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Review Article

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Sustainable healthy diets for a resilient India

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ABSTRACT

This review aims to highlight the importance of sustainable healthy diets that improve population health while minimizing adverse environmental impacts. A narrative review of literature from PubMed, Google Scholar, policy documents, and government reports published between 2010-2025 was conducted. Key studies on sustainable agriculture, dietary patterns, nutrition, and public health were summarized to identify trends, policy initiatives, and actionable strategies. Sustainable healthy diets should be accessible, economically feasible, safe, equitable, and culturally acceptable. Collaborative actions among stakeholders, including policy makers, researchers, and the community, are essential to ensure equitable access to nutritious foods. Adoption of sustainable agricultural practices and eco-friendly diets can improve health outcomes, reduce environmental burdens, and conserve resources for future generations. Community-wide adoption of sustainable meals can improve human health and reduce environmental impacts, protecting resources for future generations. We can secure resources for future generations by adopting sustainable agriculture techniques, which strike a balance between environmental stewardship and productivity.

KEYWORDS: Sustainable; Nutrition; Environment; Climate Change; Diet; Agriculture; Health

1. Introduction

The issues of nutritional deprivation and environmental degradation are increasing, with nutritionally poor diets contributing to the global disease burden. In the current times, the methods of food production and consumption are harming the environment and natural resources. Encouraging nutritious, socio-culturally acceptable and economically accessible diets that have minimal environmental impact is crucial due to sustainability concerns. Sustainable Healthy Diets are dietary patterns that promote all aspects of individuals' health and well-being, place minimal pressure and impact on the environment and are accessible, affordable, safe, equitable and culturally embraced[1].

2. Cultural and regional significance

While climate change presents challenges, India's rich culinary diversity offers solutions. India's rich and diversified cuisine is closely linked to local agricultural methods, the availability of various foods, social identity, religion and other cultural elements[2]. Recognising and incorporating regional foods and preferences into nutrition guidance to support communities is vital[3].

3. Emerging challenges

Soil nutrient depletion remains a critical concern as climate change worsens. One-third of Earth's soil is moderately degraded, and over half of agricultural land is affected. Intensive farming leads to lower nutritional value in fruits, vegetables and grains while soil fertility is reduced through selective breeding[4]. Declining soil health reduces essential micronutrients like iron, zinc and magnesium

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in staple crops, worsening deficiencies in vulnerable populations reliant on cereals. To reverse this trend, it's crucial to address soil degradation through regenerative agriculture, biofortification and balanced fertilisation. A study reported nutrient shortages in Indian agricultural soils, including S, Zn, B, Fe, Cu, and Mn, with variations across districts, states, and agro-ecological zones[5]. Excessive use of chemical fertilisers and pesticides causes adverse health effects through food consumption, such as disruption of endocrine functions, affects reproduction, increases breast cancer risk, causes abnormal growth and developmental delays in children and alters the immune function system[6]. Climate change negatively impacts crop yields and disrupts food security. A 1 ℃ rise in temperature is estimated to reduce wheat production by 4-5 million tons. Variability in monsoon rainfall and temperature has impacted crop quality, with predictions of 10-40% losses in crop production in India due to a 3 to 5 ℃ rise by the end of the 21st century. It also negatively affects sectors like dairy, poultry and fisheries[7]. Healthy plants provide essential nutrients, and a decline in plant health translates to a decline in the quality of our food intake, potentially leading to malnutrition and related health problems[8]. Micronutrient deficiencies can impact people's learning, IQ, motor skills and immune system function. For children, these effects can last into adulthood. In developing regions, many are at risk of mineral deficiencies because they consume crops grown in soils with low bioavailable mineral concentrations, resulting in low mineral concentrations in cereals, legumes and vegetables[9]. Over two billion people worldwide are deficient in micronutrients, with nearly half residing in India. According to UNICEF, in South Asia, 1 in 3 children has stunted growth, 1 in 7 children is wasted, and 1 in 2 women is anaemic. More than 80% of the Indian population faces risks of deficiencies in calcium, vitamin A, B_{12}, and folate, with more localised deficiencies in iron, zinc, and vitamin B_6. The prevalence of serum zinc deficiency in India exceeds 20%, representing a significant public health concern.

4. Rationale

The impacts of climate change on food systems and nutritional deficiencies present a dual challenge to public health in India. India scored 27.3 in the 2024 Global Hunger Index, indicating a serious hunger level, with 13.7% of the population undernourished. Among children under 5 years of age, 35.5% are stunted, 18.7% are wasted, and 2.9% of children die before their fifth birthday[12]. Climate change is also affecting biodiversity, forests, agriculture, water resources, coastal and marine ecosystems, human health, gender issues, as well as urban and infrastructure sectors[13]. Increased CO_2 levels negatively impact the vitamin content of staple crops like wheat and rice, reducing protein, iron and zinc concentrations. This is particularly concerning for India, where over 50% of women of reproductive age suffer from iron deficiency. This article explores how agricultural practices and dietary patterns impact environmental sustainability and public health, highlighting the need for and advocating strategies for a climate-resilient and nutritionally adequate food system. This manuscript is a narrative review to highlight the importance of sustainable healthy diets that improve population health while minimizing adverse environmental impacts.

5. Methodology

This review synthesized literature from PubMed and Google Scholar, supplemented by targeted searches of policy documents, government reports, and other relevant sources. The review considered publications from 2010-2025 in English, covering studies on sustainable agriculture, dietary patterns, nutrition, and public health across both global and Indian contexts. Evidence was screened for relevance, and key articles were summarized to identify trends, policy initiatives, and linkages between agricultural practices, dietary behaviours, and health outcomes.

6. Bridging health, agricultural practices and food security through sustainable healthy diet systems

In an age characterised by heightened awareness regarding health and environmental sustainability, the food choices of the populace have become increasingly significant. Food choices and eating patterns are vital determinants of human health and affect the planet's health. Dietary patterns in Southeast Asia are shifting to consumption of highly processed and out-of-home foods. The shift away from a diet rich in unrefined grains, legumes, fruits and vegetables, to a diet high in refined carbohydrates, sugars and fats leads to excess weight gain and unfavourable metabolic profile, increased risk of cardiovascular diseases, cancers and diabetes[14]. Food systems significantly impact the environment, accounting for nearly 30% of total greenhouse gas emissions in developed nations. Agricultural practices currently occupy approximately 40% of the Earth's total land surface and are responsible for around 70% of the total freshwater use. As the global population grows, the diet's environmental impact is anticipated to rise[15]. Therefore, adopting a sustainable and healthy dietary regimen is imperative, as it fosters holistic well-being and mitigates the burden on the soil and plant environment. Incorporating indigenous foods into our diets can effectively balance discrepancies, providing nutritional and environmental benefits. Indigenous foods derived from natural ecosystems are environmentally friendly and better adapted to local conditions. They resist extreme weather, low resource intensity and low carbon footprints and use environmentally sensitive technologies. Indigenous foods are rich in nutrients. Research

in various countries has reported better intake of protein, fibre, vitamin A, iron, calcium and riboflavin among people consuming indigenous foods. Ample evidence also shows that indigenous crops are important in addressing malnutrition and hunger. One example of locally grown nutritious food in India is millet, which has been an integral part of the Indian diet for centuries. Millets also benefit the environment due to their low water and input requirements.

The United Nations declared 2023 as the International Year of Millets to raise awareness and increase the production and consumption of millets[16–18]. Furthermore, supporting locally grown foods contributes to the local economy and enhances food security. Locally cultivated food bolsters the local economy by directly impacting the community's financial well-being and promoting job growth. It also minimises the supply chain and decreases dependence on far-off sources, strengthening food security[19].

7. Impact of climate change on public health, nutrition, and dietary supplements

Climate change impacts nutrition security through multiple pathways, affecting food security, livelihoods, access to food, health and socioeconomic factors[20]. It was reported that districts highly vulnerable to climate change can have more child malnutrition than relatively less vulnerable[21]. To combat these issues, interventions such as supplementation have improved population health. They have become widespread and increasingly important in consumer awareness[22,23]. However, dietary supplementation is not a universal solution. They are recommended for those with long-term nutritional deficiencies or diagnosed deficiencies. The focus should be on dietary modifications like incorporating fruits and vegetables, where vitamins and minerals occur naturally alongside other nutrients that can't be obtained from food supplements[24]. Supplements also have an environmental impact, including resource depletion, carbon-intensive manufacturing and plastic waste. Industrial agriculture was seen as a solution for a growing world with synthetic fertilisers, chemical pesticides and high-yield cereal hybrids. However, decades of these practices have reduced nutrient density, prompting a change toward regenerative agriculture to restore soil health and enhance crop nutritional value, thereby minimising the need for synthetic supplements[6,25].

8. Fostering agricultural sustainability in the face of climate change

Sustainable Consumption and Production is the focus of Goal 12 of the Sustainable Development Goals (SDGs). It underscores the imperative of achieving more with less to meet the present generation's needs without compromising those of the future generation. It targets to reduce per capita global food waste by half at the retail and consumer levels and diminish food losses throughout production and supply chains, including post-harvest losses, by 2030. This goal is connected to Goal 2: Zero Hunger, which focuses on sustainable food production systems and implementation of resilient agricultural practices that help maintain ecosystems and Goal 13: Climate Action, which seeks to enhance education, awareness and human and institutional capacity about climate change mitigation, adaptation and impact reduction[26]. The National Mission for Sustainable Agriculture, part of the National Action Plan on Climate Change, is being implemented to reduce the effects of climate change on water and food security. It aims to evolve and implement strategies to strengthen Indian agriculture's resilience to climate change. The Indian Council of Agricultural Research has launched National Innovations in Climate Resilient Agriculture (NICRA) to study the impact of climate change on agriculture and develop and promote climate-resilient agricultural technology benefiting vulnerable sections of the country. The project outputs will benefit districts and regions prone to extreme weather conditions. NICRA has initiated the Climate Resilient Villages (CRVs) concept to improve farmers' resilience and capacity to adapt to climatic variability. Through the NICRA project, Indian Council of Agricultural Research creates awareness among farmers about the impact of climate change on agriculture[27].

Two schemes, Paramparagat Krishi Vikas Yojana and Mission Organic Value Chain Development for North Eastern Region, focus on providing comprehensive support to organic farmers. Paramparagat Krishi Vikas Yojana is being implemented in all states except the North Eastern states, whereas the MOVCDNER system is only implemented in the NE states. The Mission for Integrated Development of Horticulture, Agroforestry and National Bamboo Mission aims to enhance climate resilience[28]. However, the success of these initiatives depends on practical implementation and farmer participation. A major challenge is the adoption rate of such agricultural practices, which remains limited due to financial constraints, lack of awareness and policy gaps. Strengthening incentives, such as carbon credits for farmers practising regenerative agriculture, integrating digital technology for soil health monitoring and enhancing extension services, can accelerate adoption rates. Adoption of AI technologies can offer further support, for instance, through predictive crop modeling and digital soil health monitoring. Environmental and socio-economic drivers, including climate variability, soil health, and market forces, influence agricultural practices, dietary patterns, and public health outcomes, highlighting pathways to promote sustainable nutrition and resilient agricultural systems.

9. Advancing sustainable nutrition practices

Encouraging eco-friendly methods in nutrition is vital for fostering a sense of environmental responsibility while improving the health and well-being of individuals and communities.

Infant feeding practices, such as breastfeeding, promote a healthier environment. Breast milk is a natural and biologically appropriate source of nutrients, decreasing pollution and waste associated with formula production and disposal. Encouraging breastfeeding helps lower the carbon footprint of infant nutrition, contributing to efforts to combat climate change. A nationwide programme called MAA, Mothers' Absolute Affection, aims to promote early initiation of breastfeeding and emphasises exclusive breastfeeding until 6 months of age, supported by ASHA workers and healthcare providers at health facilities[29]. In cases where exclusive breastfeeding for six months is not possible, WHO/UNICEF and national guidelines recommendations on safe complementary feeding should be followed.

The Eat Right India movement has been launched by the Food Safety and Standards Authority of India (FSSAI) to safeguard the health of both people and the environment. This initiative aims to transform the country's food ecosystem through a comprehensive systems approach. The movement is centred around three main themes: Eat Safe, Eat Healthy and Eat Sustainable. It draws inspiration from preventive and promotive healthcare strategies and aligns with flagship programs, such as Ayushman Bharat and POSHAN Abhiyaan[30].

It is suggested that diets be based on a diverse range of unprocessed and minimally processed foods. Such diets should feature whole grains, legumes, nuts and a rich assortment of fruits and vegetables. Additionally, it would be advantageous to incorporate the recommended moderate quantities of eggs, dairy products, poultry, and fish, while concurrently restricting the intake of red meat to minimal levels, in accordance with dietary guidelines tailored for specific individuals. In addition, the diversification of crops is highly recommended, particularly by incorporating underutilised traditional varieties[31]. Traditional food systems rich in millets, pulses, and leafy greens offer good alternatives to processed diets. Also, community-level nutrition education, school meal programs emphasising local produce and public campaigns on indigenous food benefits should be encouraged. These approaches should be harmonised with environmentally friendly food production practices and effective natural resource management strategies to ensure long-term ecological and nutritional benefits.

Using food waste, particularly the peels from fruits and vegetables, can lead to the development of value-added products. These include edible films, probiotics, nanoparticles, carbon dots, biochar and biosorbents. This approach promotes eco-friendliness and sustainability, and creates novel business opportunities by turning waste into valuable products[32]. Using biofortified crops: Biofortification is increasing the nutritional density of food crops by conventional plant breeding, enhanced agronomic techniques and/or modern biotechnology without compromising any attribute that consumers or farmers value[33]. This strategy is an effective and sustainable method for addressing hidden hunger by increasing the availability of micronutrients and boosting the levels of vitamins, essential amino acids, fatty acids and antioxidants in food crops[34].

Clean energy for cooking is becoming increasingly important as alternative cooking stoves that replace solid fuels with cleaner energy sources, such as biogas, gain popularity in low-income regions worldwide. A study conducted in southern India found that, besides the established benefits for respiratory health, these alternative cookstoves can enhance household nutrition and provide women with additional free time[35].

Agriculture can also be enhanced through cover cropping, reduced tillage, integrated pest management, agroforestry and natural vegetation along streams and field boundaries. These methods improve soil health, prevent erosion and replenish essential nutrients[36]. Integrated Nutrient Management is an approach to crop residue disposal, combining organic and inorganic fertilisers to maintain soil fertility and agricultural productivity[37].

Climate-smart agriculture is being promoted globally, with the FAO advocating its adoption in South Asia. A Philippines report on climate-smart agriculture report suggests combining multilevel, multi-actor and participatory on-farm and off-farm actions is more effective than technical measures[38].

In response to climate challenges and a growing population, farmers in California are increasingly adopting cover crops to prevent soil degradation and naturally fix nitrogen. Meanwhile, Ontario, Canada, exemplifies a well-established crop rotation system that integrates grains, pulses and livestock, enhancing soil moisture, fertility and pest resilience[39].

These actions span multiple levels and are interconnected, encompassing individual dietary choices, community programs, and systemic agricultural practices.

10. Call to action

The targets for nutritious diets from sustainable food systems are linked to all the SDGs. Meeting these targets requires high-quality primary health care that incorporates family planning and education about healthy eating. These targets and the SDGs related to freshwater, climate, land, oceans and biodiversity will be achieved through a strong commitment to global collaboration and action[40]. Dietary transformations are one of the most essential measures we

can take to lessen the environmental impact of our food system while also improving human health. However, nutritional guidance must be adapted to the population's cultural heritage, values and preferences to accomplish such changes[41].

Creating effective food policies requires collaboration between governments, academia, the private sector and civil society. Developing a national roadmap for climate-smart nutrition, integrating eco-friendly practices into India dietary guidelines and promoting research on indigenous superfoods can create a resilient food ecosystem. As malnutrition and environmental degradation challenges grow, all stakeholders must unite. Practical implementation of sustainable dietary and agricultural practices is limited by financial constraints, infrastructural gaps, low farmer awareness, supply chain inefficiencies, and behavioral factors that affect consumer choices. Addressing these barriers requires coordinated action across multiple stakeholders. Despite various policy initiatives and agricultural interventions, adoption remains constrained by these challenges. These factors must be considered when designing interventions for sustainable nutrition and agriculture. Policymakers should formulate stringent policies and frameworks that promote responsible production and equitable distribution. Private industries must innovate and develop technologies that enhance production while reducing waste and adopting environmentally friendly agricultural practices. The government should raise public awareness about eco-conscious practices and promote healthier choices.

11. Conclusions

Climate change and environmental degradation harm crop yields and threaten human health by disrupting food security. To ensure that everyone can access nutritious diets from sustainable food systems, stakeholders must make significant adjustments. This includes promoting healthy eating habits, minimising food loss and waste, and improving food production techniques. Achieving this goal is possible for all, but it requires support from various sectors for scientific research and action. At the community level, changing diets is one of the most important actions individuals can take to reduce the environmental impact of food systems while also improving human health. To ensure these changes are effective, dietary advice must align with the cultural traditions, attitudes, and tastes of the population.

Conflict of interest statement

The authors claim there is no conflict of interest.

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Data availability statement

The data supporting the findings of this study are available from the corresponding author upon request.

Authors' contributions

Pal S and Mallick R made significant contributions to the conceptualisation, literature review and drafting of the manuscript. Gopal KM provided essential editorial input, supervision and oversight and granted final approval of the manuscript.

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