by Passarielli [45], except for niacin, pyridoxin, thiamin, and magnesium. The sex difference in risk of micronutrient insufficiencies corroborates the gap in food insecurity, which only appears to be widening when compared with the pre-COVID-19 pandemic levels [30]. This is alarming as the achievement of SDG2 is the foundation for the development of other sustainable goals. There is thus little evidence to support optimism for the achievement of SDG3 (good health and well-being). In fact, food insecurity appears to correlate with overall poor NCD risks and outcomes, poor mental health, self-reported health, cognitive function (including dementia), and several physical health indicators in the musculoskeletal, respiratory, and cardiovascular systems in the general population of middle to older ages in India [46,47]. Similar in terms of impacts on NCD outcomes in the US, food insecurity is associated with metabolic abnormalities or augmented susceptibility to undesirable weight changes commonly predisposing to metabolic abnormalities [42–44,46]. For example, individuals with food insecurity appeared to present with higher body weight or BMI, and higher susceptibility to hunger cues [41]. These are reflected in their metabolic and hormonal changes. They showed higher 24 h respiratory quotient due to higher and lower oxidation rates of carbohydrate and fat, respectively, and lower levels of fasting glucagon-like-peptide 1, known to increase food and caloric intake [41] and body weight increase [48]. Overweight and obesity contribute significantly to the global total disease burden and all-cause mortality [49–51]. Thus, undernutrition due to food insecurity likely contributes to the risk of NCDs and all-cause mortality partly due to under-supply of all food groups, particularly healthy foods such as fruits, dark green vegetables, low fat or fat-free milk, in the case of severe food insecurity [30,40,41,46] and partly due to unlimited availability and hence consumption of unhealthy foods such as ultra-processed foods [42,44].

3.3. Excess Food Consumption

As another form of malnutrition, overweight and obesity, primarily as a result of excessive energy intake compared with the requirement, is partly linked to the technical definition of food insecurity via the effects of the types of food available [30,40,52,53]. An ecologic study based on data on the availability of household food from nineteen European countries highlighted the critical role of ultra-processed foods (UPFs) in impacting national adult obesity prevalence [53]. An increment in UPFs by 1% to total energy availability corresponded to a 0.25% augmentation in adult obesity prevalence. Ultra-processed foods are often characterized by high-energy but low-nutrient density, typically due to high levels of total fat, particularly saturated fat, added sugar, and/or sodium, and in most cases lower dietary fiber [54]. In line with this, cereal availability was inversely associated with obesity prevalence, while sugar availability and hence consumption a positive predictors of obesity prevalence, together with physical inactivity [55]. Considering the association of overweight and obesity to the risk of NCDs [39,56], it is plausible that food insecurity due to disproportional availability and hence consumption of UPFs, at the household level could at least partly mediate the linkage between overnutrition represented by excess dietary energy and risks of NCDs. This proposition is supported by Pereira de Araújo [57] based on food availability data in Portugal around a similar period as in Monteiro et al. [53]. Availability and hence consumption of ultra-processed food positively correlated with the prevalence and incidence of digestive diseases and incidence of cancers [57]. The availability of cereal, on the other hand, could negatively predict the prevalence of hypertension [55]. The nutrient profile of ultra-processed food particularly the macronutrient profile seems to contribute to its effects on excessive energy intake and thus overnutrition [56]. Other characteristics of ultra-processed food proposed to contribute to overnutrition include its undesirable portion size, effects on satiety and glycemic load, and aggressive marketing strategies, all encouraging overconsumption [53].

It is important to emphasize that the definition of the triple burden of malnutrition implies the co-existence of micronutrient deficiency and overweight and obesity due to excessive energy intake among those who experience moderate food insecurity [40,46]. Thus, it is plausible that one unifying underlying cause of overnutrition, micronutrient deficiency, and undernutrition is the availability of foods considered healthy, namely those with high nutrient density, through production, distribution, and exchange, as part of a sustainable food and nutrition system [19,40]. With the increase in food insecurity and decline in nutritional status around the globe [30], population and system-based interventions including changes to policies relevant to agriculture, food, nutrition, and international trades, concepts of socio-economic development, and hence educational campaigns and relevant advocacy work from regional to international levels are likely warranted, in addition to coordination and cooperation between the public and private sectors across the entire food and nutrition system.

4. Nutritional Challenges to Meet Sustainable Goals

Malnutrition in all its forms is increasing in developing and developed countries, and this trend is associated with a nearly 200% global population increase [58,59]. This presents a significant challenge to nutrition, health, and sustainable development. Globally, the world has adopted the United Nations 2030 agenda for SDGs, which consists of 17 goals to end poverty, improve health, and protect the planet. While SDG 1 explicitly mentions ending poverty, nutrition plays a significant role across all the SDGs, directly or indirectly [60]. There are several causes/effects of poor nutrition that pose a threat to global development, leading to child stunting, anemia in women of reproductive age, low birth weight, childhood overweight, child wasting, and lack of exclusive breastfeeding (in the first 6 months after birth) [61].

Currently, the global malnutrition situation reveals the co-existence of undernutrition, micronutrient deficiencies, and overweight/obesity in individuals, households, and populations (double-burden or as the triple burden of disease), impacting millions of people globally (21.3% under-five stunted children, 41.7% anemic individuals, 29.0% with vitamin A deficiency, 54.3% women overweight/obese, 17.0% at risk of zinc deficiency, 12.0% have inadequate iodine intakes) [61–69]. These factors have a significant combined effect on global development and health [70]. The 2024 State of the World Food Security and Nutrition Report recently revealed that as of 2023, there were 733.4 million undernourished people globally, highlighting that most of these individuals, 52% and 40%, are in Asia and Africa [71]. This underscores the urgent need for increased commitment to addressing hunger, particularly in continents with more undernourished people [71].

Additionally, this report reveals the current reality of the global food security situation, where global prevalence stands at 10.7–28.9%, with higher prevalence in Africa (58%) compared to other continents (Asia 24.8%, Latin America and the Caribbean 28.2%, Oceania 26.8%, Northern America and Europe 8.7%) [71]. The humanitarian crisis and pandemic have worsened the situation, leading to increased costs of a healthy diet and more individuals facing food insecurity compared to the pre-COVID-19 era [71,72]. The issue of food insecurity is driven by various factors such as food prices, population growth, poverty, changing consumption patterns, pressure on food production, water scarcity, biofuel production, and lack of public-private infrastructure investment [71,73]. These factors vary from country to country and contribute to undernourishment in developed and developing nations.

Addressing this challenge is crucial for progressing towards the 2030 UN Sustainable Development Goals agenda. In addition, the lack of/insufficient data required to drive policy and implementation/intervention action remains a significant challenge. However, there are sustainable solutions to these challenges [74–76]. Despite global efforts geared towards nutrition interventions, there is still more to be desired, given the current impact of COVID-19 and other global crises [77–80]. Nutrition interventions reported in many studies and reviews directly affect the SDG's progress, impacting SDGs 2 and 3, and will require scaling up at the country level to improve the impact [68,81–84]. From a nutrition standpoint, various gaps mitigate the on-track progress toward achieving the SDGs; the gaps are tailored around policy, program, and interventions [85]. Political commitment and will are crucial to meeting the current nutritional challenges and ultimate progress towards the SDGs by 2030; increasing focus on women, adolescent girls, and children at increased malnutrition risk should be the target. Government policies should be based on evidence and involve stakeholders and researchers. To ensure progress towards the SDGs, multi-sectoral efforts should prioritize countries and continents with higher malnutrition prevalence.

It is well established that the increased technological developments in the current food systems have been responsible for increased safety, nutritional value, and beneficial health outcomes [86]. However, these developments are not always perceived well by the consumer. Although the technological advancements in several other industries have received positive responses, the consumer perception of improvements and application of technological advancements in the food industry do not share the same path and, in some cases have been received with strong resistance. In particular, technological applications in foods (such as genetic modification) are most often viewed with negative attributes, while foods that are promoted for their naturalness and produced with minimum human interference are inherently viewed with positive attributes [87]. Any food production system that reduces production [88] per area may lead to greater pressure for food production elsewhere—including clearing further land for agriculture even if marginal and at the expense of biodiversity and other ecosystem services. Recent shift in food consumption trends toward plant proteins driven by concerns related to food security and sustainability [89]. Hence, changing the current global food system to make it sustainable and resilient is vital for improving global food security.

5. Conclusions

Food availability, nutrition (and thus utilization), and sustainability are closely connected elements of food security. A big challenge is the availability of a nutritionally balanced diet for everyone when the world population grows rapidly. The triple burden of malnutrition implies the co-existence of micronutrient deficiency and overweight and obesity due to excessive energy intake among those who experience moderate food insecurity. The existing agriculture and food systems are failing to ensure the supply of sufficient and nutritional food. When the availability of nutritious food becomes an issue the attainment of a balanced diet is less likely or even impossible, which leads to a triple burden of malnutrition and hence the associated longer-term health outcomes. More than 12 SDGs contain indicators for or affected by malnutrition, particularly those related to the health and well-being of the people. The current progress toward achieving the SDGs targets does not look promising. Therefore, addressing the current nutritional challenges by increasing focus on women, adolescent girls, and children at increased malnutrition risk would help in the progress towards the SDGs by 2030. To support these targets, it is important to stimulate more efforts to push the current global food system in sustainable directions to make it resilient for an improvement in the global food security situation. Furthermore, exploring modern IT and emerging AI-based technologies for more efficient resource utilization, reprocessing, and recycling of food to increase availability and nutritional quality.

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