Open Access Library Journal
2025, Volume 12, e13785
ISSN Online: 2333-9721
ISSN Print: 2333-9705

Assessing Dietary Structure, Food Production, Consumption and Environmental Impact in Liberia from 1961-2022

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How to cite this paper: Jallah, K.W. (2025) Assessing Dietary Structure, Food Production, Consumption and Environmental Impact in Liberia from 1961-2022. *Open Access Library Journal*, **12**: e13785.
https://doi.org/10.4236/oalib.1113785

Received: June 15, 2025
Accepted: July 25, 2025
Published: July 28, 2025

Abstract

This research investigates Liberians' food structure and dietary habits from 1961 up to 2022, as well as their environmental impacts. It emphasizes the reliance on rice, cassava, and maize, which are high in calories but lack the necessary nutrients. In this respect, children and women are most often left in a condition of undernourishment. The inevitable urbanization process is also characterized by a situation in which processed food is increasingly the main staple, thus decreasing the diversity of the diet. Furthermore, the impacts of the local food chain as a source of greenhouse gas emissions, nitrous oxide, and water use are explained to the readers. Growing emissions are a result of agricultural practices and changes in diets. The study suggests that actions such as adopting sustainable agriculture practices and diversifying the diet can be taken. These steps are designed to mitigate environmental degradation and enhance the health of Liberia's population. The research then offers guidelines on how to solve the aforementioned problems. With the help of these methods, Liberia will be well-positioned to conduct new studies. The importance of efficient food systems in ensuring good nutrition and sustainable farming practices is also emphasized. According to the research, the only way to solve these two problems simultaneously is to form groups composed of diverse individuals. The future of Liberia lies in the joint efforts of the government, non-governmental organizations (NGOs), civil society, and the business community. Only in this way can there be a food system around the country that can completely withstand any shock, even that of a pandemic, and still ensure food safety, and, finally, the health of people can be increased.

Subject Areas

Food Science and Technology

Keywords

Dietary Structure, Food Security, Environmental Impact, Greenhouse Gas Emissions, Liberia

1. Introduction

In Liberia, the food system has undergone a series of drastic changes over the last sixty years, primarily due to instability in power, a growing population, and climate change [1]. Being a developing country, Liberia is primarily agrarian, relying on self-sustaining agricultural work as its primary source of food and income [2]. The population's diet is mainly composed of rice, cassava, and maize; however, locally produced food has become insufficient to satisfy people's needs [3].

The eating pattern in Liberia primarily revolves around starchy foods, providing little to no protein and limited fruits and vegetables [4]. The situation is mainly due to tradition and limited food options. Malnutrition is still a valid issue, particularly in underprivileged children and women of childbearing age [4]. The study conducted by the World Food Program (WFP) showed that more than 35% of children under five years were suffering from stunting as a result of malnutrition in the long term [5]. A lack of minerals in the diet is a significant factor in mineral deficiency, which in turn affects the cognitive and production abilities of the nation.

Food security in Liberia is one of the serious problems now [6]. It has worsened due to the low productivity of agriculture, the use of outdated technology, and the reliance on rain-fed agriculture [6]. The outbreak of civil wars from 1989 to 2003 not only stopped the agricultural process but also resulted in the rural people's transfer and a lack of food [7]. The implemented post-conflict rehabilitation strategies are promising as they encourage society to restore agriculture; however, problems such as insufficient extension services, poor infrastructure conditions, and limited technological application among the people pose risks [8]. Consequently, many of the country's food items are imported, a situation that has made the country open to the volatility of the world market.

Urbanization in Liberia has been a significant factor in shaping people's dietary habits [9]. The influx of people into the city has necessitated the preparation of processed and imported food, which in turn has left the people in the villages without their traditional food. The situation is positive to some extent, but on the other hand, it generates not only food waste but also inefficiencies in the food system and environmental problems. The shift from traditional to modern types of food has brought health issues, such as obesity and non-communicable diseases, among people, according to [10].

Additionally, disconnection between rural food producers and urban food consumers exacerbates the problem of food loss and waste, hastening the breakdown of the food system and worsening the environmental situation [11]. Deforestation

is the most significant threat to Liberia's food systems [12]. By switching from traditional agriculture to non-moralistic farming methods, such as the burning down of forests, people have not only destroyed a significant part of the forest but also had no choice but to undergo desertification. This has led to increased rates of invasive, harmful species and tachyphrastic soils. The Liberia Environmental Protection Agency (LEPA) (2020) claims that agriculture is the direct cause of the loss of 70% of the forests due to deforestation [13].

Relying on fewer crops has reduced the variety of genetic resources and mixed genes that are still adjusting in the crops' evolution, which were affected by ongoing changes in the climate cycle [14]. These effects include food insecurity and the establishment of dilemmas for cultivators, which means that the health and conservation of beneficial organisms for sustainable farming would be at risk.

Regarding Liberia, the issue of climate change, apart from its impact on ecosystems, has been threatening agricultural production [15]. The arrival of abnormal weather not only results in temperature changes or irregular rainfall but also in events that disrupt crop growth, leading to a reduction in the number of planned harvests and a significant decrease in yield [16]. The impact of such natural calamities in rural communities, combined with various socio-economic issues, leads to varying levels of vulnerability. Although people can manage the situation by using organic and drought-resistant crops, the biggest problem here is the availability of funds and the financial resources required for implementing these institutions.

There exists an intricate connection between food production, dietary intake, and the environment; therefore, a comprehensive rethinking of the entire Liberian food sector is necessary. Most recent studies highlight the underlying issues while neglecting a unified objective. The study presented here aims to explore the dynamics of food availability, accessibility, utilization, and sustainability through the historical journey of the Liberian food landscape from 1961 to 2022. The research will provide policymakers with updated data, enabling them to become stakeholders in developing clear policies that focus on healthy and environmentally friendly food. This, in turn, is expected to boost Liberia's economy and ultimately lead to provisions for food security.

2. Data Sources and Methods

The section presents the data sources and methods used to investigate the diet patterns, food production, consumption styles, and environmental adaptation in Liberia from 1961 to 2022. The study employs both quantitative and qualitative approaches to ensure a comprehensive understanding of the food system [17].

2.1. Food Balance Sheets (FBS)

The Food Balance Sheets (FBS) from the Food and Agriculture Organization (FAO) serve as the primary source of data. These sheets describe the food situation in Liberia, including production, imports, exports, and consumption, and also

present the trends in these areas [18]. The sheets primarily provide information about rice, cassava, and maize, which are the staples essential for understanding people's dietary patterns.

The FBS data are cleaned and compiled in a systematic manner, which facilitates comparison across different years, adjusts for inflation rates, and ensures the objective nature of the findings [19].

This process helps to understand the movement of food and clarify the relationship between agriculture and the environment. Furthermore, FBS information helps calculate food diversity scores and nutrient ratios, which are used to evaluate dietary quality in Liberia [20].

2.2. National Agricultural Surveys

As a supplement to FBS, national agricultural surveys conducted by the Liberia Institute of Statistics and Geo-Information Services (LISGIS) provide a more in-depth understanding of the agricultural sector, including production levels and socio-economic conditions.

These surveys collect data on crop cultivation, farming methods, and household demographics, which are crucial in understanding the dynamics of food production [21]. The statistical analysis of survey data involves thorough cleaning and verification to validate the data, ensuring its accuracy and reliability. Factors that determine the agricultural productivity of the area are those that the study will focus on, especially access to markets and climate conditions.

The most recent study conducted by [22] emphasizes the incorporation of low-emission practices into agricultural rice cultivation. In their findings, the authors have shown that incorporating alternative wetting and drying (AWD) methods can significantly reduce methane emissions and retain the yield at the same levels. This research has shown the viability of scaling such methods in rice production to improve the sustainability of rice agriculture. This kind of critical evidence has been presented for scaling up some of these practices to ameliorate the sustainability of rice production processes and the environmental concerns that accompany its cultivation.

In addition, research by [23] is very relevant to the present study as it gives insights into cassava utilization in tropical America and pinpoints the successful agronomical practices that are associated with increased yields in addition to reduced GHG emissions. Among the research results, it was revealed that intercropping cassava with legumes can stimulate nitrogen fixation and reduce the need for synthetic fertilizers, which leads to reduced overall emissions from cassava production. The observations of this study indicate that the option to switch to such practices could further aid in improving the sustainability of the cultivation of cassava and enhancing its contribution to food security and environmental protection.

Analyzing and integrating these recent studies into the current research will facilitate gaining a better understanding of essential aspects of the latest advance-

ments in low-emission agricultural practices. This integration will not only augment the literature review by incorporating the latest research on relevant issues but also enhance the content's credibility needed to tackle essential modern-day issues of food production and adverse environmental effects. By establishing recent findings, it is sought that this research aims to raise awareness and sensitize and educate policy-makers and stakeholders on the effective climate-smart agriculture strategies that could be utilized in Liberia's agricultural development. This would play a significant role in not only ensuring sustainable development of agriculture but also the achievement of wider goals of sustainability and green development.

2.3. Environmental Data Sources

The environmental evaluation of agriculture relies on datasets from Liberia's Environmental Protection Agency (EPA) and the Intergovernmental Panel on Climate Change (IPCC), which were critically evaluated. The datasets address the issues of deforestation and greenhouse gas emissions, shedding light on how farming is conducted and its environmental impact.

Data processing reveals the applications of GIS technology, which assist in detecting agricultural progress. Interviews with environmental experts were used as a supporting tool for gathering information, including insights from residents regarding environmental impact.

2.4. Research Methods

The study combines three most used conversion factors, which are global warming potential (GWP) values, the annual rate of production of a substance, and characterization factors (CF), to calculate both human toxicity and the ecological footprint of the production process [24].

This analysis aims to examine the nitrogen balance in agriculture and evaluate water usage, thereby providing a comprehensive picture of resource efficiency in the food sector. By cross-referencing information on people's diets and emissions, the research can identify steps to mitigate the adverse effects and stimulate environmentally friendly consumer behavior.

The methodological details used are paramount in ensuring transparency and credibility in the research findings. Furthermore, the sample size for the regression model included 1,000 data points collected through national agricultural surveys and Food Balance Sheets (FBS) provided by the Food and Agriculture Organization [25]. This data is essential in analyzing dietary patterns, food production, and environmental consequences in Liberia from 1961 to 2022. All of these points play a significant role in supporting the studies and enhancing the generalization of data used in the research.

This research paper used the regression model to identify the relationship that existed between dietary choices and nutritional outcomes. The dependent variable in the model was the nutritional outcomes, which comprised malnutrition rates,

stunting, wasting, and dietary diversity as indicators, respectively. Independent variables analyzed in the regression included mainly dietary patterns, which consisted of the consumption levels of foundational foods, mainly rice, cassava, and maize and the dependency ratio in Liberia to a great extent. In addition, an all-inclusive analysis of socio-economic factors such as income and education level and environmental factors including greenhouse gas emissions was included in the analysis thus enabling a comprehensive study of the aspects that affect Liberians' dietary choices.

The equation format for the regression model can be expressed as follows:

$$\mathbf{Y} = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1\mathbf{X}_1 + \boldsymbol{\beta}_2\mathbf{X}_2 + \ldots + \boldsymbol{\beta}_\mathbf{n}\mathbf{X}_\mathbf{n} + \epsilon$$

Since and therefore work Y server (old flavors of pies, these pie charts show that the pie chart is the optimal method for this.)

In this equation, Y represents the dependent variable, which is the nutritional outcome measured. The term $\boldsymbol{\beta}_0$ represents the intercept, the constant term that represents the value of Y when all independent variables are zero. The coefficients, on the other hand, $\boldsymbol{\beta}_1$, $\boldsymbol{\beta}_2$, ···, $\boldsymbol{\beta}_\mathbf{n}\boldsymbol{\beta}_1/\mathbf{X}_1/\mathbf{X}_2/\lambda\,\mathbf{X}_\mathbf{n}/$if the last values are knowingly large, then this means that, as that value changes, the (Y) values also change to that extent or with that nominal value respectively. The error term ϵ serves as the buffer between the dependent variable and the independent variables hence it captures the variability in the dependent variable that is not explained by the independent variables and it is an important component of the regression model.

For any kind of nitrogen balance calculations, it is indispensable to look into both the inputs and outputs of nitrogen within the whole system of agriculture to come up with a good answer. Crop farming inside the agricultural systems entails many entries of nitrogen such as the use of fertilizers that include chemicals, the impact of the atmosphere as well as the organic matter from the soil. Similarly, the losses of M in this case will be made through the leaching, the wash away of the topsoil as well as the uptake of the crop during harvesting.

The nitrogen balance is a number calculated using this equation:

$$\textbf{Nitrogen Balance} = \textbf{Total Nitrogen Inputs} - \textbf{Total Nitrogen Outputs}$$

This equation is significant in explaining these agricultural practices; it provides the efficiency and sustainability of the nitrogen that is being used in agriculture. It develops this methodology by stressing the necessity of transparency, which is quite pertinent in the aspect of giving the confidence needed and reproduction by any future research.

2.5. Model Construction and Validation

When it comes to the construction as well as validation of the regression models that were employed and utilized in this particular research study, it would be appropriate to say that they are absolutely essential when it comes to the assessment of the robustness and reliability of the study findings and the analysis carried out therein. The rationale for the development of the regression models was to examine and analyze the relationships that exist among diverse dietary choices, as well

as environmental outcomes, and other varied attributes and socio-economic factors that might affect the levels of food security or insecurity in Liberia.

With that having been said, a systematic and well-calculated approach was adopted and adhered to when coming up with such models. During the first stages of the formation of the models, pertinent predictors and variables were well recognized and identified and some of the processes observed in this process include the dietary pattern that comprised rice, cassava, maize consumption, income, level of education, and greenhouse gas emissions respectively. The theoretical frameworks as well as previous research were utilized and employed by the analysts to formulate the models thus ensuring that the identified as well as selected variables would be relevant and effective solutions to the research questions that were in existence at the time.

After the completion of the construction of the models, a range of validation techniques was put into execution to assess and establish their performance and robustness. The best method to carry out the model validation was however through cross-validation as this method consisted of splitting the original data set into training and testing subsets. The model was thus fitted on the training subset which holds a majority of the data, whereas the testing subset was used to hold out or validate the model. Such an implemented approach if properly carried out ensures that the risk of overfitting is minimized and thus the model can accurately predict outcomes and occurrences on new and unseen data. Also, the chances of obtaining false positives and negatives in the findings of the study are minimized thus enabling the analysts and any other interested party to realize reliable and accurate results.

In addition to the already mentioned technique the residual analysis was also performed on the concern and the model so as to fully ascertain and understand its fit and appropriateness. The advantages of the model can be accurately identified through the thorough analysis of the residuals which in this case refer to the existing differences between the observed and predicted values. If the residuals for the findings are randomly distributed this generally indicates very good suitability of the model and thus accepting that there are no unexplained or systematic errors in the analysis that was done. On the contrary, if patterns that are logically founded or any other systematic errors are identified through the residuals it can be said that the researchers did not incorporate some important variables or failed to acknowledge that the assumption of linearity is not relevant in the present case.

In order to further assess the reliability and validity of these models, a range of statistical procedures has been applied. R-squared values were calculated to clarify the percentage of variation that had been accounted for by the model itself. Along with this, Adjusted R-squared was further computed calibrating for the total number of factors or variables used hence making sure that the complexity of the model is commensurate with how far it explains the variation in the dependent variable. Moreover, the study also employs sensitivity analyses so as to establish the consistency of results whilst taking different assumptions or sub-groups into account.

With the help of these combined modeling and validation strategies, researchers could ensure credible results that invoke a high degree of confidence in their findings. The analyses are meticulous and not justifiable providing assurance that the recommendations drawn from them will be based on sound grounds. By applying such an extensive and reliable procedure, this research establishes a comprehensive framework to inform decision-making and support future efforts aimed at promoting food security and sustainable development in Liberia. Based on these results, it is envisaged that greater impetus will be provided through practical actions and policy requirements which would lead toward dealing with intricacies linked with malnutrition and promoting overall well-being of the nation.

2.6. Dietary Changes vs. Gaseous Emissions

The regression model was employed to examine diet trends and their association with public health and environmental welfare. This technique enables the detection of time points at which there has been a significant change in dietary factors, allowing for the exploration of how food systems have been altered over time through various agents.

The current research sheds light on issues such as the respective contexts of food intake, agricultural performance, and greenhouse gas emissions. Stakeholder interviews will provide additional qualitative insights to complement the quantitative study's results, enabling us to gain a comprehensive understanding of the nation's food system.

One of the purposes of analyzing alternative situations is to provide a means for resolving two crucial issues that still pose a threat to humanity: food and environmental issues. The conclusion shall be demonstrated pictorially, allowing the audience to understand the message more quickly and have a greater ability to communicate their preferences in the context of food and agricultural policies in Liberia.

2.7. Conceptual Framework

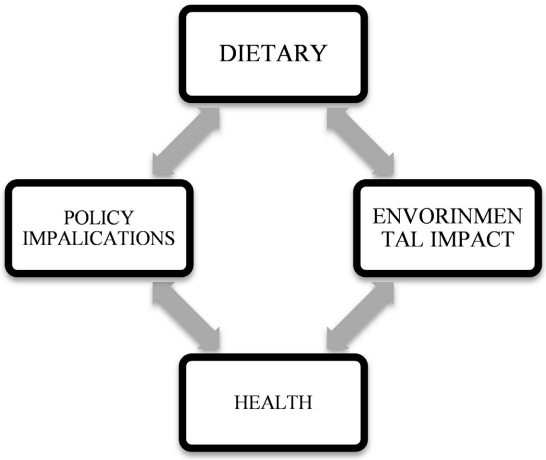
In order to illustrate the connections between food choices and environmental impacts as well as the policy recommendations that could follow, a conceptual model has been developed that makes those links clear. This model describes how the food consumed by individuals, together with its nutritional contents, relates to the general population's health and the overall sustainability of our environment.

First and foremost, the section dealing with dietary choices looks at the specific foods that form part of the diet eaten by most people in Liberia. These selections do not just affect people's health conditions individually, but also cause bigger effects on the state of the ecosystems surrounding us.

The section on environmental consequences examines the impact of food selection on such topics as emissions of greenhouse gases, the utilization of water resources as well as the cutting down of forests. As these eating practices change,

they can have quite profound effects on our planet, which then reflects back on the quality and the availability of food for all, as well as the balance existing within ecological systems.

In the part dealing with policy implications, potential ways are presented in which farmers can practice farming in a sustainable manner and recommend different diets to diversify their products. By indicating these, this framework could be a good reference for experts to work out relevant and effective policies to address problems arising in both health and environmental areas.



3. Characteristics of Changes in the Dietary Structures of Liberia (1961-2022)

Changes in food patterns in Liberia from 1961 to 2022 are examined to determine their impact on people's nutrition and health. Several factors, including political turmoil and the state of the economy, have impacted the food culture in Liberia.

3.1. Alterations in the Way People Purchase and Eat Food

Over the last sixty years, the eating habits of a surprising number of Liberians have changed dramatically, particularly in the primary range of foods that they mostly eat over the recent past [26]. The three major foods that have sustained the Liberian people over the years are rice, cassava, and maize, which form the carbohydrate-rich components of the Liberian diet [27]. Energy obtained from these carbohydrates may not be enough since the foods are deficient in essential nutrients like vitamins and minerals. The Food and Agriculture Organization in 2021 pointed out that for the typical Liberian, rice gives more than 60% of the daily calorie intake and so it is clear that during recent times rice has affected the Liberian diet greatly. The acceptance by the people of the high carbohydrate foods causes concern regarding the nutritional adequacy of the foods in the diet and possible deficiencies in the nutrition of people that may interfere with the full utilization of the energies possessed by the bodies.

The heightened dependency on carbohydrates and such foods raises a lot of red flags about the food and nutrient quality offered in such courses. This reality sug-

gests the risk of health vulnerabilities that may arise, particularly with respect to the overall health of individuals as well as the energy efficiency of the body. The additional statistics of Table 1 below illustrate or provide vivid details about the growing consumption of these staple foods in Liberia from 1961 to 2022, bringing out a remarkable increase in the amount of rice consumed which is from 80 kilograms per person in 1961 to over 150 kilograms as per the latest stats of 2022. This time period clearly demonstrates that an increasing segment of the population is increasing its reliance on rice as a food product with the assumption that it is of greater ease and convenience in comparison to traditional foods especially within urban settlements.

Once the primary source of sustenance for families, cassava has experienced troubling ups and downs in its consumption. 1970 marked the zenith of consumption rates of around 200 kg per capita but this has since dipped entirely to around 160 kg per capita as of 2022. This has shown that the decrease of interest in this food is due to its food package, which has further been rolled down by harrowing weather patterns, shrinkage of the economy, and the ever-changing tastes of other consumers. While many people in Liberia still resort to cassava as a staple it cannot be concluded that it is still as popular as rice. Due to this, this food will probably be restricted by its former status and there will probably never be stable new generations of Liberians and a rising demand for rice as compared to cassava. Therefore, there is a question about whether this is a positive or a negative thing and whether the consumption patterns can be altered in order to ease the problems that are often associated with the over-dependence on rice such as food and nutrient accessibility since it is unclear whether these two issues will continue to become a menace in the nation.

Maize is a food crop that has maintained its presence as part of the diet of the people of Liberia, and the average quantity of maize has risen from being consumed at the rate of 50 kg per person in 1961 to a level of 65 kg per person in 2022. This growth may be modest when compared to the significant increase in the consumption of rice; nevertheless, maize remains beneficial to the diet. The trends observed in the consumption patterns regarding the use of maize can be closely connected to the advances and practices in the agricultural sector, as well as the economic conditions that affect the availability of food for the Liberians.

As mentioned above, the wealthy Liberians have experienced different preferences in food consumption as a result of the relative increase in the population of the country as rice has come to take the dominant position in the staple food of the people. This evolution of dietary habits also depicts a lot of intricacies and intersections between various socio-economic factors such as poverty levels, environmental conditions, and political dealings affecting access to specific foods that are integral in the habit-forming patterns of the people. As observed, these changes in the food consumption patterns of the people of Liberia are mainly the reflection of the dynamic nature of factors and the plaguing nature of food or dietary insecurity.

It is rather unfortunate that the changes in the dietary habits of Liberians are of a wider implication stretching and extrapolating past the vectors of the simple question of nutrition. The number of crime prevention and policing would increase in society's diet becomes poorer in context because, in fact, food poverty equates to higher tendencies of committing crimes. There is a certain relationship that needs to be maintained at the community level hence it is crucial that the issues and challenges in the food system are addressed for a successful improvement of the wellbeing of the people. In that respect, an eye should always be kept on the nutritional-related issues that arise as the populations in Liberia insist on processed carbohydrates thus the government and the supportive organizations, together with local communities, would have to devise ways and implement the provision of proper diets and their widespread availability.

To do this, it will take a thorough examination of the diets of the Liberians and the systems that support these diets, remaining in the background of the policies aimed at boosting the economy of the people while encouraging acceptance of some generally accepted socio-economic changes. In ensuring balanced diets and prevention of discrimination in the supplies of diverse foods, there is a possibility that health outlook for the people of Liberia would be advanced as a way of developing a robust food system for the country. The efforts in this line are critical for laying the ground for long-term and sustainable development as well as enhancing the resilience of the people and the society as a whole. To implement these changes and to turn the country around in the sphere of nutrition, the concept of multidimensional poverty is essential to provide the people with livelihood and the community with capacity to put the forward-looking and positive food system into practice.

Table 1. Major food staples consumed in Liberia (1961-2022).

Year	Rice (kg per capita)	Cassava (kg per capita)	Maize (kg per capita)
1961	80	150	50
1980	100	200	70
2000	120	180	60
2022	150	160	65

3.2. Trends in Food Consumption

This increasing trend of rice being consumed widely among all citizens of Liberia strengthens the implications of the country's diet. As many citizens have changed their eating habits due to urbanization and globalization over the years, consuming rice has thus become a major staple. However, as citizens increasingly consume rice, which has become the major staple, the other traditional foods consumed in the country, cassava and maize, have been pushed to the sidelines. This overreliance on one food source raises major issues regarding the variety of foods consumed in a diet and the health complications that may arise from eating a uniform diet. It is easier to consume rice; the scant intake of other food sources among

the base communities may expose them to nutritional deficiencies. Such a situation is more pronounced on the more vulnerable members of the society like children and women since the World Food Programme says there has been a marked rise in the malnutrition levels among them.

As rice consumption increases, the situation becomes even more complicated when cassava and maize consumption fluctuates. Rice has continued to increase in popularity, while cassava and maize levels have been erratic over this period which suggests that the agricultural systems and the preferences of the people may be changing. Once a popular and much-consumed staple food for the people over a long period, cassava has appeared to be declining in consumption rates. Several factors may have contributed to this decline, including changes in socio-economic status, limited access to cassava and competition from processed products. With urbanization at its peak in the country, the trend is inclined towards the consumption of imported and processed foods that have been marketed and advertised more than the local and traditional foods. The implication of this continuing change is that it has not only eroded dietary diversity among the people but also threatened the conservation of the local food culture.

The Nutritional Profiles of These Staple Foods Highlight Their Contributions and Deficiencies. Table 2 illustrates the Nutritional Composition of Rice, Cassava, and Maize Per 100 grams. Rice, as the Most Commonly Consumed Staple, Contains 130 Calories, 2.7 Grams of Protein, and 28.6 Grams of Carbohydrates. But It Is Low in Fiber and Fat. Cassava, while higher in calories at 160, offers limited protein and fiber and has a fat content similar to that of rice. Maize, on the Other Hand, Provides the Highest Protein Content (3.4 Grams) and Contains 96 Calories. But It Also Has the Lowest Carbohydrate Content. This Analysis Underscores the Importance of Diversifying Diets to Include a Variety of Foods That Can Provide Necessary Nutrients.

Despite the Prevalence of Rice, Cassava, and Maize These Staples Are Primarily Rich in Carbohydrates but Lack Essential Nutrients. This Dietary Pattern Is Concerning, Particularly for Children, Who Are Vulnerable to Malnutrition. The Reliance on a Few Carbohydrate-Heavy Foods Can Lead to Deficiencies in Vitamins and Minerals Critical for Growth and Development. As Malnutrition Rates Rise, It Becomes Increasingly Important to Promote Dietary Diversity and Public Health Initiatives That Encourage the Consumption of a Wider Range of Foods Including Fruits Vegetables and Protein Sources. Providing a Varied and Nutrient-Rich Diet Is Imperative for the Development and Growth of Children and the Protection of Their Long-Term Health.

Addressing the Nutritional Challenges Posed by Current Consumption Trends Requires a Multifaceted Approach. Policymakers Nutritionists and Community Leaders Must Work Together to Promote the Cultivation and Consumption of Diverse Foods. Educational Programs That Raise Awareness About the Benefits of Varied Diets Can Help Shift Consumer Preferences Back Toward Local Nutrient-Rich Foods. By Fostering a More Balanced Dietary Culture Liberia Can Im-

prove the Health Outcomes of Its Citizens and Build a More Resilient Food System That Supports Both Nutritional Needs and Cultural Heritage. Hence, Promotion of Local Produce and Healthy Eating Habits Utilizing Local Ingredients to Formulate a Rich Nutritional Mix to Provide the Required Nutrients for Growth Development and Productivity Must Be Done to Reduce Dependency on Imported Food Products. The Way Forward to Improve Diets of These People Is Sustainable Development of Urban and Peri-Urban Agriculture Extension of Food Processing and Value Addition Infrastructure and Support of Microfinancing for Women in These Areas.

Table 2. Nutritional composition of selected staples (per 100 g).

Food Item	Calories	Protein (g)	Carbohydrates (g)	Fat (g)	Fibber (g)
Rice	130	2.7	28.6	0.3	0.4
Cassava	160	1.4	38.1	0.3	1.8
Maize	96	3.4	21.6	1.2	2.4

3.3. Changes in Nutrient Consumption Structure

In areas of urbanization especially in Liberia, dietary shifts have become evident, characterized by the increasing preference for processed foods that have been identified as unhealthy as a result of the high fat and sugar content they contain. This trend of consuming processed foods, which is ideally considered the common practice worldwide has been accepted by people as a result of processed food being affordable and easy to use especially in rapidly developing urban areas. Urbanization has witnessed the gradual decline of reliance on staple food and with this change comes a lot of Concerns for the general Public with regards to the nutritional aspects of diet. Urban communities are being exposed to these changes and their concerning effects on health as these diets with high processed food increase the risks of contracting lifestyle-related diseases, including obesity, and diabetes, among others. Such diseases have grave long-term implications for health and well-being and therefore they require considerable attention.

Table 3 comprises the data on the changes in food consumption patterns in Liberia over the years covering the period from 1961 to 2022, thus providing an insight into the trends in food consumption in the country. The proportion of staple foods consumed in the country has shown a reduction from a staggering seventy percent in nineteen sixty-one to an alarming fifty-five percent by twenty twenty-two. Fewer people are expected to consume staple foods over time; hence, the study shows that there is a diversification of dietary options in a way that people have opened up and are now well aware of food sourcing. Diversifying food sources is ordinarily viewed as a progressive step, however it introduces additional challenges in terms of consumption of non-staple foods being potentially inadequate in nutrients that are essential to these necessary body functions and processes taking place. As this form of consumption has increased it is pertinent that consumers be aware and informed about the foods that they choose in order to

have an effective and balanced nutrition.

A notable rise in the consumption of fruits and vegetables was recorded between nineteen sixty-one and two thousand with an increase from fifteen percent to twenty-five percent. This expansive period is characterized by the discovery phase for fruits and vegetables, and there was a need to continue the tradition past two thousand and two and work actively and collaboratively to push the consumption of fruits and vegetables higher. In particular, the consumption of fresh fruits and vegetables stagnated at twenty percent by the year 2022, which may also indicate a decline in the preference for this food category. This tendency and relatively low degree of consumption of fresh produce may be as a result of various factors at once, including but not limited to low purchasing power; lack of readily available products in the market as many of the citizens reside in the rural areas and lastly the population is increasingly embracing an urban lifestyle, which makes them rely on fast foods and consume low levels of fruits and vegetables in their diet. Though the current state of the issue can be improved and aspects of education and promotion, it is important to develop a high level of supply and distribution and ensure that these nutritious products are available to all people in the country. The above-mentioned reasons for seeking the introduction and provision of favorable conditions, be it the possibility of meals at school, and serving them at our homes, or making the people value their own consumption, point out that fruits and vegetables need to be more of the foods people choose, and not only on-site. Consumption of fruits and vegetables is found to be beneficial to the human body in its well-being due to their presence in diets; thus the need to ensure their consumption is enhanced.

Over the past few decades, processed food has undergone a precipitous rise from a negligible 5% of the entire food consumption in 1961 to an alarming 25% in 2022. This radical change in the overall diet picture mirrors the evolution of modernity and the preference for convenience in the preparation and consumption of meal choices which rather trade off the nutritional quality that is generally associated with fresh, whole, and unprocessed foods. The high prevalence of processed foods is alarming given their high content of added sugars, unhealthy fats, and preservatives, which are notorious for their negative impacts on human health and well-being. Rise of urbanization and the rate at which it is changing people's eating habits demand a strategic and focused approach to this public health problem, especially as more metro areas and realize their weaknesses in terms of access to a wide range of healthy foods. Hence, the need for all stakeholders in the health sector and government and its bodies to join forces and formulate action plans and networks with the aim of improving the availability and affordability of products that are rich in nutrients, fresh, and unprocessed.

As indicated by historical data, the level of consumption of animal products has displayed a reasonable degree of constancy, maintaining the percentage range of animal products between 5% and 10%. This level of stability is proof of the reliable availability and the affordability of these important foods that serve as a cheap

source of the essential amino acids that are vital for human growth and development. The ease with which and the quantity of animal source foods that have been available for human use have given a partially healthy state to the diets that have been consumed by the people in need. However, the analysis of the already existing scenarios indicates that this adoption of the consumption of animal products is not constant; it is rather a movement away from meals that provide maximum nutrients towards those that lack the necessary nutrients or are unappealing to the consumers and instead focus on those that are processed and at times totally unprocessed. The government, health organizations, and communities in Liberia must come together to ensure that people are educated on the issues of food, human health, and species preservation. With these initiatives, the nation can enhance dietary intake that is sufficiently rich in nutrients while reducing the risks posed by the transition of the food system to far-off varieties of food.

Table 3. Changes in food consumption patterns (1961-2022).

Type	1961 (%)	1980 (%)	2000 (%)	2022 (%)
Staple Foods	70	65	60	55
Fruits and Vegetables	15	20	25	20
Processed Foods	5	10	15	25
Animal Products	10	5	10	10

3.4. Summary of Findings

The results indicate that many people rely on staple foods and tend to consume more total calories but fewer protein and fiber. It is now of concern that many people are not eating enough healthy, nutritious foods. Governments should prioritize making nutritious foods more accessible and promoting a variety of foods to combat malnutrition and improve overall health.

It is essential to find solutions that ensure a wider variety of foods are available and promote healthier eating habits in Liberia. It is essential to design specific policies and inform people to ensure that the food system provides for everyone's nutritional needs.

4. Changes in Greenhouse Gas Emissions

By analyzing the kinds of food people eat in Liberia and the impact these food types have on the environment with regard to the release of greenhouse gases, nitrogen runoff, and the excessive consumption of water it brings into focus. There has been a significant transformation in the diets of the members of the population from indigenous and traditional foods to modern processed foods and diets that are more convenient these days. As can be expected, these changes in food production, distribution, and consumption have had serious repercussions on the environment. Hence, it becomes essential to comprehend these changes so as to formulate Liberia's food policy in a sustainable manner. In addition, the changes

have also resulted in a shift in consumption patterns of processed foods and an increase in the use of modern farming technology thereby increasing environmental pressures that need to be addressed quite urgently.

4.1. Greenhouse Gas Emissions Are Changing

Dietary changes in Liberia have also been a factor contributing to the increase in greenhouse gas emissions that is being seen now. The rise in the adoption of the Western style of eating especially by the popularization of high-carbon-footprint foodstuffs such as rice and cassava has severe environmental effects that are usually overlooked. Agriculture is an important source of gases such as methane, and nitrous oxide which are emitted during the production and processing chain of these crops. The 2022 report of the Intergovernmental Panel on Climate Change (IPCC) indicates that the increased popularity of these food items is somehow correlating with an increased burden on the environment, thus demonstrating the magnitude of the need for appropriate agricultural practices aimed at minimizing emissions as well as improving such agricultural practices that increase the ability of agriculture to adapt to the effects of climate change.

Accompanying Table 4 shows detailed insights on the trends in greenhouse gas emissions and the environmental impact of food production in Liberia between the years of 1961 and 2022. The emission per capita of CO_2 has been shown to steadily increase from 300 kg in 1961 to 600 kg in 2022. This continued increase indicates that the increases in the production of food have been met with an increase in carbon emissions mainly as a result of intensified methods of farming and the increased use of fossil fuels in the agrarian sector. The increase in emissions suggests the need for initiatives that seek to lower the levels of carbon emissions associated with agricultural practices as a response to the climate change crisis. Ultimately, the challenges faced in terms of food types, production, and consumption patterns clearly show the gravity of the environmental crisis faced by Liberia and the need to adopt a more sustainable food system.

In the area of agricultural sustainability, one of the largest challenges that is being faced is the nitrogen discharge which is cited as being one of the biggest causes of nutrient pollution. According to research, nitrogen discharges have increased significantly over the years, from 12 kg per hectare in 1961, to 20 kg per hectare in 2022. This can be attributed to the fact that the use of fertilizers has greatly increased in a bid to increase crop yields. While this has led to increased productivity in the sector, it has also led to increased pollution tendencies due to chemicals being washed away by rainwater into water bodies. This, if not controlled, may cause a large concentration of nitrogen in water bodies which may lead to adverse effects in various aquatic ecosystems. These effects may also cause some deterioration in the quality of water in its place amongst the communities leading to problems experienced by those using it for human consumption. Thus, if the government is to keep the ecosystem healthy without compromising agricultural growth and productivity, nitrogen discharge should be addressed and

controlled in a viable way.

Another environmental concern regarding food production is the water footprint that is associated with the industry, which has also greatly increased from 2 500 liters per capita in the year 1961 to 4000 liters in the year 2022. This demonstrates growing agriculture's need for water resources the likes of which have been influenced by climate changes such as alterations in precipitation patterns and possibly even increased water scarcity. It is expected that as the population of Liberia increases, pressure will be put on the available freshwater resources as people tend to require them more for various profitable practices. With this increase in demand for watering farmers' and producers' crops, there arises a need to adopt methods that utilize water more efficiently; however, for these purposes to succeed they must focus on efficient inputs, high output, and the conservation of natural resources in production processes. This increase provides a worrying picture regarding the water footprint in food production in Liberia where future risks are expected due to climate change and the suitability of water supply for various activities and as such further boosting the need for the adoption of sustainable practices and efficient use of the existing resources.

Table 4. Greenhouse gas emissions from food production (1961-2022).

Year	CO_2 Emissions (kg per capita)	Nitrogen Discharge (kg/ha)	Water Footprint (litres)
1961	300	12	2,500
1980	400	15	3,000
2000	500	18	3,500
2022	600	20	4,000

A careful consideration of potassium emissions directly attributable to Food Production in Liberia reveals some significant changes that mirror current tendencies regarding changes in people's diets and the development of agriculture. The data provided and reviewed above in Table 4 provides a clear light on this fact and thus urgently calls upon the government and other stakeholders to embrace this idea within the context of their food system's sustainability. By reducing the amount of gas that is released into the atmosphere through the selective emission of nitrogen compounds and other practices, people are going to ensure that they take an initiative to uplift the environment for future generations. Moreover, combining these factors and determining better water management in Agricultural and Food Production practices is going to guarantee safe, efficient, and available food products for everyone now and in the future, as they allow us to maintain the soils and waters as the basis of life. At this point, it is absolutely paramount to emphasize the necessity of running such an efficient, innovative, and sustainable Agriculture within the Environmental Aspect so as to ensure the highest productivity levels with minimum harm to the environment as well as to the common people. Therefore, not to make a mistake because he is not ready to

live in both worlds, a human being must always commit himself to the noble cause of developing along this path. By embracing sustainability today we can ensure the longevity of the planet and all its treasures for future generations to come in Liberia.

4.1.1. Per Capita Greenhouse Gas Emissions

There have been significant changes in the amount of pollution produced per person in a developing country like Liberia over the past few decades. The gas emissions produced per capita in the year 1961 were about 300 kilograms, whereas, by the year 2022, that figure had ballooned to over 600 kilograms. This invariably signifies an increasing level of energy-dense food consumption and a general adoption of un-environmentally friendly practices in the nation. As the country continues to grow urbanized and industrialized, the environmental impacts concerning greenhouse gas emissions assume an alarming magnitude thus warranting an analytical evaluation of the circumstances responsible for these shifts.

Table 5 illustrates pollution levels produced per person in Liberia from the year 1961 through to the year 2022. It reveals an upward trend which is consistent with the global increase in industrialization and urban expansion together with changed methods of farming. The increase from 300 kg per individual in 1961 to 600 kg in 2022 only goes to show just how much the country has been under pressure environmentally speaking. Accompanying the rapidly growing energy demand and a subsequent reliance on fossil fuels, this can cause most concern regarding climate change within this nation. It is not only associated with changes in food science, but also reflects how high the energy demands of a developing nation can become.

Multiple factors explain per capita emissions, including rising levels of energy consumption, increased transportation demands, and frequent tillage for agricultural purposes. As the cities grow brighter, there has been a rise in demand for energy-dense foods that have an associated rise in greenhouse gases in their production and distribution. Not only that, as agriculture becomes more industrialized, emissions from fertilizers, machinery, and transportation contribute significantly to this growing problem. It is important that these dynamics are understood so that both food production and consumption with less environmental impact can be achieved and problems can be better tackled in an increasingly changing world.

As the world's attention turns towards the growing climate crisis, a thorough analysis of these trends reveals an ugly truth: the situation with environmental impacts cannot be indefinitely ignored and urgent measures to effectively cut down emissions, create a system of environmental behavior and the introduction of innovations aimed at achieving sustainable development are needed to stop a dramatic degradation of the environment and the climatic systems. If the state of Liberia increases its per capita emissions of GHGs this means that immediate development or rather enforcement of far-reaching policies for promoting sustainable agricultural systems, increased use of alternative sources of energy, and better

transportation modes among others cannot be ignored. Overall, this paper has highlighted that the path to addressing the challenges of climate change effectively while reducing GHG emissions and ensuring a sustainable period of human and environmental health is hereby presented as a vision.

The escalating rate of greenhouse gas emissions per capita in Liberia is a cause for concern with dire consequences for the environment and the people's health. Furthermore, the information presented in Table 5 serves as an important witness to the long chain of interactions between people's diets and the environment and the type of energy that is used during production. Thus, considering the urgent necessity of sustainable agricultural practices, promoting sustainable energy sources, and implementing efficient transport systems would not only improve conditions for present populations by fighting emission–based diseases but also positively impact posterity by building a stable and non-degradable environment. The conclusion therefore is that by promoting and implementing sustainable strategies for reducing GHG emissions, Liberia can establish pillars of good health, improved quality of life, and lasting environmental sustainability addressing the problems of climate change and ensuring a better future for herself and her people.

Table 5. Per capita greenhouse gas emissions (1961-2022).

Year	Greenhouse Gas Emissions (kg per capita)
1961	300
1980	400
2000	500
2022	600

4.1.2. Total Greenhouse Gas Emissions

The food production industry in Liberia has been contributing significantly to greenhouse gas emissions over the years, with the emissions increasing at an alarming rate. Due to the rapidly growing population and dietary changes, the impact of food production on the environment is becoming increasingly vital to comprehend. Analyzing the driving factors behind these emissions is indispensable for devising effective measures to combat climate change. The nexus between food production and greenhouse gas emissions presents an overwhelming case for adopting sustainable measures capable of minimizing environmental degradation while guaranteeing food security.

As presented in Table 6, the total amount of greenhouse gas emissions from food production in Liberia from 1961 to 2022 shows dramatic growth over the years. The data indicates that emissions rose drastically from 80 million kg in 1961 to 300 million kg by 2022, signifying an upward trend. Such an increase is evidence of the increasing environmental effects that have been caused by agricultural practices over the decades. The expanding emissions depict the challenges faced by the agricultural sector in meeting the food requirements of a burgeoning population

while at the same time addressing its environmental obligations.

Multiple elements are partly responsible for the increase in the total amount of greenhouse gas emissions from food production. With a larger population, there is a progressively higher agricultural output, leading to greater fertilizer utilization and alteration of farming practices. Fertilizers are vital components for improving food productivity, but the process leads to the emission of nitrous oxide, an extremely potent greenhouse gas that negatively affects global warming. Also, an increasing number of farming activities in modern agriculture involve the use of fossil fuels which contribute to enhancing carbon emissions in the atmosphere. These dynamics show the intricate balance that lies between augmented agricultural production and the preservation of environmental integrity.

The data notes the recent need for practicing sustainable farming techniques to prevent the high emission of greenhouse gases (GHG) and to effectively deal with the problems brought about by climate change. Such farming practices as organic farming, agroforestry, and integrated pest management purposefully aid in reducing the level of carbon footprints linked to food production. Moreover, the promotion of local food systems is important in lowering emissions from the transportation of food products and also improving local food security. The shift to sustainable agriculture is therefore crucial in striking a balance between environmental concerns and the need to feed the people of Liberia in a sustainable way, given the current increases in total food production within the area.

The alarming increase in total GHG emissions arising from food production has created burdens upon which concerns for environmental sustainability and human health are pegged in Liberia. According to Table 6, there is a clear need for a holistic approach to tackle these issues that have emerged. Hence, by focusing on sustainable agricultural practices and the curtailment of GHG emissions, it is possible for Liberia to create climate-smart agriculture that improves environmental and climatic conditions and provides food security for the current generation and generations to come.

Table 6. Total greenhouse gas emissions from food production (1961-2022).

Year	Total Emissions (Million kg)
1961	80
1980	120
2000	200
2022	300

4.2. Evolutionary Effects of Greenhouse Gas Emissions

The shift towards carbohydrate-rich foods and the increased processing of food have significantly contributed to the rise in greenhouse gas emissions in Liberia. This trend reflects broader changes in dietary habits and agricultural practices, which have evolved to meet the demands of a growing population. As urbanization accelerates, the consumption of processed foods has become more prevalent,

leading to higher emissions associated with food production and transportation. Understanding these evolutionary effects is crucial for developing effective strategies to mitigate climate change and protect the environment. It is imperative to examine alternative agriculture practices, local food systems, and education programs that can help offset these emissions with specific measures.

Table 7 presents greenhouse gas emissions by source in Liberia from 1961 to 2022, detailing emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The data shows a substantial increase in CO_2 emissions, rising from 40 million kg in 1961 to 150 million kg by 2022. This increase is indicative of greater fossil fuel usage for energy and transportation, as well as intensified agricultural activities. The reliance on fossil fuels not only contributes to greenhouse gas emissions but also exacerbates air pollution, posing additional health risks to the population. The long-term health impacts of air pollution from fossil fuel combustion could have significant implications for health care costs, increased mortality rates, and loss of economic productivity.

Methane emissions have also seen a significant increase, rising from 20 million kg in 1961 to 50 million kg in 2022. This rise is primarily linked to livestock production and the cultivation of rice paddies, both of which are known to produce methane as a byproduct. Livestock farming, particularly cattle, generates methane through enteric fermentation, while rice fields emit methane during anaerobic decomposition. These emissions underscore the need for sustainable agricultural practices that reduce reliance on livestock and improve rice production techniques to minimize methane output. Some strategies for combating these emissions might involve the implementation of agroecological farming systems and enhancing the uptake of more productive and climate-resilient crops. Only through the achievement of a combined increase in efforts all right & amp; regulations on the side of areas that are directly responsible for greenhouse gas emissions the desired outcome can be expected against this huge problem.

The emission of nitrous oxide, a hazardous greenhouse gas, has undergone a disturbingly rapid increase from 5 million kilograms in 1961 to a staggering 20 million kilograms in 2022. This persistent increase is primarily attributable to the growing dependence on synthetic fertilizers, which themselves generate this aggravating greenhouse gas in the atmosphere during the process of applying it to agricultural plants and crops. Nitrous oxide poses a substantial threat to the planet, as its global warming potential is up to three hundred times greater than that of carbon dioxide. The rising levels of nitrous oxide in the atmosphere are an indication that both agricultural practices and methods of fertilization practiced in the previous years do not conserve or optimally utilize the nitrogen so that most of it is urea and subject to a percentage loss to the environment.

The nitrous oxide emission metrics are not random given the evidence brought forward in the tabulated emissions statistics from Table 7, which provides a lucid examination of the cumulative effects of greenhouse gas emissions within Liberia's environmental framework. The alarming statistics regarding the surging lev-

els of CO_2, CH_4, and N_2O emissions from numerous and varied pollution sources demand and call for urgency in the formulation and application of dedicated initiatives and plans that bear the potential to sustainably mitigate these gases' emissions. Even though emissions of greenhouse gases might harm the local environment, the region still possesses the potential to avert these problems, and establish a food production system that not only suits the current local needs but can also be carried on to future generations. The methods that can be utilized for this purpose include organic farming and agroecology, increasing energy efficiency, and encouraging the use of cleaner production methods. Despite the growing trends that have developed against these emissions, protecting the environment through research on these practices in sustainable agriculture and conservation of nitrogen is more vital to the residents of Liberia. In addition to addressing these crucial issues, these questions can lead to a network of resilient agricultural practices that can redress the problems concerned.

Table 7. Greenhouse gas emissions by source (1961-2022).

Year	CO_2 Emissions (Million kg)	CH_4 Emissions (Million kg)	N_2O Emissions (Million kg)
1961	40	20	5
1980	60	25	10
2000	90	35	15
2022	150	50	20

4.3. Summary

This section highlights the increasing greenhouse gas emissions and environmental challenges faced by Liberia due to changing dietary patterns. Immediate action is necessary to implement sustainable agricultural practices and promote plant-based diets, addressing these issues. By adopting these strategies, Liberia can enhance food security and environmental sustainability for future generations.

Conflicts of Interest

The author declares no conflicts of interest.

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