East African Journal of Health and Science, Volume 7, Issue 1, 2024
Article DOI: https://doi.org/10.37284/eajhs.7.1.1729

East African Journal of Health and Science
eajhs.eanso.org
Volume 7 Issue 1, 2024
Print ISSN: 2707-3912 | Online ISSN: 2707-3920
Title DOI: https://doi.org/10.37284/2707-3920

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

The Nexus between Climate Change and Nutrition Security and the Impact of this Relationship on Diet-Related Non-Communicable Diseases

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Article DOI: https://doi.org/10.37284/eajhs.7.1.1729

Date Published:

01 February 2024

Keywords:

Climate change, NCDs, Nutrition security, Diet Related NCDs, Diabetes, Hypertension.

ABSTRACT

Life-threatening climate change, and burgeoning nutrition insecurity compounded by a steady rise in chronic non-communicable diseases (NCDs) are the defining issues of our time. This study is an exploration of the nexus between climate change and nutrition and the impact of this relationship on diet related NCDs. Quantitative methodologies, utilizing a descriptive cross-sectional study design was adopted. The study was carried out across Kenya, informed by the devastating climate changes and NCD cases the country has experienced recently. To recruit the study participants, a random sampling technique was adopted to select a sample size of 190. The study utilized an online questionnaire uploaded on KoboCollect and the link to the questionnaire was shared via WhatsApp, Facebook, Twitter, LinkedIn, and email. The quantitative data was downloaded and synchronized with Statistical Package for Social Science (SPSS version 26.0) which was used to analyse the data. The study found that an increase in the price of basic food commodities, reduced amount of reliable agricultural output, destruction of crops, and change in the nutritional content and food composition are some of the major effects of climate change on nutrition security. Moreover, the study found that depletion of nutrition sources leads to diet-related NCDs (diabetes and hypertension) through increased consumption of unhealthy foods (calory and fat-dense diets), reduced access to recommended food for those living with diabetes and hypertension, and lack of food diversification. The study also found that increased demand for healthy foods has both positive and negative implications. Positive impacts reported include increased agricultural activities and innovations to address the growing demand for healthier. Negative impacts reported include strain on food production capacity and unsustainable agriculture practices that have long-term health effects. Policymakers are called upon to formulate policies that guarantee public health even amid the evolution of innovations that promise to address shortfalls in food availability, accessibility, reliability, and utilization.

Article DOI: https://doi.org/10.37284/eajhs.7.1.1729

APA CITATION

Oduor, K., Mburu, W. & Wanjiru, T. (2024). The Nexus between Climate Change and Nutrition Security and the Impact of this Relationship on Diet-Related Non-Communicable Diseases *East African Journal of Health and Science*, *7*(1), 60-79. https://doi.org/10.37284/eajhs.7.1.1729.

CHICAGO CITATION

Oduor, Kevin, Wambui Mburu and Teresiah Wanjiru. 2024. "The Nexus between Climate Change and Nutrition Security and the Impact of this Relationship on Diet-Related Non-Communicable Diseases". *East African Journal of Health and Science* 7 (1), 60-79. https://doi.org/10.37284/eajhs.7.1.1729.

HARVARD CITATION

Oduor, K., Mburu, W. & Wanjiru, T. (2024) "The Nexus between Climate Change and Nutrition Security and the Impact of this Relationship on Diet-Related Non-Communicable Diseases", *East African Journal of Health and Science*, 7(1), pp. 60-79. doi: 10.37284/eajhs.7.1.1729.

IEEE CITATION

K., Oduor, W., Mburu & T., Wanjiru, "The Nexus between Climate Change and Nutrition Security and the Impact of this Relationship on Diet-Related Non-Communicable Diseases", *EAJHS*, vol. 7, no. 1, pp. 60-79, Feb. 2024.

MLA CITATION

Oduor, Kevin, Wambui Mburu & Teresiah Wanjiru. "The Nexus between Climate Change and Nutrition Security and the Impact of this Relationship on Diet-Related Non-Communicable Diseases". *East African Journal of Health and Science*, Vol. 7, no. 1, Feb. 2024, pp. 60-79, doi:10.37284/eajhs.7.1.1729.

INTRODUCTION

The world is grappling with unprecedented challenges that threaten human existence, cutting across nearly all facets of life. From infectious and chronic diseases to climate changes, food insecurity, cybersecurity threats, economic inequality and political instability among others, human existence is threatened every day (Lautensach, 2020). While the challenges are enormous, some of them have dominated global discussions due to the scale and magnitude of their occurrence. Lyons (2019) observes that life-threatening climate change, and burgeoning nutrition insecurity compounded by a steady rise in chronic non-communicable diseases (NCDs) are the defining issues of our time. The link between these three dominant global threats is intricate, further impacting humanity negatively. For instance, changes in the climate and increases in extreme weather events are among the reasons behind a global rise in hunger and poor nutrition (Hasegawa *et al.,* 2021). Fisheries, crops, and livestock may be destroyed or become less productive. With the ocean becoming more acidic, marine resources that feed billions of people are at risk. Changes in snow and ice cover in many regions, especially the Arctic, have disrupted food supplies from herding, hunting, and fishing (Ford *et al*., 2021). Heat stress can diminish water and grasslands for grazing, causing declining crop yields and affecting livestock.

With climate change exacerbating nutrition insecurity, another problem sets in; chronic non-communicable diseases. The dimensions of nutrition and food insecurity are varied and include accessibility, access, use and utilization, and stability (Mosadeghrad *et al*., 2019). These aspects of nutrition are closely linked to NCDs. It is noteworthy that poor nutrition is one of the major risk factors for NCDs. Food system inequities are a key driver of NCDs as these restrict the poor's access to healthy food. Food systems are instrumental in shaping consumer food preferences, attitudes, and food cultures, and they influence the selection of food that people consume. In recent years, the consumption of processed and ultra-processed food and beverages has increased in many African countries, including Kenya. Natural foods (those that have undergone minimal processing) have been abandoned due to the dwindling prospects in agriculture and the overreliance on ultra-processed foods which are easy to prepare (Mosadeghrad *et al.,* 2019). The consequence of this practice is seen in the burgeoning cases of NCDs.

According to the World Health Organization (2021) report, the global prevalence of NCDs stands at a staggering 74%. In Kenya, 55% of all hospital admissions and 50% of hospital deaths are attributable to NCDs. Global health actors are exploring the impact of climate change and

Article DOI: https://doi.org/10.37284/eajhs.7.1.1729

nutrition and food insecurity on NCDs, with several initiatives already set in motion. Despite the evident linkages between NCDs and Climate Change, there remains a notable gap in understanding the pathways and magnitude of the impact of climate exposures on nutrition and diet related NCD outcomes. As such, there is a growing body of need for more research on these three important global issues to generate useful insights critical for mounting a robust response, contributing to the development of integrated solutions and informed policies essential for addressing these global crises effectively. This study is an exploration of the nexus between climate change and nutrition insecurity and the impact of this relationship on diet related NCDs (hypertension and Type 2 Diabetes).

Problem Statement

Climate change, nutrition insecurity, and diet-related non-communicable diseases (NCDs) represent three major global threats that are intricately linked, yet awareness and understanding of these connections remain limited. Extreme weather, water scarcity, biodiversity declines, and other climate disruptions are severely impacting food supplies, reducing the availability of and access to nutritious diets. This leads to increased consumption of highly processed foods, which exacerbates hypertension, diabetes, and other NCDs (De Araújo *et al*., 2021). Simultaneously, these climate stresses introduce substantial socioeconomic barriers that inhibit healthcare access and medication adherence for those already diagnosed. However, critical knowledge gaps around the pathways and magnitude of the influence of climate exposures on nutrition, diet quality, and NCD outcomes constrain the development of integrated solutions. Better characterization of climate change impacts on local food systems, dietary adequacy, and NCD prevention and control is urgently needed to inform coordinated policies and programs that enhance climate resilience, food security, and public health. This study aims to explore the intricate relationships between climate change, nutritional adequacy, and diet-related NCD prevalence to reveal critical evidence and perspectives to catalyse cross-sectoral action to address these defining crises of the 21st century jointly.

Research Objectives

- To examine the impact of climate change on nutritional security.
- To establish the impact of depletion of nutritional sources on NCDs (hypertension and diabetes).
- To establish the demand for healthier diets and their impact on nutrition security.

LITERATURE REVIEW

Impact of Climate Change on Nutrition Security

Climate change profoundly affects nutritional security through multiple pathways. Increased temperatures, changing rainfall patterns, biodiversity declines, and more intense and frequent extreme weather events are reducing yields of staple crops, fruits, vegetables, fish, and livestock that provide essential macro- and micro-nutrients (FAO, 2019). Climate impact modelling studies predict average global crop yields could fall over 20% by 2050, with greater declines in Sub-Saharan Africa (Chapman *et al*., 2020). Reduced local food production from climate disruptions diminishes dietary diversity and stable access to diverse nutrient sources.

Simultaneously, climate instabilities in food supplies increase market prices as availability decreases, curtailing food affordability and consumption, particularly among poor populations. During climate shocks like droughts or floods, affected communities are forced to adopt negative coping strategies to survive, including consuming low-quality seed stock, skipping meals, or reducing portion sizes, pulling children from school to work for income, selling productive assets like livestock or equipment, and migration - all of which further entrench nutritional insecurity (Shakeel & Shazli, 2020).

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The most nutritionally vulnerable groups – infants, children, adolescent girls, and women – suffer the most acute deprivations from these climate challenges. Key barriers include less diverse diets, inadequate breastfeeding support, shortened birth intervals, and increased burdens on women to secure food, water, and energy in climate-stressed contexts (Devine & Lawlis, 2019). In essence, climate variability and extremes directly constrict the availability, access, utilization, and stability of nutritious foods – four key pillars underpinning nutrition security from households to national levels (FAO, 2019). Climate change also exacerbates existing social, economic, and health vulnerabilities, further marginalizing already nutritionally deprived populations. Integrated solutions that enhance the climate resilience of local food systems and empower communities to adapt are urgently needed to combat these impacts.

Impact of Depletion of Nutritional Sources on NCDs (Hypertension and Diabetes)

The depletion of nutritional sources driven by climate disruptions greatly exacerbates the risk and burden of diet-related non-communicable diseases (NCDs) like hypertension and diabetes. Reduced consumption of fruits, vegetables, whole grains, and fibre due to climate impacts directly increases NCD risk factors (Khan *et al.*, 2022). Low intake of these recommended protective foods is linked to being overweight, higher blood glucose, unhealthy cholesterol levels, and high blood pressure – all precursors for diabetes, cardiovascular disease, and other NCDs (Okube *et al.*, 2020). When local crop productivity declines, processed foods high in fat, sugar, and salt tend to replace missing nutrients (Tirado *et al.*, 2013). Consumption of these cheap, readily available, nutrient-poor foods further escalates NCD risk, especially obesity and diabetes. In India for example, increased cultivated land used for nutritionally deficient cereals may be linked to growing diabetes prevalence (Minocha *et al*., 2017).

During climate shocks, affected households also adopt negative coping strategies that influence NCD outcomes. Asset sales, school dropouts, additional loans, and distressed migration disrupt livelihoods and access to healthcare (Matita *et al.*, 2022). Medication adherence, routine screening, and other positive health behaviours decline, complicating treatment for those already diagnosed. Mental stress is also amplified, which can physically manifest in higher blood pressure and blood glucose levels. Furthermore, climate change severely undermines NCD prevention and control by depleting the production of protective foods while shifting consumption towards unhealthy diets. Climate disruptions also introduce substantial socio-economic and psychosocial stresses that impede access to diagnosis, treatment, and control of hypertension, diabetes, and other NCDs. Integrated solutions addressing food system resilience, social protection, healthcare access, and mental health support are vital to mitigate these current and projected impacts (Owino *et al.*, 2022).

Demand for Healthier Diets and the Impact on Nutrition Security

The growing consumer demand for healthier diets is transforming food systems with both positive and negative implications for nutrition security. Health-conscious trends are spurring agricultural diversification towards more fruits, vegetables, grains, and pulses to supply nutrient-dense foods (Hemathilake & Gunathilake, 2022). Smallholder programs assisting farmers in increasing productivity and accessing high-value produce markets are being implemented. Home and community gardening are also expanding in urban areas to meet demand. These production shifts can enhance income for vulnerable farmers while improving the availability and affordability of diverse, nutritious foods (Lal, 2020).

However, increased pressure on limited land and water resources could displace staple crop cultivation in favour of more profitable fruits and vegetables, potentially threatening calorie availability for the poorest consumers. Trends towards organic farming may also reduce yields in some contexts, limiting cheaper food access without significant productivity advancements.

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And where climate resilience practices are not adopted concurrently, a sole focus on supplying healthier foods could heighten agricultural system vulnerabilities to weather extremes, undermining the stability of nutritional sources. On the food industry side, changing consumer preferences are driving product reformulation, innovative processing methods for nutrient retention, and launches of new "healthy" packaged items. But ultra-processed foods high in salt, sugars, and artificial ingredients also now tout their nutrition credentials for marketing appeal, despite links to rising obesity rates. Stricter regulations on nutritional claims are warranted to counter this practice (Sherling, 2023).

In essence, meeting escalating demand for quality diet could positively or negatively influence nutrition security depending on how the food system responds. Climate-conscious cultivation of diverse, nutritious produce, productivity advancements, and supply chain development show promise for enhancing the availability, access, and utilization of healthy diets. However, environmental and consumer protection measures are equally vital to ensure these transitions also provide stable, sustainable, and equitable nourishment for all (Stavrianakis & Farmer, 2019).

Research Gap

While early evidence links climate risk, nutritional adequacy, and NCDs, more focused research is vital to characterize these intersections and inform integrated action truly. Key gaps include studies quantifying impacts across wider food groups, market access, dietary diversity, and subsequent NCD development to guide policies and programs (Matita *et al.,* 2022). Investigating varied climate influence pathways on nutrition and NCDs also warrants attention, like biodiversity changes affecting diets, water scarcity, and food safety, income fluctuations reducing healthcare affordability, and mental stress exacerbating NCD symptoms. Evaluative studies on existing initiatives jointly addressing climate resilience, food security, and NCDs are needed to build an evidence base for replicating and scaling integrated approaches. Addressing these gaps can help refine understanding of climate-nutrition-NCD linkages and accelerate impactful solutions.

MATERIAL AND METHODS

Research Design

The study utilized a descriptive cross-sectional study design to investigate the nexus between climate change and nutritional security and the impact of this relationship on diet related NCDs. A descriptive study approach was used because it enables the identification of the nature of existing conditions without subject manipulation (Mugenda & Mugenda, 1999).

Study Location

The study was carried out across Kenya, informed by the devastating climate changes and NCD cases the country has experienced recently. Kenya's experience with climate change is increasingly intertwined with the increase of diet related NCDs, as shifting weather patterns affect agricultural practices and food availability, adding to changes in dietary habits that affect public health.

Inclusion and Exclusion Criteria

Inclusion Criteria

Those who had access to the internet/smartphone and could comfortably respond to online surveys were eligible for the study. Respondents were required to be 18 years of age and above. Those included in the study had the ability to read, write, understand, and gave their consent to participate in the study.

Exclusion Criteria

The study excluded those who were without access to the internet/smartphone and could not consent to the study.

Sampling Method

The study adopted a random sampling technique. The questionnaire was sent to prospective study

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participants via WhatsApp groups, Facebook, LinkedIn, and Twitter.

Sample Size Determination

For the study to be able to use the findings and results to make generalizations, a confidence level of 95 % was arrived at based on the Fisher *et al*. (1998) formula of sample size determination. The desired sample size was calculated based on the established 55% prevalence of NCDs (hospital deaths) in Kenya.

$$n = \frac{z^2\,(p-q)}{d^2}$$

n = desired sample size; Z = standard normal deviation usually set at 1.96 which corresponds to a 95% confidence interval; P = Characteristic prevalence of NCDs is at 55%; d = degree of accuracy desired which is 5%.

$$n = \frac{1.96^2\,(0.55*0.45)}{0.05^2} = 380$$

The sample size was adjusted by dividing it by a half yielding a sample size of 190.

380/2 = Sampe size= 190

Reducing the originally calculated sample size of 380 to 190 was a necessary decision based on a pragmatic balance between statistical requirements and resource constraints. While the Fisher *et al.* (1998) formula initially suggested a larger sample, logistical limitations such as time, budget, and accessibility of participants prompted the adjustment. The selected sample size of 190 remains statistically viable, providing sufficient power to detect meaningful effects given the effect size and variability in the data. This reduction allows for a more manageable and feasible data collection process without compromising the study's ability to draw meaningful conclusions, ultimately ensuring the study's successful execution within the available resources.

Research Instruments

The study utilized an online questionnaire uploaded on KoboCollect and the link to the questionnaire was shared via WhatsApp, Facebook, Twitter, LinkedIn, and email. The questionnaire link was shared until the desired sample size was reached. The link was then revoked so that no more responses could be received.

Validity and Reliability of the Instruments

To achieve validity, relevant literature was reviewed, and the questionnaire was developed as per the study objectives. To ensure reliability, the questionnaire was pre-tested with 15 handpicked respondents. Their feedback on the questionnaire was incorporated into the development of the final questionnaire.

Data Collection

The online data collection took 6 weeks. This was ample time to reach the desired sample size for the study.

Study Variables

In this study, the dependent variable is the "Nexus between Climate Change and Nutrition Security and the Impact of this Relationship on Diet-Related Non-Communicable Diseases." This complex phenomenon is assessed through three distinct yet interconnected independent variables, each representing a specific research objective. The first independent variable aims to "examine the impact of climate change on nutritional security," exploring the multifaceted ways in which climate change influences the availability and accessibility of essential nutrients. The second independent variable seeks to "establish the impact of depletion of nutritional sources on NCDs (hypertension and diabetes)," investigating how the diminishing nutritional resources, driven by climate change, may contribute to the prevalence of diet-related non-communicable diseases. Lastly, the third independent variable focuses on "establishing the demand for healthier diets and their impact on nutrition security," examining the evolving dietary preferences and their implications for overall nutrition security in the face of climate-induced changes. Together, these independent variables collectively contribute to unravelling the intricate

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relationships between climate change, nutrition security, and the emergence of diet-related non-communicable diseases.

Data Analysis and Presentation

The quantitative data was downloaded and synchronized with Statistical Package for Social Science (SPSS version 26) which was used to analyse the data. A rigorous analysis process facilitated the generation of meaningful insights and informed the recommendations. Descriptive statistics, including frequencies, percentages, and averages, were employed to present an overview of participants' responses. The results were presented using a combination of graphical representations, such as charts and graphs, to enhance clarity and visual interpretation.

Ethical Considerations

This study conformed to the highest ethical standards and the need for respect for human rights and freedom. The respondents for the study were not coerced and participation was voluntary. The respondents were informed regarding the procedure and the need for research with clear instructions. The confidentiality and privacy of the subjects were protected and maintained during the study as the questionnaires did not have any personal identifiers.

FINDINGS

This section is a summary of the research findings. The findings are presented in tables and figures. A description is provided for each entry.

Questionnaire Return Rate

The target population of this study was 190 participants. At the end of data collection period, 153 participants had successfully completed and returned the questionnaire, a response rate of 80.53%. According to Fan & Yan (2010), researchers face an imminent challenge of low questionnaire return rate in online surveys, barely above 60%. The present study therefore achieved a satisfactory response rate.

Socio-Demographic Characteristics of the Respondents

According to the study findings, 58.2% of the participants were males, female (41.2%) and 0.6% preferred not to reveal their sexual orientation. Age-wise, the study attracted most participants aged between 26-35 (55.4%), followed by participants aged 18-25 (29.9%). Ten-point one percent (10.1%) and 3.4% of the participant respectively were aged between 36-45 and 46-55. In terms of religious affiliation, a majority of the participants were Christians (93.5%) with Muslims being 1.3% of the study participants. The rest of the participants —5.2% indicated “other” religion. When asked to specify, as similar percentage —0.6% mentioned Agonistic and Hindu, and another similar percentage — 1.3% mentioned “no religion” and “just being spiritual”.

Education-wise, a majority of the study participants —85.1% had university-level education, followed by tertiary/college (8.4%), secondary school (5.2%), and primary school at 0.6%. In terms of marital status, 70.8% (109) of the study participants were single, 27.9% were married and 0.6% were divorced. In terms of residence, 64.4% (97) of the study respondents lived in the urban area, 19.0% (29) in peri-urban, and the rest —17.6% (27) lived in the rural area.

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Table 1: Socio-demographic characteristics of the respondents

Independent Variable	Response	Frequency	Percentage
Gender	Female	63	41.2
	Male	89	58.2
	Prefer not to say	1	.7
Age	18-25	29.9	31.1
	26-35	53.2	55.4
	36-45	9.7	10.1
	46-55	3.2	3.4
Religion	Christian	144	93.5
	Muslim	2	1.3
	Other	8	5.2
	Specify; Agnostic (0.6%), Hindu (0.6%), No religion (1.3%), Just spiritual (1.3%)		
Level of Education	Primary school	1	0.6
	Secondary school	8	5.2
	Tertiary/college	13	8.4
	University	131	85.1
Marital Status	Divorced	1	.6
	Married	43	27.9
	Single	109	70.8
Residence	Peri-urban	29	19.0
	Rural	27	17.6
	Urban	97	63.4

Impact of Climate Change on Nutrition Security

The findings on the impact of climate change on nutritional security are enumerated below.

Are you Experiencing Climate Change in your Residence?

The study participants were asked to indicate if they were experiencing climate change in their community/residence. The findings are reported in the *Table 2*.

The study found that 92.2% of the study participants are experiencing climate change in their residences while 3.3% are not experiencing climate change in their residences. The study also found that 4.6% of the respondents do not know whether they are experiencing climate change.

Table 2: Experiencing climate change

Response	Frequency (N=153)	Percentage (%)
Yes	141	92.1
No	5	3.3
I do not know	7	4.6
Total	**153**	**100**

Forms of Climate Change Experienced

The respondents who indicated that they experience climate change were asked to mention in what form they are experiencing climate change. The findings are summarized below.

When asked about the forms of climate change, they are experiencing, 79.4% (112) of the study respondents indicated a reduction in the amount of rainfall, 70.2% (99) —increased average temperature, 37.6% (53) —an increase in severe drought, 32.2% (46) —increased intensity of extreme events and 2.1% (3) —others. Flooding, land degradation and erosion, and changes in rainfall patterns were mentioned as other forms of climate change experienced by 2.1% of the study respondents.

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Table 3: Forms of climate change experienced by respondents

Responses	N	Percent	Percent of Cases
Increased average temperature	99	31.6	70.2
Reduction in the amount of rainfall	112	35.8	79.4
Increase severe drought	53	16.9	37.6
Increased intensity of extreme events	46	14.7	32.6
Others	3	1.0	2.1
Total	**313**	**100.0**	**222**

a. Dichotomy group tabulated at value 1

How Increase in Average Temperature Has/Would Negatively Impact Nutrition Security

The study participants were asked to indicate how an increase in average temperature in their residence has/would affect nutrition security. The findings are summarized in the *Table 4*.

When asked to indicate how increased average temperature affects nutrition security, 77.6% (118) mentioned increased price of food commodities, followed by 63.8% (97) —reduced amount/quantity of reliable agricultural yield, 54.6% (83) —destruction of crops leading to low produce, 40.1% (61) —change in nutrient content and food composition, 34.9% (53) —increased heat stress in livestock's and 10.1% (16) — decline in certain fish stock at the seas.

Table 4: Effects of increased average temperature on nutrition security

Responses	N	%	% of Cases
Reduced amount/quantity of reliable agricultural yield	97	22.7	63.8%
Increased heat stress in livestock	53	12.4	34.9%
Destruction of crops or lowering crop productivity	83	19.4	54.6%
A decline in certain fish stock due to increased temperature at the seas	16	3.7	10.5
Changes in nutrient content and food composition	61	14.3	40.1
Increased price of food commodity	118	27.6	77.6
Total	**428**	**100.0**	**281.6**

a. Dichotomy group tabulated at value 1

How has/would a Reduction in the Amount of Rainfall affect Nutrition Security?

The study participants were asked to indicate how a reduction in the amount of rainfall has/would affect nutrition security. The findings are summarized in the table below.

A similar number of participants, 112 each (74.2%), indicated that a reduced amount of rainfall affects nutrition security through an increase in prices of basic food commodities and reduced water availability for crops and livestock. The rest, 53.0% (80), 40.4% (61), and 39.7% (60) respectively indicated that reduced amount of rainfall affects nutrition security through poor quality produce due to deteriorating water quality, unsafe agricultural practices leading to unhealthy produce, and heavy reliance on irrigation.

Table 5: Effect of reduced rainfall on nutrition security

Responses	N	%	% of Cases
Reduced water availability for crops and livestock.	112	26.4	74.2
Heavy reliance on irrigation	60	14.1	39.7
Poor quality produce due to deteriorating water quality	80	18.8	53.0
Unsafe agriculture practices lead to unhealthy produce	61	14.4	40.4
Increased price of food commodity	112	26.4	74.2
Total	**425**	**100.0**	**281.5**

a. Dichotomy group tabulated at value 1

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How has/would Increase in Severe Drought affect Nutrition Security?

The study participants were asked to indicate how an increase in severe drought has/would affect nutrition security. The findings are summarized in the *Table 6*.

According to the study findings, 71.1% (108) of the study participants indicated that increased drought affects nutrition security through decreased crop yield; 70.4% (107) through poor diet due to stress on sources of livelihood; 51.3% (78) through the death of livestock's; 48.7% through the abandonment of crop farming and livestock keeping and 17.8% through the increased probability of wildfires.

Table 6: Effect of increased drought on nutrition security

Responses	N	%	% of Cases
Decreased crop yield	108	27.4	71.1
Death of livestock	78	19.8	51.3
Abandonment of crop farming and livestock keeping	74	18.8	48.7
Increased probability of wildfires	27	6.9	17.8
Poor diet due to stress on sources of livelihoods	107	27.2	70.4
Total	**394**	**100.0**	**259.2**

a. Dichotomy group tabulated at value 1

How Has/Would an Increase in the Intensity of Extreme Events Affect Nutrition Security?

The study participants were asked to indicate how an increase in intensity of extreme events has/would affect nutrition security. The findings are summarized in *Table 7*.

76.4% (113) of the study participants believe that an increase in the intensity of extreme events has/would lead to an increase in the price of basic food commodities; 52.7% (78) —inability to cultivate land for healthy produce; 46.6% (69) — death of livestock; 45.9% (68) —soil erosion leading to destruction of crops and 39.2% (58) — damage to food stores.

Table 7: Effects of increase in intensity of extreme events on nutrition security

Responses	N	%	% of Cases
Increased price of food commodity	113	29.3	76.4
Inability to cultivate land for healthy produce.	78	20.2	52.7
Soil erosion leads to the destruction of crops.	68	17.6	45.9
Death of livestock.	69	17.9	46.6
Damage to food stores.	58	15.0	39.2
Total	**386**	**100.0**	**260.8**

a. Dichotomy group tabulated at value 1

Impact of Depletion of Nutritional Sources on NCDs (Hypertension and Diabetes)

Major Sources of Food

The participants were asked to indicate the major sources of food in their area. The findings are summarized below.

According to the study findings, 77.1% of the respondents indicate that the major sources of food in their area are local food stores/markets, followed by 15.0% who indicate that residents engage in agriculture to produce their food and 3.9% who indicated that they get relief food from the government and humanitarian organization.

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Table 8: Major sources of food

Response	Frequency	Percentage
Directly from the farms (residents engage in agriculture)	23	15.0
Other	3	2.0
Purchase from local food stores/markets	118	77.1
Relief food by government and humanitarian organizations	6	3.9
Missing	3	2.0
Total	**153**	**100**

According to the study findings, 77.1% of the respondents indicate that the major sources of food in their area are local food stores/markets, followed by 15.0% who indicate that residents engage in agriculture to produce their food and 3.9% who indicated that they get relief food from the government and humanitarian organization.

Is Supply of Food Consistent?

The respondent was asked to indicate if the supply of food in their area (from whatever source) is consistent. The findings are summarized below.

Slight half of the study participants —51.6% (79) indicated that the food supply in their area is not reliable. The rest, 48.4%, revealed that the supply of food is consistent as there is food available throughout the year.

Table 9: Consistency of food supply

Response	Frequency	Percentage
No, the supply is not reliable	79	51.6
Yes, we have food we need throughout the year	74	48.4
Total	**153**	**100**

Why is Food Supply Unreliable?

Those who indicated that the food supply was not consistent were asked to explain. The findings are summarized below.

When asked why the supply of food is not reliable, 50.6% of these respondents blamed it on the interruption brought about by the reduced availability of food locally and globally; 34.2% cited reduced agricultural activities due to climate change; 11.4% cited reduced supply of relief food due to global food shortage while the rest cited "other" reasons including obsession with cash crop farming.

Table 10: Why food supply is unreliable

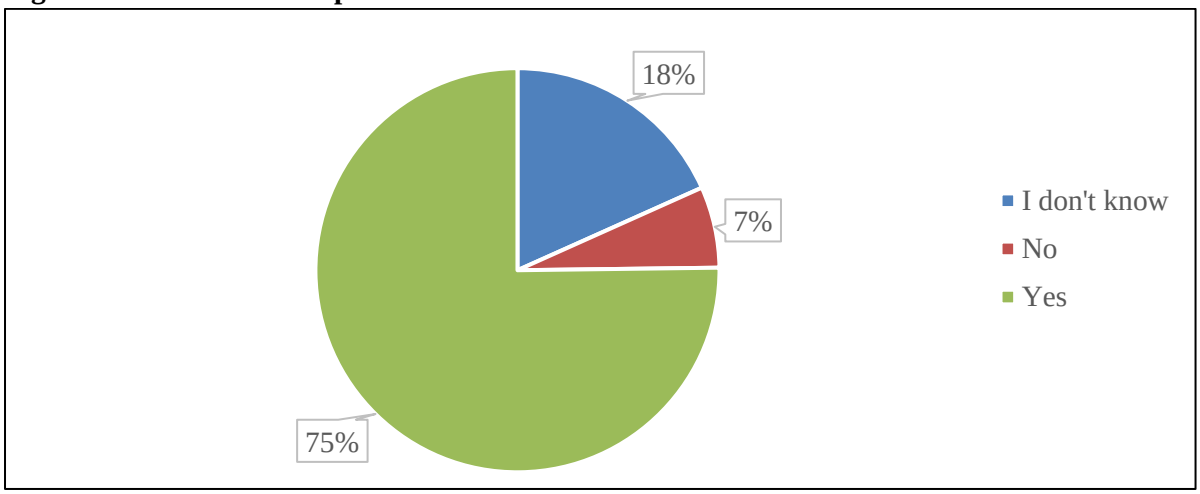
Response	n	%
Agricultural activities have greatly reduced due to climate changes	27	34.2
Local food supply chain has been interrupted due to the reduced availability of food locally and globally	40	50.6
Other	3	3.8
Relief food supply has been reduced due to global food shortage	9	11.4
Total	**79**	**100**

Whether Depletion of Nutrition/Food Sources Has Led/Would Lead to NCDs (Hypertension and Diabetes)

The findings are reported in the figure below. Most of the study participants (75.2%) indicated that depletion of nutrition/food sources has led/would lead to hypertension and diabetes while 18.3% mentioned that they do not know. The rest, 6.5% of the study participants indicate that depletion of nutrition sources would not lead to hypertension and diabetes.

Article DOI: https://doi.org/10.37284/eajhs.7.1.1729

Figure 1: Link between depletion of nutrition source and NCDs



How Depletion of Nutrition Sources Leads to Hypertension

The findings are summarized in the table below. When asked how depletion of nutrition sources has led/would lead to hypertension, 75.5% of the study participants mentioned that this could happen when people resort to unhealthy foods that cause hypertension; 80.0% through increased stress levels, 63.6% through lack of access to recommended diet for people living with hypertension, 58.2% through lack of access to healthy foods and 0.9% cited other ways.

Table 11: Impact of depletion of nutrition sources on hypertension

Responses	N	%	% of Cases
Lack of access to healthy food would lead to high blood pressure.	64	20.9	58.2
People resorting to unhealthy foods that increase blood pressure	83	27.1	75.5
Increase in stress levels leading to high blood pressure	88	28.8	80.0
Lack of access to recommended diet for people living with high blood pressure	70	22.9	63.6
Other	1	0.3	0.9
Total	**306**	**100.00**	**278.20**

a. Dichotomy group tabulated at value 1

How Depletion of Nutrition Sources Leads to Diabetes

The findings are summarized in the *Table 12*. A majority of the study respondents (83.6%) cited that depletion of nutrition sources would lead to a poor diet (a diet high in fat and calories) and increase the risk of diabetes followed by 68.2 % who mentioned that it would lead to reduced access to recommended diet for people living with diabetes. Half of the participants, 50.0% cited lack of food diversification while 1.8% selected "other".

Table 12: Effect of depletion of nutrition source frequencies

Responses	N	%	% of Cases
Reduced access to recommended diet for people living with diabetes.	75	33.50	68.20
Poor diet (diet high in fat, calories) that increases the risk of diabetes.	92	41.10	83.60
Lack of food diversification	55	24.60	50.00
Others	2	0.90	1.80
Total	**224**	**100.00**	**203.60**

a. Dichotomy group tabulated at value 1

Article DOI: https://doi.org/10.37284/eajhs.7.1.1729

Impact of Demand for Healthier Diets on Nutritional Sources

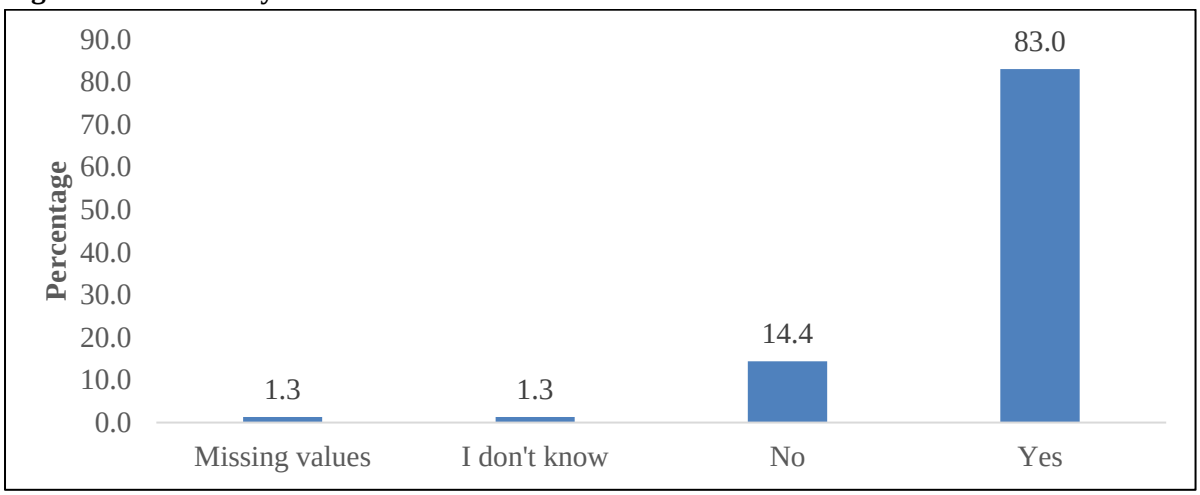
The study sought to understand the impact of reduced accessibility and availability of nutritious and healthy foods on NCDs; specifically, hypertension and diabetes. The respondents were asked several questions in this regard. The findings are summarized in tables and figures below.

Availability of Healthy Foods

The respondents were asked to indicate whether or not there are healthy foods in their area. The findings are in the *Figure 2*.

When asked if healthy foods are available in their area, 83.0% said yes, 14.4% said no, 1.3% said that they do not know. The rest, 1.3% of the study participants did not respond to the question.

Figure 2: Are healthy foods available?

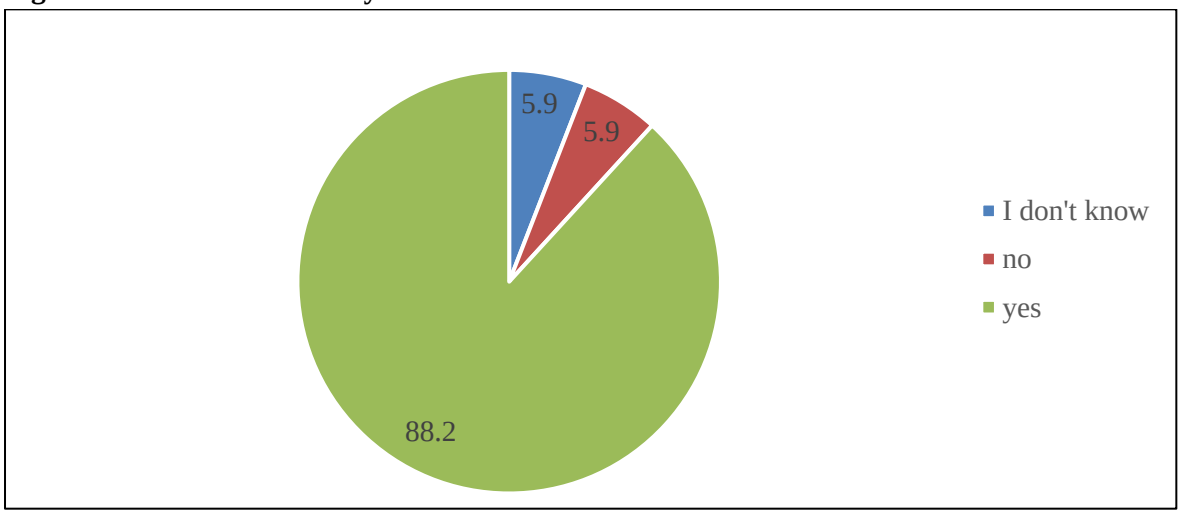


Is there Demand for Healthy Foods

The study sought to investigate the demand for healthy foods. The findings of the study are summarized in the *Figure 3*

A majority of the study participants —88.2%, reported that there is demand for healthy foods in their area. Those who indicated that there is no demand for healthy foods, or they do not know were 5.9% each.

Figure 3: Demand for healthy foods



Examples of Healthy Foods in Highest Demand

The study participants were given a list of healthy foods to choose from. Below is a summary of healthy foods in highest demand among the participants and people they know.

Article DOI: https://doi.org/10.37284/eajhs.7.1.1729

According to the study findings, vegetables are highest in demand as reported by 45.1% (69) of the study respondents. This was followed by fruits at 14.4%, whole grains and nuts at 10.5%, fish at 6.5%, eggs at 5.9%, and lean meat and poultry at 5.2%. Non-response rate was 11.8%. Other healthy foods not listed but also in highest demand include different types of legumes, lactose-free milk, and olive oil.

Table 13: Examples of healthy foods in highest demand

Variable	Frequency	Percentage
Eggs	9	5.9
Fish	10	6.5
Fruits	22	14.4
Vegetables	69	45.1
Lean meat and poultry	8	5.2
Others	1	.7
Whole grain and nuts	16	10.5
No response	18	11.8
Total	**153**	**100**

Motivation for Healthy Foods

The study sought to establish what motivates people to seek healthy foods. The findings are enumerated below.

When asked about their motivation toward healthy foods, a majority of the study respondents —51.0% (78) credited the increased knowledge of the benefits of healthy eating/diet even as 34.6% (53) cited the need to prevent and control diet-related NCDs such as diabetes and high blood pressure. Eight-point five percent (8.5%), 3.9%, and 1.3% respectively credited high level of education, increased disposable incomes, and improved mental health. One person, representing 1.3% cited “other reasons”.

Table 14: Motivation toward healthy foods

Variables	Frequency	Percentage
High level of education among the residents	13	8.5
Increased disposable income of residents	6	3.9
Increased knowledge of the benefits of a healthy diet	78	51.0
Linked to improved mental health	2	1.3
Other reasons?	1	.7
The need to prevent and control diet related NCDs such as diabetes and high blood pressure	53	34.6
Total	**153**	**100**

How the Demand for Healthy Foods Positively Impacts Nutrition Security

The study sought to investigate how increased demand for healthy foods positively impacts nutrition security. The findings are summarized below.

When asked how increased demand for healthy foods positively impacts nutrition security, 67.6% of the respondents indicated that it leads to increased agricultural activity and food production, followed by 65.5% of the respondents who cited increased innovation to address the demand for healthy foods and optimized production. Forty-eight percent (48.0%) of respondents indicated that increased demand for healthy foods leads to increased income for farmers; 24.3% and 20.3% of respondents respectively indicated that increased demand for healthy foods leads to the emergence of new species of healthy foods and increased importation of healthy foods.

Article DOI: https://doi.org/10.37284/eajhs.7.1.1729

Table 15: Positive impact of demand for healthy foods

Responses	N	%	% of Cases
Increased agricultural activities and food production.	100	29.9	67.6
Increased income for farmers thereby being able to cater to other dietary needs.	71	21.3	48.0
Increased innovation to address the demand for healthy foods and optimize production	97	29.0	65.5
Increased importation for healthy food	30	9.0	20.3
New species of healthy foods	36	10.8	24.3
Total	**334**	**100.0**	**225.7**

a. Dichotomy group tabulated at value 1

How Demand for Healthy Foods Negatively Impacts Nutrition Security

The findings are summarized in the *Table 16*. The strain on food production capacity and unsustainable agricultural practices to address the demand for healthy food in the short term was cited by a majority of the study respondents (65.5% and 54.1% respectively) as negative impacts of increased demand for healthy foods. Similarly, reduced financial accessibility as prices of healthy food soar and increased importation of healthy food to address shortfall while impacting local agriculture were blamed by 46.6% and 43.9% of the study respondents. Thirty-two-point four percent (32.4%) and 28.4% of the study respondents respectively cited reduced availability of recommended diet for people with certain NCDs and diminished staple food for people who rely on them.

Table 16: Negative Impact of increased demand for healthy foods

Responses	N	%	% of Cases
Strain on food production capacity	80	20.00	54.10
Unsustainable agricultural practices to address the demand in the short term	97	24.20	65.50
Increased importation of healthy food to address shortfall while impacting local agriculture	65	16.20	43.90
Reduction in availability of recommended diet for people living with certain NCDs such as hypertension and diabetes.	42	10.50	28.40
Affect food security for population that rely on staple foods	48	12.00	32.40
Reduced financial accessibility as prices of healthy food go up	69	17.20	46.60
Total	**401**	**100.1**	**270.9**

a. Dichotomy group tabulated at value 1

DISCUSSIONS

Impact of Climate Change on Nutrition Security

The present study reported that 92.2% of the study participants are experiencing climate change. This finding is consistent with the findings of a report published in the Public Health Newswire which indicated that by October 2021, about 85% of the world's population was grappling with human-driven climate change (Barna, 2021). This study found that climate change is experienced by a majority in the form of reduced amount of rainfall, increased average temperatures, and an increase in severe drought. Indeed, these findings agree with a publication by Interactive Country Fiches (2022) which observed that Kenya is experiencing a distinct warming trend, coupled with a significant diversity and reduction in observed rainfall trends, and natural hazards such as floods and droughts. The publication by Interactive Country Fiches further unravels Kenya's warming trend with a projected increase of the average temperature by 1.7 °C by 2050 and 3.5 °C by the end of the 21st century.

In terms of the different forms of climate change that impact food security, the present study

Article DOI: https://doi.org/10.37284/eajhs.7.1.1729

reported that increased average temperatures largely lead to an increase in prices of basic food commodities, reduced amount of reliable agricultural output, destruction of crops, and change in the nutritional content and food composition. Empirical findings by Dasgupta & Robinson (2022) confirm that for every 1 °C of temperature anomaly, severe global food insecurity increased by 1.64% (95% CI 1.6-1.65) in 2019. Indeed, these findings not only show that temperature anomaly has not only elevated food insecurity, but the magnitude of its impact has increased over time. It should be noted, however, that the study by Dasgupta and Robinson (2022) failed to provide evidence regarding the aspects of nutrition security impacted by climate change. Fortunately, Habib-ur-Rahman *et al.,* 2022 reported that the temperature rise leads to food insecurity through decreased crop-growing period and crop evapotranspiration which ultimately reduce the yield and subsequently lead to increased prices of agricultural products as the laws of demand and supply set in.

The present study also looked at the impact of reduced amounts of rainfall on nutritional security. Increased prices of basic food commodities, reduced water available for crops and livestock, poor quality produce due to deteriorating water quality, and unsafe agricultural practices in response to the deteriorating rainfall. These findings are almost similar to the findings of a study by Felix & Romuald (2012) which assessed rainfall shocks, food price vulnerability, and food security in sub-Saharan African countries. The authors submitted that local food prices in most parts of sub-Saharan Africa and the world at large are strongly influenced by climate factors including reduced rainfall and increased temperature. Further, the scholars noted that increased average temperature and reduced rainfall are also linked to other forms of climate change such as droughts and extreme events which also worsen food security situations (food availability and proportion of undernourished people) (Felix & Romuald, 2012; Kinda & Badolo, 2019).

Impact of Depletion of Nutritional Sources on NCDs (Hypertension and Diabetes)

The present study sought to establish how depletion of sources of nutrition/food due to climate change has led/would lead to diet related NCDs. First, the study participants were asked to indicate the major sources of food in their area. The study found that local food stores/markets are the major sources of food with a few people engaging in agriculture to produce their food. Yet still, the present study found that some people also rely on relief food from the government and humanitarian and charitable organizations. The fact that a majority source their food from markets could be a pointer to the abolishment of agriculture and reliance on imported food or those produced elsewhere within the country. This assertion is almost consistent with an article on agriculture in Kenya, dubbed "Insights in Kenya" which revealed that statistically, the agricultural industry in the country has registered reduced agricultural production due to various factors including climate change (Paul, 2022). Kenya, like many other countries, is grappling with an unprecedented drought due to close to 6 years of below-average rainy season.

Reliability of food is one of the aspects of food security. The present study found that the food supply has not been reliable over the years, which could be attributed to unpredictable and unstable agricultural production. The study participants indicated that they blame the unreliability of food supply on the interruptions brought about reduced availability of food locally and globally, suggesting that other factors besides climate changes could be attributable to this phenomenon. Reduced agricultural activities due to climate changes were cited, in addition to the obsession with cash crop farming. In a study on the Impact of Climate Variability and Change on Food Security in Sub-Saharan Africa by Affoh *et al.* (2022), similar findings to those of the present study are reported. The study found that food reliability, in addition to accessibility, availability, and utilization, has been greatly impacted because

Article DOI: https://doi.org/10.37284/eajhs.7.1.1729

of reduced agricultural activities attributed to a host of factors including climate change.

Concerning how depletion of nutrition/food sources impacts diet related NCDs (diabetes and hypertension), the presented study found that most of the study participants believe that depletion of nutrition/food sources (especially those food recommended to those living with diabetes or hypertension) would lead to diabetes and hypertension. On probing further, the present study found that depletion of nutritional sources would lead to hypertension through consumption of unhealthy foods (as healthy foods are depleted), increased stress levels, and lack of access to recommended diet for people living with hypertension. These findings are in agreement with Khan *et al* (2022) who observed that reduced consumption of fruits, vegetables, whole grains, and fibres due to climate impacts directly exacerbate NCD risk factors. The present study also reported that depletion of nutritional sources could lead to diabetes due to poor diet (calorie and fat-dense diets), reduced access to recommended diets for people living with diabetes, and lack of food diversification. These findings are in tandem with Okube *et al.* (2020) who indicated low intake of these recommended protective foods is linked to being overweight, higher blood glucose, unhealthy cholesterol levels, and high blood pressure – all precursors for diabetes, cardiovascular disease, and other NCDs.

Impact of Demand for Healthier Diets on Nutritional Sources

As a build-up to the question of how demand for healthier diets positively or negatively impacts nutritional sources, the study investigated some of the foods that are high in demand. The study found that vegetables and fruits are the highest in demand due to the perception that they are healthy. Indeed, the Harvard School of Public Health confirms this perception, submitting that a diet rich in vegetables and fruits can significantly lower the risk of blood pressure, heart diseases, and stroke, in addition to offering protection against some types of cancer and lowering the risk of blood sugar build-up linked to risks of diabetes (Harvard, 2012). This study further reported that increased knowledge of the benefits of healthy eating/die and the growing need to prevent and control die related NCDs tops the list of motivations towards healthy eating. Limited studies have been conducted on motivation for healthy eating and those that exist have studied completely different variables from those of the present study. For instance, Ashton et al. (2016) conducted a study on motivation and barriers to engaging in healthy eating, citing factors such as convenience/ease of access to food and cost. The findings are grossly at variance with those of the present study and could be attributed to the framing of questions in the questionnaire.

Looking at how increased demand for healthy foods positively impacts nutrition security, the study found that it leads to increased agricultural activity and food production, in addition to acting as a catalyst for agricultural innovation. While the present study, including other past studies (Stavrianakis & Farmer, 2019; Lal, 2020) observed that increased demand for healthier foods spurs agricultural activities, Hemathilake & Gunathilake (2022); Food and Agriculture Organization, 2017 make a stark contrast by observing that while the demand for healthy foods and other agricultural products is skyrocketing, there is limited land available for agricultural expansion. FAO submits that satisfying the increased nutritional demands is likely to lead to more intense competition for land as other priorities, including infrastructural needs. The present study's finding on increased innovation due to increased demand for healthier food is however in tandem with Rabadán *et al* (2021) submission that the current demand for healthy and sustainable foods has encouraged the development of new alternatives even in traditional agricultural products.

While the positive impact of increased demand for healthier diets is glaring, there are fair share of attributable negative outcomes. The present study found that this demand leads to a strain on food production capacity and unsustainable agricultural practices. As noted earlier, FAO

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(2017) warns that satisfying increased nutritional demands is complex and could lead to more intense competition for land as a natural resource. This intense competition could potentially, though inadvertently, lead to unsustainable agricultural practices touted as a "silver lining" to the increased demand for healthier foods. Even as Rabadán *et al.,* 2021 submit that the current demand for healthy and sustainable foods has encouraged the development of new alternatives even in traditional agricultural products, he denounces the evolution of ultra-processed food high in salt, sugar, and artificial ingredients which are a catalyst for diet related NCDs such as diabetes and hypertension.

CONCLUSION

The study reports that increased average temperatures, reduced amount of rainfall, and severe droughts are fuelling nutrition/food insecurity through reduced agricultural activities, increase in price of basic food commodities as the law of demand and supply sets, and unsustainable agricultural practices among others. The study further reports that depletion of nutritional sources impact diet-related NCDs (diabetes and hypertension) through the consumption of unhealthy foods (calorie or fat-dense diet), lack of access to recommended diet for those living with diabetes and hypertension, and diminished opportunity for food diversification. The positive and negative implications of increased demand for healthy diets have been enumerated in this study. Increased agricultural activities and food production, combined with increased innovation are reported in this study as the leading positive outcomes. Inversely, the strain on food production capacity and evolution of unstainable agricultural practices, together with increased overreliance on ultra-processed foods touted as "healthy foods" are some of the negative implications of increased demand for healthy diets.

Recommendations

With climate change ravaging, nutrition security will most likely continue to deteriorate. Policymakers are called upon to formulate policies that guarantee public health even amid evolution of innovations that promise to address shortfalls in food availability, accessibility, reliability, and utilization. Being that nutrition security is a universal phenomenon, governments across the world must close ranks and address the worsening global food situation. While at it, sustainable agricultural practices that are in tandem with public health dictates and those that improve health outcomes (addressing risk factors for diet related NCDs) must be prioritized.

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