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ASSESSING FOOD SECURITY ACROSS DIFFERENT DEMOGRAPHICS: A MULTIVARIATE ANALYSIS OF CONSUMPTION PATTERNS

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ABSTRACT

Introduction: This study addresses the urgent need to assess food security in Ecuador, considering the diversity of the population. It emphasizes the importance of understanding dietary differences and consumption patterns of specific ethnic groups to improve food policies. **Objective:** To analyze food security in Ecuador using principal component analysis (PCA), identifying consumption patterns in different population groups to inform more effective and adaptive nutrition strategies. **Methodology:** A cross-sectional design collected data on dietary habits and demographic characteristics in various regions of Ecuador. PCA was used to explore the interrelationships of dietary variables and establish links between different groups of people. The open-access database was utilized to integrate available data. The target sample consisted of 1,312 households, evenly distributed between the provinces of Los Ríos and Guayas, excluding Guayaquil. **Results:** PCA revealed unique consumption patterns within certain demographic groups. Significant factors contributing to food security were identified, highlighting areas of vulnerability and strength. Quantitative and qualitative data provide valuable insights into the food dynamics of Ecuador. **Discussion:** The PCA results were interpreted, emphasizing the diversity of diets and their impact on food security. The implications of the identified patterns were examined, discussing their influence on intervention strategies and food policy. **Conclusion:** The findings highlight the need for equitable and adaptive food policies, considering population diversity. Recommendations were made to improve food security in critical areas, supporting inclusive and sustainable approaches. This study provides a comprehensive assessment of food security in Ecuador, informing more effective policies adapted to the country's demographic diversity.

Keywords:

food security, principal component analysis, consumption model, demographic groups, socioeconomic inequality.

1. INTRODUCTION

Food security is an important global issue and involves the supply, access, and utilization of sufficient and nutritious food to meet people's nutritional needs. However, understanding how different population groups experience food insecurity is essential for developing effective strategies to address food inequities (Kansiime et al., 2021).

Food security is not a homogeneous concept, and its understanding must take into account the specific dynamics of different population groups, which may include differences in age, gender, socioeconomic status, and geographic location (Coleman-Jensen et al., 2021).

Dietary patterns worldwide are changing, but not simultaneously, from a poor plant-based diet containing fresh and unprocessed foods to a diet rich in sugar, fats, and foods of animal origin that contains highly processed foods (Bodirsky et al., 2020).

The incidence of malnutrition in absolute numbers continues due to population growth; this "nutritional transition" has resulted in a shift in public health concerns from infectious and neonatal diseases associated with undernutrition to chronic diseases associated with overconsumption, such as diabetes and cardiovascular diseases (Kent et al., 2020).

A suboptimal diet is currently a major health risk worldwide, and costs 255 million disability-adjusted life years (DALYs) each year. A healthier diet could prevent between 11 and 12 million premature deaths in adults each year (Niles et al., 2020).

La Global food demand is affected not only by this dietary change, but also by population growth, demographic changes, lower levels of physical activity, and greater food waste in households. The growing demand for food is the main driver of agricultural production and, therefore, the principal interface between human society and the environment (Litton et al., 2021). Agriculture occupies one third of the world's land surface and accounts for 70% of the blue water produced by human activity. Food systems account for between 21% and 37% of anthropogenic greenhouse gas emissions (Bin et al., 2020).

Agriculture also increases the release of polluting nutrients into the environment and is one of the main causes of the fivefold increase in excess nitrogen in terrestrial systems compared with the pre-industrial period (Hasegawa et al., 2021).

Assessment of food security across different demographic groups: a multivariate analysis of consumption patterns

Finally, agriculture contributes significantly to air and water pollution, soil degradation, antibiotic resistance, new pathogens, and biodiversity loss.

Undernutrition, overnutrition, and food-related environmental pollution coexist in all regions of the world, are affected by common factors, and require common solutions, but they have long been analysed in academic silos (Van Dijk et al., 2021).

Consumer behaviour, including dietary choices and food waste, is at the centre of the three issues, and any policy aimed at changing behaviour in these areas must carefully consider the trade-offs and synergies (Morales et al., 2021).

The Lancet Commission on the Global Syndemic of Obesity, Undernutrition and Climate Change highlighted that the synergy among these three epidemics is the most serious health challenge of the twenty-first century and urged the scientific community to carry out modelling studies in order to provide evidence for policymakers to tackle the global syndemic and generate collaboration among different communities (Fitzpatrick et al., 2021).

Therefore, our study compiles a comprehensive inventory of international food consumption and evaluates the various symptoms of the global epidemics within a consistent framework (Tao et al., 2020), thereby enabling an integrated analysis of global health, food systems, and environmental change. Our main research question is: How have the various symptoms of the food-related global epidemics evolved worldwide in recent decades? What would the consequences be if the observed dietary changes were to continue in the future? (Fitzpatrick et al., 2021).

The symptoms analysed included the prevalence of underweight, overweight, and obesity, height, caloric intake, household food waste, dietary patterns, and the overall demand for food and animal feed (Laborde et al., 2021), using a multivariate analysis to comprehensively explore multiple dimensions of food consumption patterns and how these patterns relate to food security (Kitz et al., 2022).

By considering several variables simultaneously, multivariate analysis will provide a more complete and specific picture of how consumption patterns affect the food security of specific population groups. This approach promises to reveal complex relationships and to enable the identification of key determinants that may not be detectable in more traditional univariate approaches (Béné et al., 2021).

To evaluate the data collected from surveys and polls at the local, regional, or national level that provide detailed information on eating habits, food availability, and levels of food security (Hirvonen et al., 2021). By linking the results with demographic variables, the aim is to deepen the understanding of how specific policies and programmes can more effectively address food insecurity gaps (Friant et al., 2020).

Identifying existing food security gaps and recommending specific and tailored strategies is vital in order to meet the unique needs of each population group (Elsahoryi et al., 2020). In this process, the aim is to promote a more inclusive and effective food policy that adapts to the diversity of our society and ensures that all people have access to safe and nutritious food at all stages of life.

Food security, understood as the supply of sufficient and nutritious food and sustained access to an active and healthy life, is a global problem with unique manifestations in different geographic and demographic contexts (Ahn et al., 2021). In the specific case of Ecuador, the significant cultural and geographic diversity requires a detailed and specific assessment of food security for different population groups (Sallie et al., 2020). The purpose of this study is to carry out an assessment of food security in different population groups, based on an analysis of multivariate consumption patterns in Ecuador, in order to better understand the complexity and changes in food security in this context.

Ecuador is rich in cultural and geographic diversity and has unique challenges and opportunities in terms of food security, according to the FAO, IFAD, UNICEF, WFP, and WHO study in 2020. Differences in consumption patterns, resource availability, and the socioeconomic conditions of different population groups (Fang et al., 2021), such as different geographic regions, ethnic groups, and socioeconomic levels, require comprehensive assessments that go beyond traditional methods.

The use of multivariate analysis in this study not only makes it possible to examine complex relationships among multiple food security variables, but also identifies specific consumption patterns that may affect food security in Ecuador (Omotayo et al., 2022). The simultaneous consideration of different aspects such as eating habits, resource availability, and socioeconomic variables will help to achieve a more comprehensive and specific understanding of food security in the country.

Assessment of food security across different demographic groups: a multivariate analysis of consumption patterns

The research focuses on the collection and analysis of data from national and regional surveys that provide detailed information on consumption patterns and food security for different population groups. It focuses on the Ecuadorian reality (FAO, IFAD, UNICEF, WFP and WHO, 2020), striving to achieve concrete and relevant results that may serve as a basis for the development of an effective and sustainable food policy in the country.

Ultimately, this research aims not only to identify areas in which Ecuador's food security needs to improve, but also to provide valuable information (Herforth et al., 2020) for the development of interventions and strategies that meet the specific needs of each population group, thereby helping to ensure that all Ecuadorians have access to food security and nutritious food (Sallie et al., 2020).

2. OBJECTIVES

2.1. General Objective

To assess food security in different demographic groups through the multivariate analysis of food consumption patterns.

2.2. Specific Objectives

- To identify the socioeconomic and demographic factors that influence food consumption patterns.
- To determine how variables such as age, gender, educational level, income, and geographical location affect eating habits.
- To use multivariate analysis techniques to identify underlying patterns in food consumption.

3. METHODOLOGY

The estimates are based on an open-source model, which was used to integrate the available data. The target sample is defined as 1,312 households, uniformly distributed. Provinces of Los Ríos (656 samples) and Guayas (656 samples), excluding cities such as Guayaquil. In each province, the sample distribution is as follows: in Los Ríos, 50% for rural families and 50% for urban families; period in this province (Picchioni et al., 2022). Sixty percent of Guayas is located in urban areas, while the remaining 40% is located in rural areas. A confidence level of 95% and a margin of error of 5%. For the evaluation, it is recommended to survey the same households surveyed in the first round (Elsahoryi et al., 2020). However, it is

obvious that the proportion of invalid numbers is high: 49% of the telephone numbers are not suitable (Mora et al., 2020).

Around 44% went to a message mailbox or simply refused to answer the telephone. Although 2% responded to the call, they declined to participate in the survey (Elsahoryi et al., 2020). In order to define whether the sample collected in the field was large enough to satisfy the minimum required in terms of the level of significance and the error established in the proposed design (Bin et al., 2020), the National Employment, Unemployment, and Underemployment Survey —ENEMDU²— for the year 2021 is analysed. It was conducted by the National Institute of Statistics and Census in order to extract the sample parameters (mean, standard deviation, among others) of the household income variable so as to recalculate the sample size with the recommended parameters (Litton et al., 2021).

The original design contemplated maximum variability. ENEMDU is a survey designed to obtain information on labour indicators and captures information on household income in order to estimate the indicator of poverty and extreme poverty by income at the national, urban, and rural levels (Niles et al., 2020). For the annual estimate, the sample design allows representative results to be obtained at the provincial level for urban and rural areas.

Understanding clusters as regions, creating geographical areas with certain characteristics in order to create homogeneous units, together they form the sampling frame (Kent et al., 2020). Thus, there are 685,000 houses within the province of Guayas where 64% of the households in the study area live, and 67% of the houses are located in cities with the universe (Tao et al., 2020). The characteristics of the population by province and region were defined and obtained, then, upon calculating, it is observed that the sample size corresponds to the 95% confidence level and the 5% margin of error (Owens et al., 2020).

The methodology described ensures the representativeness of the sample at the national level by combining careful geographic selection, socioeconomic stratification based on robust data (ENEMDU), and the use of appropriate statistical parameters (95% confidence and 5% margin of error). In this study, a methodology has been designed to ensure that the sample of 1,312 households is representative at the provincial level in Los Ríos and Guayas, and by extension, can provide valid inferences at the national level, taking into account the geographic and socioeconomic distribution.

² by its Spanish acronym.

Assessment of food security across different demographic groups: a multivariate analysis of consumption patterns

The key aspects that guarantee the representativeness of the sample are discussed below.

3.1. Geographic Distribution

3.1.1. Selected Provinces

Los Ríos: 656 households (50% rural and 50% urban).

Guayas: 656 households (60% urban and 40% rural), excluding the city of Guayaquil in order to avoid excessive urban bias.

This equitable selection between urban and rural provinces makes it possible to capture differences in demographic and socioeconomic characteristics between urban and rural areas.

3.1.2. Regional Representation

Geographic clusters: The creation of clusters as homogeneous regions within each province helps to capture internal variability, ensuring that geographic areas with similar characteristics are grouped for more detailed analysis.

3.2. Socioeconomic distribution

3.2.1. National Employment, Unemployment, and Underemployment Survey (ENEMDU)

Sample parameters: ENEMDU provides critical sample parameters (mean, standard deviation) on household income, which are used to recalculate and adjust the sample size, ensuring that the sample is sufficient to represent different socioeconomic levels.

3.2.2. Income coverage

Household income: ENEMDU captures information on household income, which is essential for estimating poverty and extreme poverty indicators, both at the urban and rural levels. This allows for an adequate stratification of the sample according to income levels.

3.3. Confidence level and margin of error

3.3.1. 95% confidence level and 5% margin of error

Adequate sample size: These statistical parameters guarantee that the sample is sufficiently large to provide precise and reliable estimates for the population under study.

3.4. Challenges and solutions in representation

3.4.1. High proportion of invalid numbers and non-responses

Mitigation strategies: Although 49% of the telephone numbers were not suitable and 44% did not respond, it was recommended to survey the same households in successive rounds in order to maintain consistency and improve the response rate.

3.5. Analysis and additional adjustments

3.5.1. Maximum variability

Original design: The original design contemplated the maximum possible variability, ensuring that the characteristics of the population were well represented.

3.5.2. Readjustment of the sample size

Continuous reassessment: With the use of ENEMDU data, the sample size was recalculated to verify that it complies with the established levels of significance and error, adapting the sample according to the observed characteristics of the population.

3.6. Limitations

Although the methodology employed seeks to minimize limitations and ensure a representative sample, it is essential to recognize and address the possible sources of bias and limitations in data collection. Considering these limitations allows a more precise interpretation of the results and contributes to the continuous improvement of data collection methodologies in future studies. These limitations include possible biases in data collection due to the high non-response rate, as well as other factors that may influence the validity of the findings.

3.6.1. High non-response rate

Proportion of invalid numbers: The high proportion of invalid telephone numbers (49%) represents a significant challenge. This may be due to changes in contact numbers, errors in the database, or lack of updating of the contact information.

Message mailboxes and refusals: A high percentage of respondents (44%) did not answer the calls, either by sending them to message mailboxes or by directly refusing to participate in the survey. In addition, although 2% of the respondents answered, they declined to participate, which also contributes to the non-response rate.

3.6.2. Possible biases in data collection

Non-response bias: The high non-response rate may introduce biases into the data, since those who decide not to participate may have socioeconomic, demographic, or attitudinal characteristics different from those who do respond. This bias may affect the representativeness of the sample and, therefore, the validity of the results.

Variability in availability: The availability and willingness to participate in surveys may vary significantly between rural and urban regions, which may introduce an additional bias into the sample. Rural areas, in particular, may have less access to means of communication and, therefore, lower participation in telephone surveys.

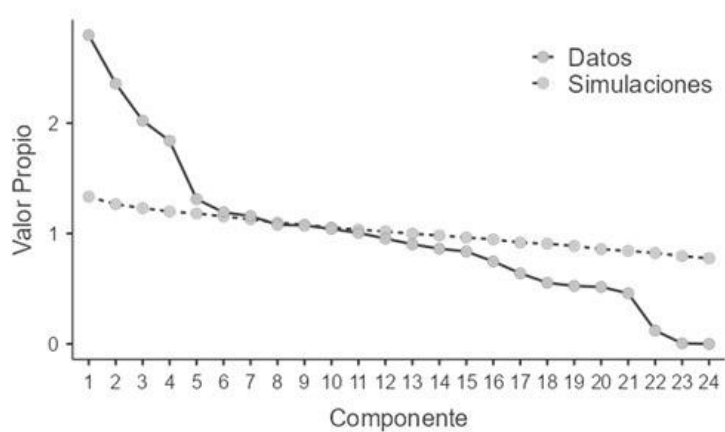
Dependence on secondary data: Although ENEMDU 2021 provides a solid basis for recalibrating the sample, dependence on secondary government data may limit the ability to capture recent changes in the socioeconomic structure of the population. Income parameters and other socioeconomic indicators may have changed since the implementation of ENEMDU, but the data are not updated with optimal frequency.

Limitations in geographic stratification: The exclusion of major cities such as Guayaquil may limit the understanding of urban dynamics in large metropolitan areas. This may result in an underrepresentation of the specific problems and characteristics of large cities. Although the clusters were designed to be homogeneous, there may be significant variability within them that is not fully captured, which may affect the precision of the results at the microregional level.

4. RESULTS

Trajectories of demographic growth, demographic changes, and income development based on five shared socioeconomic pathways (Li et al., 2021). Our assessment began by predicting the prevalence of underweight, overweight, and obesity, which are presented in Figure 1.

Figure 1. Scree plot



Source: Own elaboration.

The traditional approach of separating food waste from food consumption by using uniform regional fractions of food waste is satisfactory for assessing the potential for environmental mitigation (Fitzpatrick et al., 2020) (Table 1).

Table 1. Assumption checking

Prueba de Esfericidad de Bartlett		
χ^2	gl	p
16.717	276	<,001

Source: Own elaboration.

Assessment of food security across different demographic groups: a multivariate analysis of consumption patterns

Test statistic (χ^2): this value indicates the magnitude of the discrepancy between the observed correlation matrix and the correlation matrix expected under the null hypothesis; the value is substantially high, suggesting that there are significant differences between the observed and expected correlations. Degrees of freedom (df): this represents the number of variables minus one (Friant et al., 2020). In this case, there are 276 degrees of freedom. The p-value (p) is extremely small (< 0.001), which indicates very high statistical significance (van Dijk et al., 2021) (Table 2).

Table 2. *Initial Eigenvalues*

Componente	Valor Propio	% de la Varianza	% Acumulado
1	279.716	116.548	11.7
2	235.782	98.243	21.5
3	202.188	84.245	29.9
4	183.929	76.637	37.6
5	131.159	54.650	43.0
6	119.177	49.657	48.0
7	115.802	48.251	52.8
8	108.008	45.003	57.3
9	107.319	44.716	61.8
10	104.111	43.380	66.1
11	100.576	41.907	70.3
12	0,95433	39.764	74.3
13	0,90199	37.583	78.1
14	0,86261	35.942	81.7
15	0,83709	34.879	85.1
16	0,74705	31.127	88.3
17	0,63921	26.634	90.9
18	0,55404	23.085	93.2
19	0,52497	21.874	95.4
20	0,51609	21.504	97.6
21	0,45847	19.103	99.5
22	0,12114	0.5047	100.0
23	0,00526	0.0219	100.0
24	6,75e-5	2.81e-4	100.0

Source: *Own elaboration.*

The initial international growth projections are provided below as an indicator of short-term growth (Hasegawa et al., 2021). By combining estimates of body mass

index and height with data on physical activity and projections of demographic change, food energy requirements can be estimated, assuming a balanced body weight, which is a good indicator of food intake (Table 3).

Table 3. *Principal Component Analysis.*

Components Loadings								
	Component							
	1	2	3	4	5	6	7	Unity
área						0,602		0,5478
b10_1				0,693				0,4635
b10_2				0,674				0,4839
b10_3				0,418				0,6572
b10_4					0,728			0,3715
b10_5					0,767			0,3720
b10_6				0,693				0,4070
b10_7						0,467		0,7102
b10_8							0,516	0,7099
b10_9				0,376		0,342		0,7213
b10_10							0,488	0,6617
b11							0,315	0,8824
b12					0,673			0,3893
b13							-0,492	0,5947
b14	0,939							0,1182
b15	0,922							0,1476
b16	0,774							0,3940
b17			0,993					0,0106
b18			0,992					0,0119
b19								0,9756
b20						-0,491		0,7077
b21								0,9637
c1		0,978						0,0103
c2		0,978						0,0104
Note. 'varimax' rotation was used								

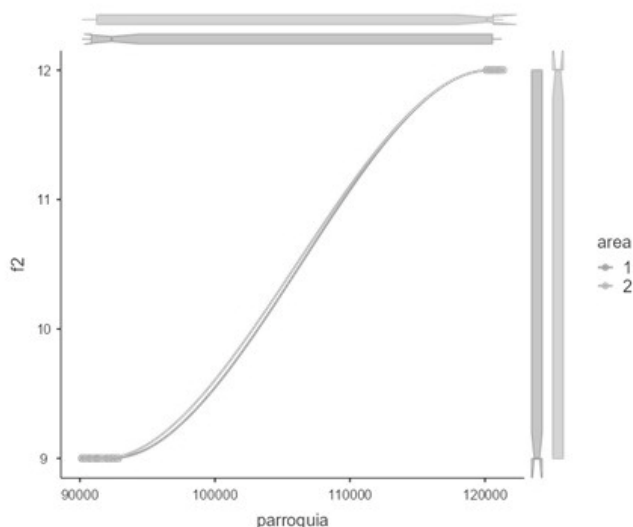
Source: *Own elaboration.*

The p-value is lower than the commonly used significance level of 0.05, which leads to the rejection of the null hypothesis; since the p-value is significantly lower than 0.05, there is statistical evidence to reject the null hypothesis that the correlation matrix is an identity matrix (Naylor et al., 2021). This suggests that there is sufficient correlation among the observed variables to justify the

Assessment of food security across different demographic groups: a multivariate analysis of consumption patterns

application of factor analysis to the data being evaluated. That is, there are significant correlation patterns among the variables that justify dimension reduction and the identification of underlying factors, which are presented in Figure 2.

Figure 2. *Scatter Plot.*



Source: *Own elaboration.*

Unlike estimates of food demand, which are the sum of food intake and food waste, separate estimates of food consumption are not available in public statistics and can only be estimated indirectly (Morales et al., 2021). Although this study provides valuable information, it also acknowledges its limitations and offers opportunities for future research.

The analysis of food security in different population groups in Ecuador contributes to the existing knowledge base and provides significant guidance for the development of specific policies and strategies.

5. DISCUSIÓN

The principal component analysis identified key underlying factors that explain changes in consumption patterns (Brouwer et al., 2020). These factors may be related to socioeconomic, geographic, or cultural dimensions, and identifying them is crucial for understanding the causes of food insecurity among different population groups (Fitzpatrick et al., 2021).

The diversity of consumption patterns revealed by the principal components highlights the need to address food security issues (Mandal et al., 2021) in an individualized manner according to the specific characteristics of each population group (Walker et al., 2021). Different underlying factors may require specific strategies to ensure access to nutritious food.

The different consumption patterns among population groups also indicate inequalities in food security (Kummu et al., 2020). Some groups may be more vulnerable to food insecurity due to economic, geographic, or cultural factors (Erokhin et al., 2020), which underscores the need for specific interventions.

The relative contribution of socioeconomic variables to the principal components highlights the importance of addressing economic disparities in food security (Kitz et al., 2022). Strategies to improve access to nutritious foods must consider factors such as income, education, and employment. The results allow for the development of specific and contextualized interventions adapted to the particular needs of each demographic group (Sawyer et al., 2021). This may include policies to promote local food production, nutritional education programmes, and strategies to address specific barriers to access to healthy foods (Kitz et al., 2022).

It is very important to recognize the limitations of the analysis, such as dependence on data quality and sample representativeness (Béné et al., 2021). Further research is recommended in order to deepen the analysis of specific areas of food insecurity identified and to assess the long-term impact of the proposed interventions (Walker et al., 2021).

Tailored strategies based on an understanding of the determinants are essential for effectively and sustainably improving food security in different demographic contexts (Wolfson et al., 2021).

6. CONCLUSIONS

An assessment of food security in different population groups highlights the importance of understanding the specific complexities of each population group in order to address food security effectively in Ecuador.

The diversity of consumption patterns identified through principal component analysis reflects the richness of Ecuador's culture and geography. The country has different regions and communities with different eating habits that must be taken into account when developing strategies to improve food security.

Assessment of food security across different demographic groups: a multivariate analysis of consumption patterns

Identifying the underlying factors through their principal components makes it possible to recognize that food security is influenced by a series of socioeconomic, geographic, and cultural variables. This in-depth understanding is essential for designing interventions that address the specific concerns of each demographic group.

The assessment reveals unique challenges for food security and opportunities for effective interventions. For example, identifying specific consumption patterns can help to implement nutritional education programmes adapted to the needs of each region.

Current inequalities in food security underscore the importance of an equitable approach to ensure that all communities, regardless of their geographic location or socioeconomic characteristics, have access to nutritious and safe food. Equity must be the cornerstone of future policies and programmes.

The results have important implications for the development of food policy in Ecuador. The recommended policies focus on promoting local production, access to nutritious foods, and the implementation of specific support programmes to meet the needs of each population group.

Recognizing and addressing the differences and unique needs of each population group lays the foundations for a more effective and equitable approach to improving food security in the diverse and dynamic context of Ecuador.

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Raffo Babici, Vilma; Calderón Cisneros, Juan Tarquino & Almeida Monge, Elka Jennifer

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