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Sustainable Diets: Bridging between Climate Change and Food Security: A Systematic Review

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ABSTRACT

There is a complex relationship between climate change and the security and sustainability of the food system, which significantly affects human health. Different factors of climate change can have a positive or negative effect on the food system and pattern. This article aimed to discuss various strategies to control or avoid these effects.

Studies published from the beginning to 2024 analyzing "the effect of climate change on food security and role of sustainable diets" were searched in Google Scholar, Pubmed, and Web of Science. Related articles were reviewed among the screened articles.

The effects of climate change on food production and availability, as well as extreme weather events, affect both the physical and economic accessibility of food. Climate change also affects the stability and resilience of food systems, which has long-term implications for food security. Additionally, efforts to achieve food security through agricultural intensification and land expansion contribute to greenhouse gas emissions from deforestation and land use changes.

The solution lies in establishing a sustainable nutrition and food system that ensures food security for all without compromising future generations' economic, social, and environmental well-being. Numerous scientific sources have investigated and approved some of these nutritional and dietary patterns, such as Eat-lancet, vegetarian, and Mediterranean diets. Certainly, more interventions focusing on sustainable food patterns and other adaptation methods and necessary strategies for their widespread implementation are needed.

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Introduction

Climate change has emerged as one of the most pressing global challenges in recent decades, which encompasses long-term shifts in temperature, weather patterns, global warming, and greenhouse gas emissions [1]. The impacts of climate change are wide-ranging, including droughts, water scarcity, rising sea levels, wildfires, melting polar ice caps, and loss of biodiversity [2]. Various frameworks have been developed to address these risks, such as the Sustainable Development Goals (SDGs). Sustainable development aims to ensure a prosperous future for society while safeguarding the environment and the rights of future generations [3]. The SDGs, established in 2012 to succeed the Millennium Development Goals, encompass critical objectives such as poverty eradication, hunger alleviation, disease prevention, and literacy promotion [4].

Two specific SDGs focus on the nutrition sector: SDG2 aims to achieve zero hunger, improve food security, eliminate malnutrition, and promote sustainable agriculture, while SDG12 emphasizes responsible production and consumption [5]. Despite efforts made in recent decades, food insecurity remains a significant issue in many countries, particularly developing nations. The Food and Agriculture Organization (FAO) defines food security as ensuring access to safe and nutritious food, meeting dietary needs and preferences, and enabling individuals to lead active and healthy lives. The State of Food Security and Nutrition in the World 2019 report revealed that over 820 million people suffered from hunger in 2018, primarily in Africa, Latin America, and Asia. Additionally, more than two billion people experienced some level of food insecurity, with 8% of the population affected in developed regions like North America and

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Europe, which underscore the dysfunctionality of the global food system, exacerbated by climate change [6, 7].

Climate change directly impacts food security through various channels, including loss of rural livelihoods, degradation of marine and coastal ecosystems, terrestrial and inland water ecosystems, and food systems. Projections have indicated that by 2080, 15% of the world's population could face a water crisis [8]. As the global population continues to grow, expected to reach 9.7 billion by 2050, the availability of resources for food production diminishes, further aggravating food insecurity [9]. However, progress towards achieving SDGs aimed at eliminating malnutrition and poverty by 2030 is inadequate, with only a quarter of countries on track to meet targets related to stunting, wasting, and overweight [6, 7].

This study provides an overview of the effect of climate change on food security and nutrition, encompassing physical effects on agroecosystems and livelihoods, underscoring the urgency of addressing climate change to eradicate hunger and enable the agricultural sector to adapt. Furthermore, the imperative of mitigating climate change to levels is stressed to ensure food security and nutrition for all, advocating for "sustainable diets." This paper explores the intricate relationship between diet, climate change, and food security by providing examples and describing their components. The structure of the paper is organized as follows: firstly, the challenges posedby climate change and potential adaptation solutions are discussed; secondly, sustainable food systems and proposed policies are presented; thirdly, sustainable diets are introduced and comprehensively reviewed; and finally, the issue of food wastage is addressed alongside potential solutions due to its significant impact on food security.

Method and Materials

A comprehensive systematic search was conducted on PubMed, Web of Science, Google Scholar, and Scopus to identify relevant literature published between 2000 and 2024. The search utilized Medical Subject Headings (MeSH) vocabulary and appropriate terms, including ("food security" OR food insecurity OR food safety OR food supply OR "food availability" OR "food system" OR "agriculture") AND ("climate change*" OR "weather" OR "temperature" OR "precipitation") AND ("sustainable diet" OR "sustainable nutrition" OR sustainable diets OR diet* pattern). Additionally, reference lists of included studies and previous review articles were scrutinized to ensure comprehensive coverage and inclusion of eligible records. Articles were assessed based on titles, abstracts, and full texts to determine eligibility.

Results

Agricultural Productivity

Changes in temperature and precipitation patterns in the United States accounted for 70% of the variability in agricultural productivity growth from 1981 to 2010. Liang et al. found that continued trends could lead to an annual decrease in agricultural productivity ranging from 2.84% to 4.34% [10]. In a study across 35 African countries, rainfall variability significantly impacted agricultural productivity, whereas temperature showed no discernible effect [11]. Conversely, in an Asian context, increased CO_2 emissions and rising temperatures had a detrimental long-term effect on agricultural productivity, despite a short-term positive correlation between CO_2 and productivity [12].

Food Distribution

Global food manufacturers and retailers are actively addressing climate-related risks, including heightened variability in raw material supplies, increased costs, water scarcity, disruptions in distribution networks, workforce challenges, and evolving consumer preferences, which collectively influence global food system stability and security [13].

Access to Food Resources

Climate change-induced reductions in land productivity are projected to decrease food crop production in South Asia, potentially escalating food prices and exacerbating regional food insecurity [14]. In Sub-Saharan Africa, climate shifts are compelling reliance on markets due to diminished crop yields and extended periods of food scarcity, placing added pressure on market efficiency and operational costs [15, 16]. Studies in various European regions have indicated that climate change contributes to increased food prices; for instance, the 2003 heatwave in France resulted in a 25% decline in fruit harvests, while rising temperatures in Ukraine caused a 13% reduction in grain production [17, 18].

Food Preferences and Dietary Needs

Dietary preferences vary globally and are deeply rooted in cultural practices. Research by Long et al. highlighted that traditional pork-based meals in Japan incorporate diverse ingredients such as abundant vegetables and modest meat portions, effectively reducing the overall carbon footprint of the dish [19]. In contrast, dietary patterns in the USA reflect lower diet quality and higher greenhouse gas emissions, necessitating shifts towards diets that substitute plant-based proteins for beef, pork, and poultry [20]. The Danish adaptation of the EAT-Lancet reference diet, known as the Danish plant-rich diet, serves as the basis for climate-friendly food-based dietary guidelines (FBDGs). Transitioning Danish adults from their current average diets to the Danish plant-rich diet could reduce carbon footprints by 31% [21].

Discussion

Climate change profoundly affects human health, mainly through associations with infectious diseases, mortality rates, and respiratory and cardiovascular diseases. Elevated temperatures and extreme heat correlate with increased incidences of cardiovascular and respiratory ailments, stroke, neurological disorders, myocardial infarction, childhood asthma, and pediatric respiratory diseases [22]. Additionally, changes in temperature, extreme heat, aridity, and cold temperatures are linked to heightened healthcare utilization, including emergency department visits, hospital admissions, and ambulance services.

In addition, climate change contributes to undernutrition, malnutrition, child stunting, and deficiencies in both children and adults due to extreme weather events. Environmental factors also play a role in childhood stunting [23]. Climate-induced disruptions to ecosystems diminish both the quantity and quality of food, exacerbating food insecurity, which, in turn, heightens disease susceptibility and mortality rates [5]. Projections have suggested that climate change may reduce global food availability, potentially leading to decreased consumption of fruits, vegetables, and red meat and predicting 529,000 deaths globally over the next three decades [13, 24]. Climate change and variability threaten food safety by affecting the occurrence and persistence of disease-causing microorganisms, thereby increasing the risk of foodborne illnesses [1].

Climate Change Adaptation Strategies (CCAS)

Farmers employ diverse strategies to adapt to climate change, such as utilizing modified crops, adjusting planting or harvesting times, planting trees, increasing fertilizer or pesticide use, conserving soil and water resources, diversifying livelihoods, and adjusting livestock management practices. The adaptation strategies are influenced by age, gender, income, livestock ownership, and access to weather-related information. Women are more interested in applying adaptation strategies, whereas age shows an inverse relationship [26-28]. The adverse impacts of climate change on productivity often result in higher commodity prices and necessitate more intensive management practices, expanded cultivation areas, reallocation through international trade, and reduced consumption [29]. For instance, adopting altered cultivation methods, implementing modern irrigation techniques, and promoting crops with lower water requirements effectively mitigate climate change effects in Iran. Addressing greenhouse gas emissions and combating desertification are critical to reducing climate change impacts [30]. Local agricultural knowledge and practices contribute to achieving sustainable agriculture. Workshops that facilitate knowledge sharing among farmers play a crucial role in climate change adaptation, enhancing productivity and sustainability. Low awareness of the health benefits of locally produced organic food often leads to the widespread consumption of cheaper imports, undermining local markets. Integrated land use planning transportation projects and affordable housing initiatives can improve low-income individuals' financial stability and mental health, ensuring access to nutritious food and mitigating adverse impacts on natural conditions, economic welfare, and food security [31].

Sustainable Diets: A Solution

Over the past 50 years, changes in food production have alleviated hunger, increased life expectancy, reduced infant and child mortality, and alleviated global poverty. However, increased food accessibility, urbanization, and rising incomes have led to a nutritional transition crisis, manifesting in:

- More than 820 million undernourished individuals
- 151 million stunted children
- 51 million wasted children
- Over 2 billion people suffering from micronutrient deficiencies
- 1-2 billion adults overweight or obese
- Nearly doubling global diabetes prevalence in the past 30 years [5, 32].

A sustainable food system integrates all elements and activities related to food production, processing, distribution, preparation, and consumption to provide food security and ensure health while minimizing ecological impact and safeguarding the rights of future generations [5]. The sustainable food system comprises four interconnected dimensions, each crucially linked to agriculture: health, environmental sustainability, economic viability, and social equity. Thus, dimensions should shift in the food basket to prioritize nutritious, culturally appropriate, accessible, affordable, and low-waste diets [1, 5, 22, 32-42]. Aligning with the transition in the food basket, sustainable diets offer a pivotal approach to achieving a sustainable food system. Dietary guidelines are critical in addressing sustainability challenges within diets and food systems by promoting improved nutrition and health outcomes while reinforcing ecological, economic, and cultural resilience. Identifying gaps in sustainability within dietary guidelines helps integrate multiple sustainability dimensions into evolving food systems. Tailoring national dietary recommendations to encompass distinct sustainability sub-dimensions through targeted programs tailored to each country's unique attributes enhances policy coherence and stakeholder engagement across food system development [31, 43].

Sustainable diets optimize individual health and well-being across all dimensions, minimize environmental impact, ensure accessibility, affordability, safety, and equity, and uphold cultural acceptability. They are designed to support optimal growth and development at all life stages, minimize all forms of malnutrition (undernutrition, micronutrient deficiencies, overweight, and obesity), reduce dietary-related noncommunicable diseases, and preserve biodiversity and planetary health. Energy consumption and carbon footprint are evaluated using a hybrid Input-Output Analysis-Life Cycle Assessment (IOA-LCA) method to assess the environmental footprint of different diets [38]. Dietary greenhouse gas emissions, contributing to climate change, can be reduced by eliminating meat from diets [44].

GRAPHICAL ABSTRACT [45, 46]….

Eat-lancet

A group of scientists (2019) presented a series of reference values for all food groups to show that adhering to these values can make food production sustainable and stick to 1.5°C changes in temperature, which is responsible for 10 billion people.

EAT-Lancet References: Protein Intake

The provided values are based on prospective studies conducted on the consumption of red meat **[**37**,** 39**]**:

Various dietary patterns, including vegan, vegetarian, pescatarian, or semi-vegetarian, have been associated with a 12% lower overall mortality risk compared to omnivores. A plant-based dietary score has shown a linear inverse relationship with the risk of type 2 diabetes and coronary heart disease [39]. In middle and low-income countries, the recommended intake ranges from 0 g/day to approximately 28 g/day of red meat, with a midpoint of 14 g/day for the reference diet.

Diary

The recommended calcium intake of 1200 mg/day in the USA is derived from studies lasting three weeks or less. Regions with low dairy consumption and calcium intake have demonstrated lower fracture rates than areas with high dairy consumption (WHO, 2003). There is no significant reduction in fracture risk among adults who consume more than 500 mg of calcium daily. The reference diet provided in the EAT-Lancet report contains 718 mg/day of calcium. A report such as that published by EAT-Lancet offers valuable information, but it has some limitations as well, which primarily focuses on the production and consumption stages of the food system, neglecting the social and economic aspects [34, 42, 47, 48].

Vegetarian Diet

Vegetarian diets have been associated with a lower incidence of type 2 diabetes, obesity, coronary heart disease, and other noncommunicable diseases, as well as greater life expectancy. Shifting to ovolactovegetarian

and vegan diets could result in median reductions of -35% and -49% in greenhouse gas emissions, respectively. Shifting to ovolactovegetarian and vegan diets could also reduce land use by -42% and -49.5%, respectively. Adopting an ovolactovegetarian diet can achieve a median decrease of -28% in water consumption. The vegetarian diet outperforms the national average diet regarding overall environmental footprint, with 3.14% lower energy consumption and 12.7% lower carbon footprint. All vegetarian diets are not equally sustainable, and there is substantial variability among the vegetarian diets. The flexitarian diet is often recommended due to its lower environmental impact and proven health benefits [35, 37, 39, 41].

Considerations during Complementary Feeding Period

A vegetarian diet, against a healthy omnivorous diet like the Mediterranean diet, carries several risks, such as the risk of critical micronutrient deficiency or insufficiencies or the risk of growth retardation resulting in different outcomes in neurophysiological development and growth.

There is no data documenting the protective effect of vegetarian or vegan diets against communicable diseases in children aged six months to 2-3 years [40].

Mediterranean Diet

Claims have been made in several international reports that the Mediterranean diet offers the best consumption pattern regarding both the environment and health. However, a specific assessment of the Mediterranean diet in comparison with other dietary patterns is lacking [49]. The Mediterranean diet is more than just a nutritional model and involves all stages before food consumption, including crop selection, growing, harvesting, fishing, processing, and food preparation. These activities are carried out to respect lands and landscapes, conserve traditional practices, and preserve fishing and farming activities in Mediterranean communities. The Mediterranean diet was added to the Representative List of the Intangible Cultural Heritage of Humanity in 2010 due to its cultural and sustainable characteristics [38].

Food Loss and Food Waste

Food loss occurs before reaching the consumer, while food waste occurs after consumption. Food loss and waste negatively affect food security and nutrition and contribute significantly to greenhouse gas emissions, environmental pollution, degradation of natural ecosystems, and biodiversity loss. For instance, in 2010, food loss and waste during the retail and consumer stages in the United States resulted in approximately 160 million metric tons of CO_2-equivalent greenhouse gas emissions [5, 50]. Individuals are responsible for improving consumption habits, increasing awareness and information, and encouraging interdepartmental cooperation and systemic thinking among professionals to address these issues.

Conclusion

The current global context is characterized by various crises, such as obesity, undernutrition, and climate change, all of which present significant health risks. Nutrition, health, and the environment are intricately linked across the lifespan. Climate change and pandemics have a detrimental effect on food systems, worsening global food insecurity. Agricultural and food systems significantly affect the environment, climate, dietary habits, and health. Yet, proactive management, agricultural investments, and dietary adjustments can effectively alleviate the effects of climate change. Educating farmers on local production and sustainability practices within the food system, alongside addressing financial challenges, could serve as a viable strategy and policy to combat climate change and food insecurity.

Declarations

Limitations and Strengths

This study is the first comprehensive review of the effect of climate change on food security, sustainable diets, and their role. However, this investigation focused primarily on the impact of factors such as temperature, precipitation, and greenhouse gases on specific subgroups of the food system due to limited access to sufficient information. The publication bias could not be entirely excluded. There was considerable heterogeneity between the included studies. In addition, all included studies were not methodologically appropriate. The potential methodological problems of studies were bias regarding selection, performance, detection, and reporting. Further studies are needed to examine the interaction between sustainable diets and climate change, compare sustainable diets in

terms of health and overall utility, and delve into the details of these topics.

Authors' contributions

A. Ashabi designed and supervised the study, and M. Soltanian conducted research and wrote the paper; M. Soltanian was primarily responsible for the final content. All authors read and approved the final manuscript.

Conflict of Interests

There is no conflict of interest to declare.

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