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Artificial Intelligence for Sustainable Societies

Introduction to Data Science

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The Food Security Dashboard - Data Science Project Report

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Abstract

Food Security is a critical global challenge that affects around 673 million people and is driven by complex interaction of economic, environmental, and political dimensions. This report presents a multidimensional analysis from the concept of Food Security and an interactive dashboard that aims to examine the drivers of the Prevalence of Undernourishment (PoU). With data from the Food and Agriculture Organization (FAO) and World Bank (2000–2024), we aim to operationalize the four pillars of food security: Availability, Affordability, Utilization, and Stability.

Leveraging this analysis, we developed a map-based dashboard that helps navigating the relationships among these indicators at the country level, enabling users to identify regional vulnerabilities and trends. By integrating machine learning analysis with interactive data visualization, this project aims to provide an explanatory tool of correlations and the root economic causes of hunger.

Introduction

Hunger is still one of the most urgent global challenges and affects individuals, families, communities, and entire societies. Today, an estimated 673 million people live with chronic hunger, meaning that almost one out of every eleven people does not have enough food to meet basic daily needs (FAO et al., 2024). Children are particularly vulnerable: 148 million experience stunting due to prolonged malnutrition (UNICEF et al., 2023), and nearly half of all global child deaths continue to be connected to insufficient or inadequate nutrition. Since 2019, an additional 152 million people have been pushed into hunger as a result of increasing armed conflicts, the still-unpredictable consequences of the climate crisis, and persistent socioeconomic inequalities (FAO et al., 2024).

These conditions generate a chain of negative effects that extend beyond the lack of food, often determining long-term health of entire communities, educational performance, labour productivity, and even the stability of political systems. In many ways, hunger is a result and cause of a broader spiral of social problems, where vulnerability becomes more rooted over time. In this sense, ensuring reliable access to sufficient and nourishing food is not only a fundamental human right but also a matter of global justice, since the burden of hunger is disproportionately concentrated in countries that historically contribute the least to global crises yet experience their effects in a greater magnitude.

Addressing hunger requires a perspective that goes beyond looking at food production or supply only. Individuals’ and communities' ability to obtain and consume adequate food is influenced by a combination of economic conditions, environmental pressures, demographic trends, and political stability. Because these factors interact with one another, understanding hunger as a global phenomenon demands a multidimensional approach that allows identifying structural inequalities and long-term vulnerabilities.

Acknowledging this complexity, we aim to provide the foundation and software structure to analyse relevant indicators to explain hunger and to continue building upon by adding new pillars or indicators that contribute to explaining in a more comprehensive manner the complex situation of food security and hunger world wide. The indicators included in this first version constitute a first attempt to draft a big picture of food security.

This report aims to describe the conceptual foundations and analytical process of Food Security and the correspondent technical process from the data science and engineering perspective.

The Food Security Dashboard

Many different factors determine whether people can effectively access adequate food, and because these factors interact with each other, in order to understand the main barriers of this process, it is required a multidimensional perspective. In this sense, the concept of food security provides a useful framework because it helps explain how various dimensions come together to shape people's real ability to obtain and consume nutritious food. According to the World Food Summit (1996), food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food. To make this idea more concrete, the framework is divided through four main pillars, each considering a specific dimension of the problem:

- **Availability:** presence of sufficient quantities of food of appropriate quality, supplied through domestic production, stocks, or imports (FAO, 2006).
- **Access:** ability of individuals or households to acquire appropriate food for a nutritious diet, involving both physical access and economic access (purchasing power) (World Bank, 2024).
- **Utilization:** proper biological use of food, which requires an adequate diet, clean water, sanitation, and sufficient healthcare to reach a state of nutritional well-being (FAO, 2006).
- **Country-based context:** indicators that provide more information about the economic situation of the country. These might be used as explanatory or control.

In order to translate these concepts into visual and interactive insights, the Food Security Dashboard aims to provide a clear, accessible tool to explore these multiple dimensions of Food Security. By combining spatial visualization with country-level comparisons, the dashboard helps users see how the indicators that compose food Security patterns vary across regions and how different indicators contribute to each country's situation. It also allows users to identify which dimensions carry more weight in specific settings. By bringing these elements together, the project seeks to support informed analysis, encourage accountability, and contribute to the ongoing global effort to understand and address food security.

The **main objectives** of this dashboard are to:

a. Analyse the main drivers of Food Security at the country level.
b. Develop an interactive platform with maps and graphs to visualize and compare key indicators of food Security across countries.
c. Analyze the four pillars using a wide set of variables and explore how they correlate.
d. Identify regional patterns to understand where specific barriers are most prevalent.

We collected several datasets related to each of the dimensions of analysis, performed extensive data cleaning, and merged them to construct a unique dataset by country, covering approximately the years 2000 to 2024–2025. After building this unified dataset, we carried out descriptive analysis to identify patterns, trends, and gaps. We performed regression analysis to identify the explanatory variables for undernourishment as our target variable. We also computed the correlation coefficient by country in order to understand the main drivers of hunger at the country level.

The main output of the dashboard is a choropleth world map that uses color patterns to represent the values of each indicator. Users can select any indicator to visualize and explore data across countries. When selecting a specific country, the interface allows users to view its time-series evolution or compare it directly with one or more other countries.

This interactive structure helps users understand the key factors that may contribute to increases or reductions in malnutrition indicators. Beyond simply showing numerical values, the dashboard provides a clearer picture of how food production, poverty, and population trends interact. By exploring these patterns, users can identify where challenges are most severe and where progress is occurring, ultimately supporting strategies and decisions aimed at reducing hunger worldwide.

The long-term vision of this project is to create an accessible, data-driven platform that empowers individuals, researchers, and policymakers to better understand the global dynamics of food Security. By integrating multiple open-data sources and unifying them in an intuitive analytical dashboard, the project seeks to visualize complex indicators and to contextualize the structural factors that shape hunger across countries.

The system aims to serve as a transparent and reliable tool capable of answering key questions such as:

- Which countries are improving or declining in food security?
- How do economic shocks, inflation, poverty, and population changes affect the prevalence of undernourishment?
- Which regions are the most vulnerable, and why?

Ultimately, the project aspires to support more informed decision-making and promote social justice by highlighting where inequalities persist and where interventions could be most effective.

Methodology

Indicators and datasets

There are multiple variables that can be used to operationalize the multiple dimensions of Food Security. However, the following criteria was used to prioritize one indicator per pillar: i) availability of data for as many countries as possible, 2) data from 2000 to recent years - 2024 minimum, and 3) reliability of sources: World Bank and FAO.

In this context, the model and dashboard utilizes historical, country-level time-series panel data from 2000–2024 or 2025 in some cases. The following are the dataset used to link to the food Security dimensions chosen for analysis:

Table 1. Dataset Food Security Dashboard

Pillar	Indicator	Years - Source	Description
Food Security - (Dependent)	Prevalence of Undernourishment (PoU)	2001-2024, World Bank	The percentage of the population consuming insufficient dietary energy (calories).
1. **Availability** (Explanatory)	Per Capita Food Production/Supply	1961-2022, World Bank	Measures the physical presence of food (production + imports - exports - use for non-food).
2. **Affordability** (Explanatory)	Consumer price index - Food - Inflation rate	2000-2025, FAO (monthly)	Measures the economic barriers to obtaining food. High prices or high food-expenditure share indicate poor access.
3. **Utilization** (Explanatory)	Average dietary energy supply adequacy	2000-2022, FAO (annual)	Measures the nutritional quality/variety of the diet. It is used as a proxy for *dietary quality/adequacy* when specific biological data is missing.
4. **Social and political context** (Explanatory or control)	GDP per capita	1960-2024, World Bank	Economic and political conditions.
	Poverty Rate	1960-2024, World Bank	

Population	1960-2024, World Bank

The scope of this project encompasses the full cycle of a data-driven application: from data acquisition and processing to visualization and exploratory analysis. The main components included in the scope are:

Data Collection

Collecting and integrating datasets related to food security pillars, including undernourishment, food production, inflation, poverty, dietary energy supply, GDP, and population. These were mainly retrieved from the World Bank and the FAO.

Data cleaning

The data analysis required to have a unique dataset with values at the country level by each year available. For this, cleaning, normalizing, and merging multi-source datasets into a single structured format was done using Python libraries like Pandas and Numpy.

- GDP, Poverty, Population, Food Calories and Undernourishment

  Variables were renamed for merge, empty or NaN values were dropped and the dataset limited to the timeframe selected (2000 to the latest year available). In this case, we filtered by the chosen indicator - GDP per capita, PPP (current international $).

  In the case of Poverty, an interpolation was applied since it proved to be an important variable to run in the model and dropping all NaNs resulted means removing crucial data for Global South countries, which are overall the most affected countries by hunger. More details about the process will be provided below.

- Energy Supply Adequacy

  Since the values represent the average over a three-year period, we consider only the mean of the period to represent the year. Unusable columns, as well as nullable and NaN values, were also removed.

- Consumer Price Index - Inflation rate

  To understand the shock on the economy of increases in prices as one of the most important barriers on the accessibility dimension, the following assumptions and additional computing was performed.

  a. Inflation rate calculation: CPI does not provide insightful information per se in this analysis. For this, a year-over-year inflation rate was computed using a manual merge. This method ensured accurate inflation calculation by matching values only between the same month in consecutive years, avoiding errors caused by missing data in the time series.

b. Annualization: even though in this case monthly data was available, to run the analysis with the rest of datasets that are on yearly basis, the 12 monthly inflation rates were aggregated into two distinct annual features for the model:
   - Mean Inflation (lag_mean_food_inflation): captures sustained, chronic stress (the average annual economic burden).
   - Max Inflation (lag_max_food_shock): captures outliers that represent isolated but significant shocks as well as shows volatility (the single worst price spike), which often triggers a food crisis.

Project Approach and Processes (Data Pipeline)

The project follows a structured ETL (Extract, Transform, Load) pipeline designed to handle the heterogeneity of global socio-economic data. The process begins with Automated Data Extraction from the World Bank and FAO files available publicly on their websites..

The Transformation phase is the most critical: it involves synchronizing different time scales (monthly vs. annual), normalizing differences between countries' names (e.g. United States, United States of America, America) and spatial scales (ISO-3 country codes). We implemented a specialized sub-routine for "Economic Stress Calculation," where raw CPI data is transformed into year-over-year inflation metrics and shock indicators (Max vs. Mean).

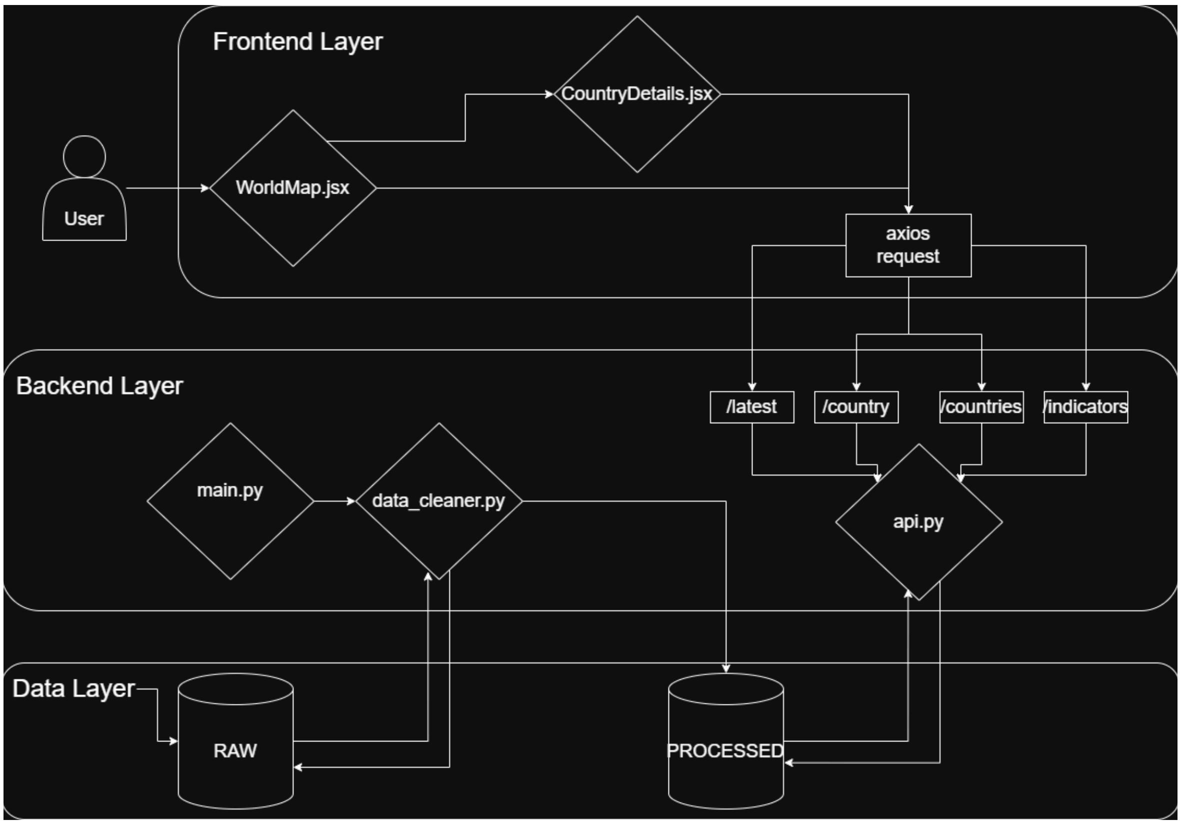
The processed data is then loaded through a FastAPI backend via RESTful endpoints, allowing the frontend dashboard to dynamically request and visualize indicators. This modular pipeline ensures that updates to data sources, feature engineering, or analytical methods can be incorporated with minimal disruption to the overall system.

Engineering and System Architecture

The Food Security Dashboard is implemented as a modular web application composed of a Python-based backend and a JavaScript-based frontend. The backend is built using FastAPI and is responsible for loading the cleaned panel datasets, computing derived features (e.g., mean and max food inflation), and exposing them through RESTful endpoints. These endpoints return country-level and year-level indicators in JSON format (Global Starvation Map – Backend Repository).

On the client side, the frontend is implemented in React and communicates with the FastAPI backend via HTTP requests. The dashboard renders an interactive choropleth world map, time-series plots, and comparison charts by consuming the API responses. This separation between backend and frontend ensures that the data processing logic is encapsulated in the server, while the browser focuses on visualization and user interaction. The architecture also allows the system to be extended in the future with additional endpoints, new visualizations, or more advanced predictive models without redesigning the entire application (Global Starvation Map – Frontend Repository).

Figure 1. System Architecture of the dashboard



Source: author’s creation

Methods and Algorithms

Correlation Matrix

Having done a first link between pillars to understand Food Security with a first round of indicators, a correlation matrix was run to assess the suitability of these indicators to be introduced in the subsequent model.

The matrix (see Figure 2) suggests that the most meaningful indicators are Adequacy of Energy Supply, Food Calories, Max/mean inflation rate, GDP per capita, and Poverty. However, later on we understood that including both max and mean inflation rate and both Adequacy of Energy

Supply and Food Calories, might introduce a collinearity error in the model, since these two sets of indicators behave almost identically.

Therefore, to avoid repeating information and introducing noise into the model, we selected only the strongest indicator from each pair. We chose Energy Supply Adequacy because it captures the quality of supply better than simple calories. We selected Max Inflation Shock because sudden price spikes are often more dangerous for food security than a steady average inflation rate. We also included Poverty and GDP per Capita to complete the economic picture.

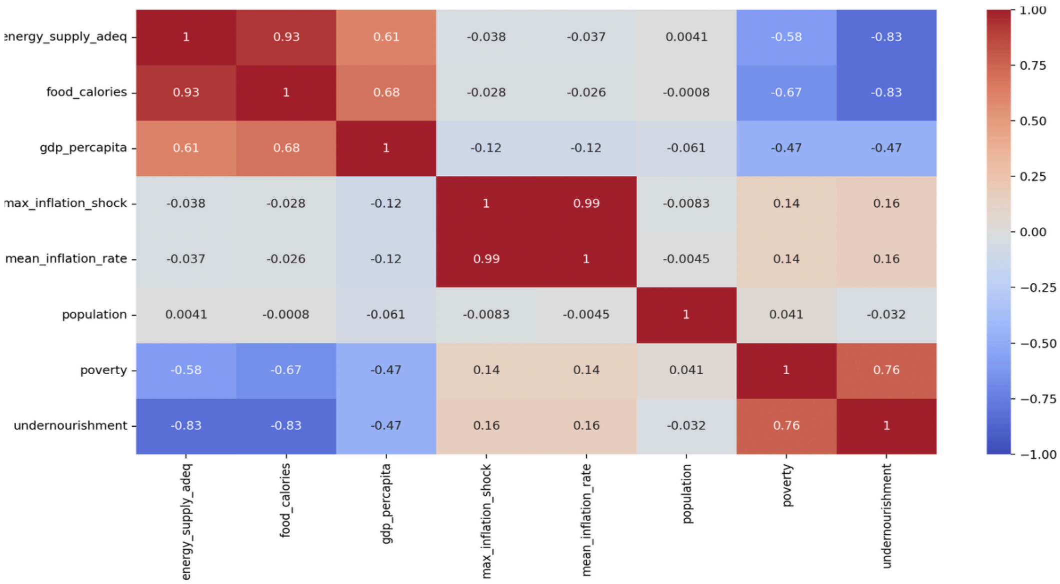
After reshaping the dataset to fit into the model, we decided to split the data based on a year, which is the most optimal way of doing it when handling time-series datasets. In this case, we choose 2020 as the threshold to divide training and testing data since it gives robust data inputs for all indicators to be tested later on.

Then, we had to make decisions about one of the most important indicators in the model: poverty. At the beginning we debated if keeping it was an option given all the data missing. However, the research and the correlation matrix suggested that keeping was key, but some assumptions had to be made in order to introduce it in the model. Simply deleting every row with a missing value would have removed many developing nations from the analysis, biasing our results. Instead, we applied an imputation strategy to fill these gaps responsibly across the entire time series (2000–2024), following these rules:

1. We used a linear interpolation which draws a straight line between both before and after a missing year to estimate the middle values. For this, the limit was 5 years. For example, If a country had data for 2015 and 2018 but missed the years in between, the Linear Interpolation would allow us to replace the missing values for values between the existing data.
2. For missing recent data, we carried that value forward to the next missing values. So, for instance, If a country stopped reporting in 2021, we carried that value forward to 2024. However, we set a strict limit of 3 years for this. If data was older than 3 years, we did not use it.

This approach allowed us to save over 1,000 data points that would have been lost, while attempting to ensure robustness and accuracy by stating rules that would avoid errors or fallacies. The final cleaned dataset contains 2,111 observations ready for the model.

Figure 2. Correlation matrix



Source: Author's creation based on data retrieved from FAO (2024) and World Bank (2025)

Model - Regression

Once this analysis has been conducted, we proceed to run the regression analysis to measure how much each indicator actually impacts food security. In this case, we decided to go for a Supervised Regression - Multiple Linear Regression as the primary analytical engine. The objective is to estimate the elasticity and significance of each independent variable on the Prevalence of Undernourishment (PoU).

The general model specification is:

$$PoU_{it} = \beta_0 + \beta_1(Availability)_{it} + \beta_2(Access)_{it} + \beta_3(Utilization)_{it} + \beta_4(Context)_{it}$$

Where:

- PoU_{it} is the undernourishment rate for country i at time t
- β represents the regression coefficients, which quantify the magnitude of impact each pillar has on hunger.

The model performed well, achieving an Accuracy (R^2) of 0.7254. This means our four indicators can explain approximately 72.5% of the variation in global hunger, which is a strong result for a social science model (Figure 3)

At each indicator level it is observed that Energy Supply Adequacy (see Table 2) is the most powerful factor. The negative sign confirms that increasing the sheer availability of food is the most effective way to reduce undernourishment. It is mathematically more than twice as impactful as any other variable in our model.

Second, Poverty (see Table 2) constitutes the main barrier to access. Even if food is available, a high poverty rate prevents people from buying it. The model shows a clear link: for every point poverty rises, hunger increases significantly.

Third, Inflation Shocks (see Table 2) play a smaller but specific role. While the average cost of living matters less, sudden spikes in inflation (shocks) destabilize families and slightly increase hunger.

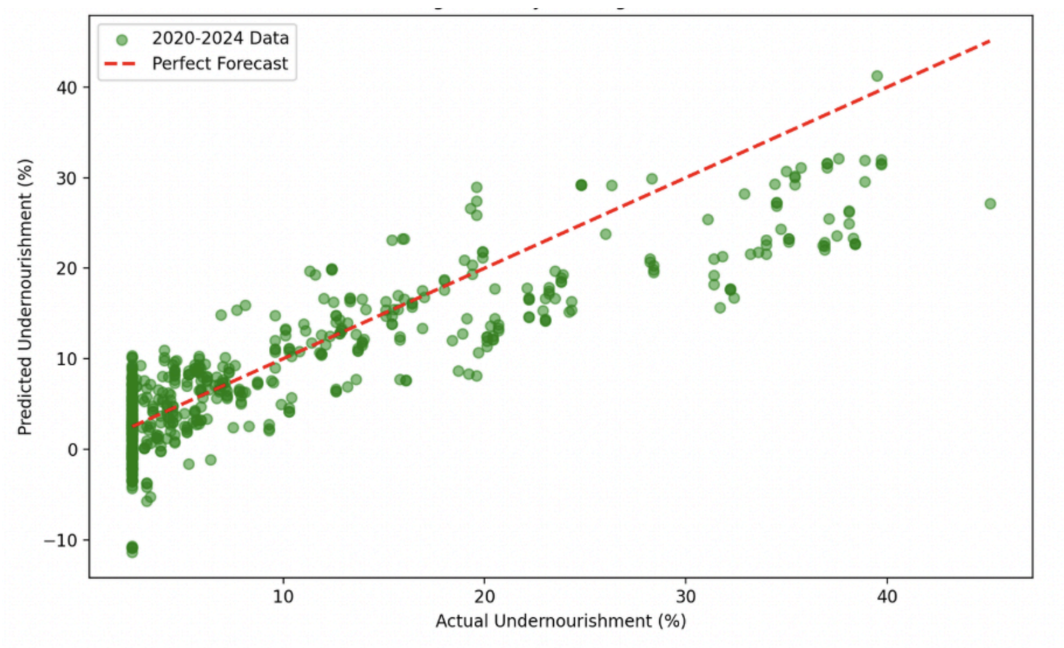
Finally, the result for GDP per Capita (see Table 2) is interesting because it is almost zero. This suggests that simply having a wealthy economy does not automatically solve hunger if inequality exists. Once we account for Poverty and Food Supply, the overall GDP of a country becomes less relevant to predicting whether people go hungry. The fact that more wealth in a country does not have much impact on reducing undernourishment might suggest, however, high levels of inequality in a country. In this case, it would be interesting to add this indicator to the analysis.

Table 2. Results of linear regression

Indicator	**Weight**
energy_supply_adeq:	-0.42
gdp_percapita:	0.0001
poverty:	0.18
max_inflation_shock:	0.0177
R-Squared (Accuracy):	**0.7254**

Source: Author's creation based on data retrieved from FAO (2024) and World Bank (2025)

Figure 3. Forecasting accuracy: testing on years 2020+



Source: Author's creation based on data retrieved from FAO (2024) and World Bank (2025)

Pearson Correlation Analysis

To complement the regression analysis and to provide an interpretable exploratory measure of association, we computed the Pearson correlation coefficient between undernourishment and selected socioeconomic indicators at the country level.

For each country c, the Pearson correlation coefficient was calculated between the time series of the Prevalence of Undernourishment Y_c and each socioeconomic indicator $X_c^{(k)}$, across the available years. Formally, the correlation is defined as:

$$P_c^{(k)} = corr\left(X_c^{(k)}, Y_c\right)$$

where $X_c^{(k)}$ represents the values of indicator k for country c over time, and Y_c denotes the corresponding undernourishment rates.

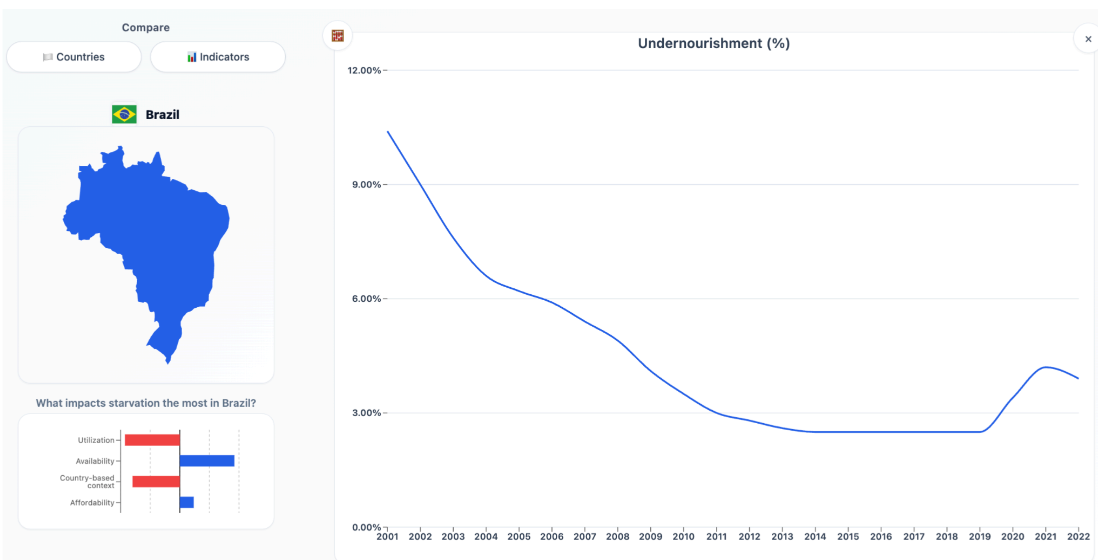
The Pearson correlation coefficient takes values in the interval [−1,1], where values close to 1 indicate a strong positive (direct) relationship, values close to −1 indicate a strong negative (inverse) relationship, and values near zero suggest weak or no linear association. In this context, a positive correlation implies that increases in the indicator are associated with higher levels of undernourishment, while a negative correlation suggests a potential mitigating relationship.

This analysis was performed (see Figure 5) independently for each country, allowing the identification of country-specific drivers of hunger rather than relying solely on global averages. The resulting correlations are used in the dashboard as an explanatory tool, helping users understand which socioeconomic factors are most strongly associated with undernourishment within a given national context.

It is important to note that correlation does not imply causation. The Pearson coefficient is used here as an exploratory measure to highlight linear associations and guide interpretation, while causal inference is addressed more formally through the subsequent regression analysis.

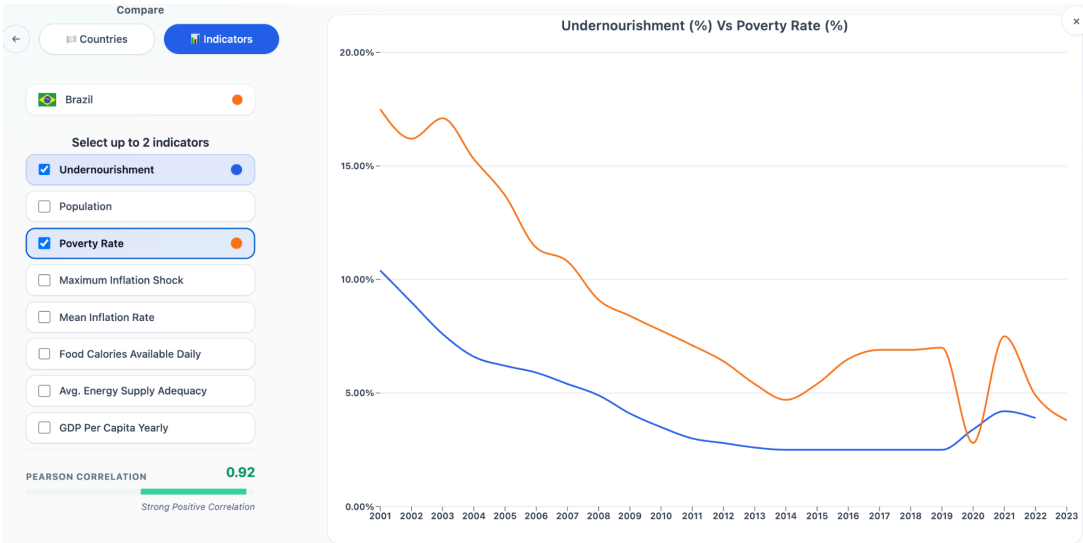
The correlation coefficients were included in the dashboard at the country level as Figure 4. Illustrates. First we provided an overview of the correlation of all variables and undernourishment (see Figure 4) . Then, in a more detailed view when comparing by indicators at the country level, the specific coefficient is provided (see Figure 5).

Figure 4. General overview of correlation coefficients between variables and undernourishment



Source: Author’s creation based on data retrieved from FAO (2024) and World Bank (2025)

Figure 5. Detailed correlation coefficients between selected variables



Source: Author's creation based on data retrieved from FAO (2024) and World Bank (2025)

Project Results

The project resulted in the implementation of a functional Food Security Dashboard designed to explore global patterns of undernourishment through a multidimensional perspective. By integrating indicators related to food availability, affordability, utilization, and broader socioeconomic conditions, the dashboard allows users to observe how these dimensions interact across countries and over time.

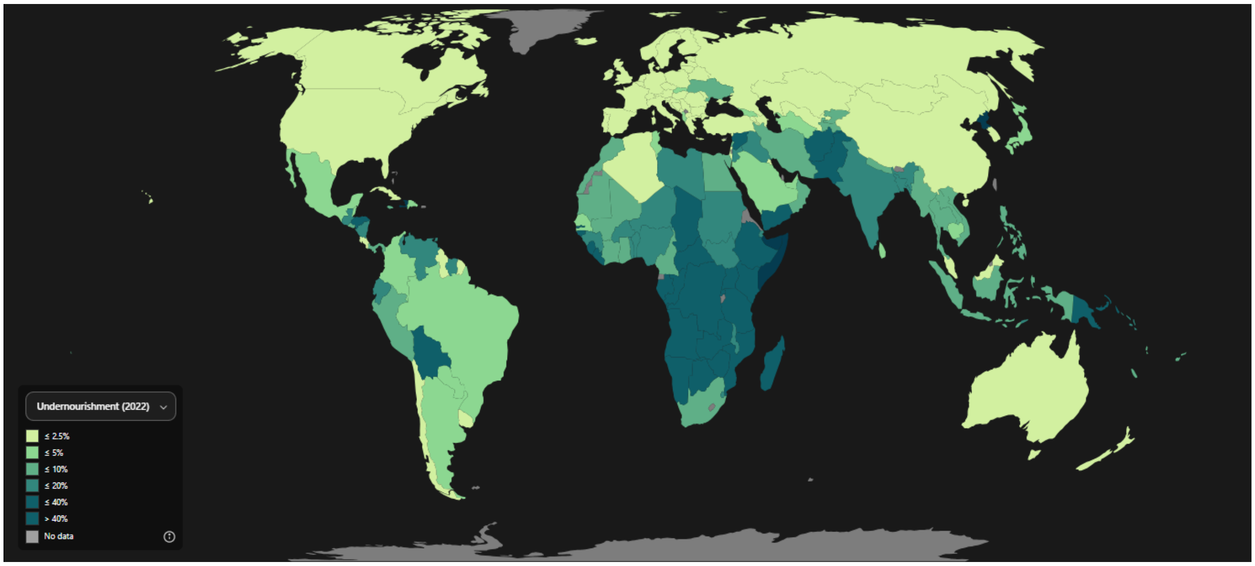
The main output is a choropleth world map that uses colors to represent the values of each indicator (see Figure 6). Users can select an indicator among the options mentioned above to visualize and explore normalized data across countries. By selecting a specific country, the panel enables users to view its time-series data, compare different indicators, or compare it directly with other countries (see Figure 7).

This allows the user to understand key factors that may contribute to increases or reductions in malnutrition indexes. Beyond simply visualizing numbers, it provides a clearer picture of how food production, poverty, and population trends are connected. By exploring these patterns, users can identify where challenges are most pressing and where progress is being made, helping to inform decisions and strategies aimed at reducing hunger worldwide.

The dashboard aims to translate complex, multi-source food security data into an interpretable analytical framework. Through exploratory analysis, the project highlights the relationships between undernourishment and related variables, such as poverty rates, food price volatility, dietary energy availability, and many others.

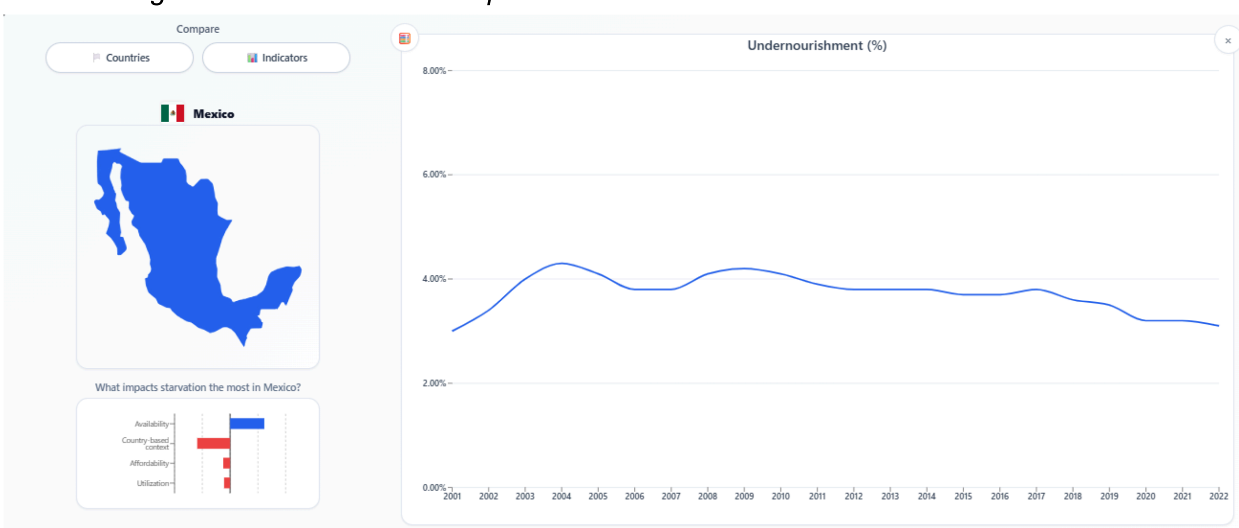
The creation of derived indicators, particularly those related to inflation shocks, demonstrates how to analytically connect the data with real-world issues of starvation. These measures help differentiate between long-term economic pressure and sudden disruptions, both of which play distinct roles in shaping food insecurity outcomes.

Figure 6. Choropleth map of global undernourishment levels (2022)



Source: Author's creation based on data retrieved from FAO (2024) and World Bank (2025). See Food Security Dashboard (2025).

Figure 7. Data visualization panel - Undernourishment time-series for Mexico

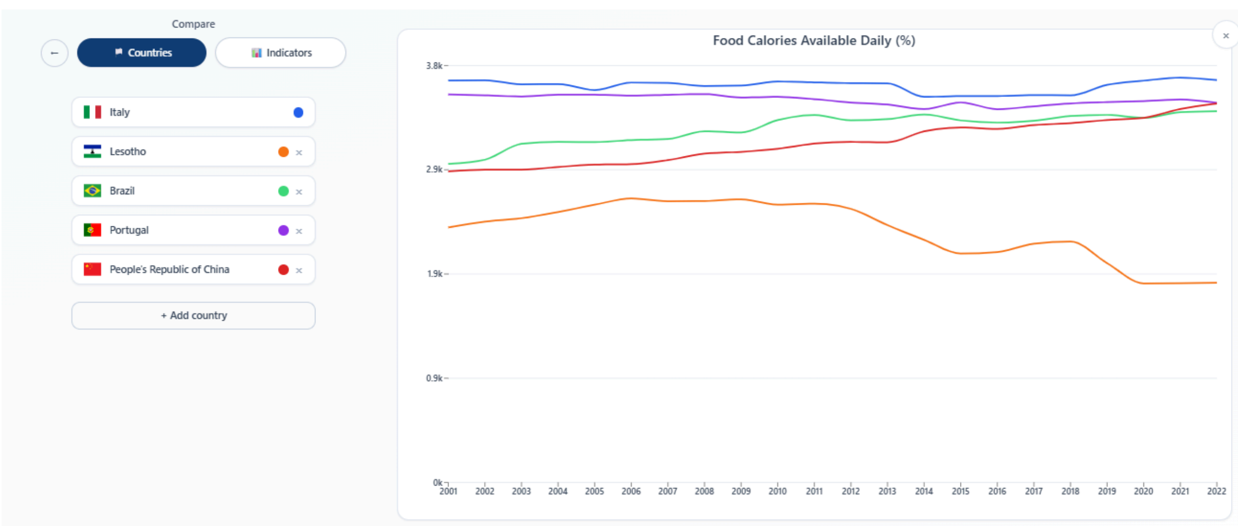


Source: Author's creation based on data retrieved from FAO (2024) and World Bank (2025). See Food Security Dashboard (2025).

Figure 8. *Poverty rate for Madagascar in comparison with all the other countries and the global average.*

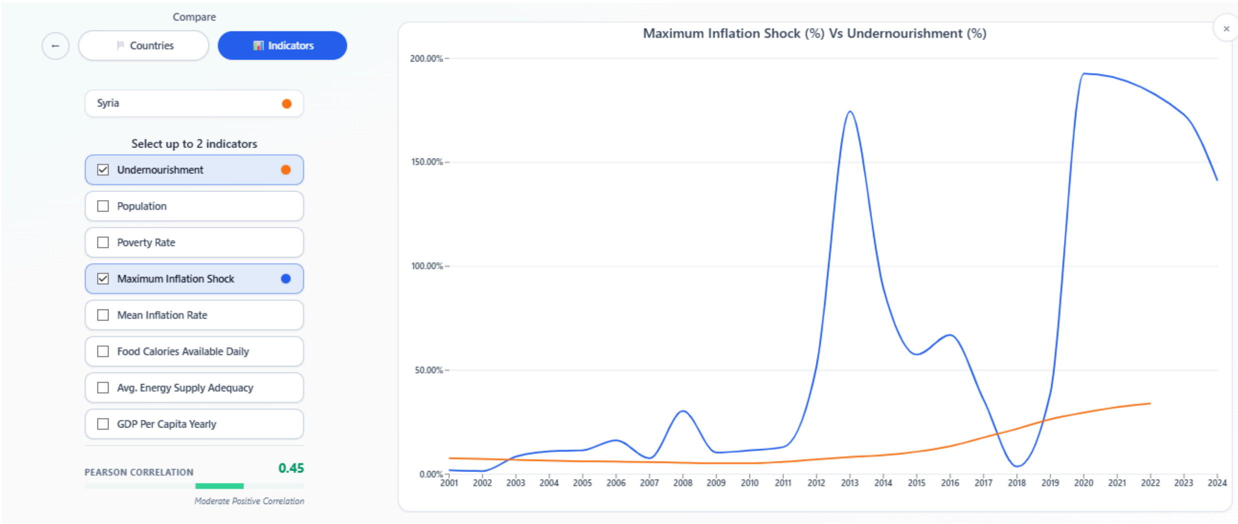
Source: Author's creation based on data retrieved from FAO (2024) and World Bank (2025). See Food Security Dashboard (2025).

Figure 9. Food Calories Available Daily - comparison between Italy, Lesotho, Brazil, Portugal and China.



Source: Author's creation based on data retrieved from FAO (2024) and World Bank (2025). See Food Security Dashboard (2025).

Figure 10. Comparison between Maximum Inflation Shock and Undernourishment for Syria showing a moderate positive correlation.



Source: Author’s creation based on data retrieved from FAO (2024) and World Bank (2025). See Food Security Dashboard (2025).

Conclusion

The development of the Food Security Dashboard has transitioned from a theoretical exercise into a functional tool for multidimensional analysis. By integrating Python based data analysis and processing with an interactive interface, we have created a platform where the abstract concepts of global hunger become visible trends. Our primary activity consisted in merging fragmented datasets from the World Bank and FAO, allowing us to run the regression models that shaped our understanding of the four pillars.

While each pillar plays a significant role, our analysis reveals that they don't impact food security in the same way or with the same intensity. The Availability pillar is often misunderstood; our data shows that even when food production is high, hunger persists if the other pillars are weak. It’s a reminder that growing enough food is only half the battle. On the other hand, the Access pillar, as mentioned, frequently acts as the primary 'bottleneck.' We observed that inflation and low purchasing power can effectively 'lock' people out of markets, even when the shelves are full.

The Utilization dimension adds another layer of complexity, where we see that the quality of what is consumed matters just as much as the quantity. In several regions, even if calories are available, a lack of clean water or dietary diversity means that the biological 'use' of that food is compromised, leading to stunting despite caloric intake. Finally, the Country-based context of these systems is what often determines a country's long-term trend. Our model suggests that countries with high volatility, whether from climate shocks or political unrest, struggle to maintain any progress made in the other three areas. It proves that food security isn't a static achievement, but a fragile balance that requires all four pillars to be functioning at once.

Project Activities and Results

Project activities were developed by both authors, with an even distribution of responsibilities throughout the project. We were involved together in all main tasks, including data research, collection, cleaning, interpretation, and visualization. Analytical choices and technical decisions were also discussed before being implemented. To keep the work aligned, two meetings per week were held to review what was being done, address emerging issues, and decide on the next steps.

The work was organized into three main phases. The first phase focused on conceptual research, indicator selection, and data collection from FAO and World Bank sources. The second phase involved data cleaning, feature engineering, and exploratory analysis, including the construction of derived indicators such as food inflation shocks and the preparation of panel data suitable for regression analysis. The third phase concentrated on presenting results through the development of the interactive dashboard, integrating maps, time-series visualizations, and country comparison tools.

As an outcome of these activities, the project generated both analytical findings and technical deliverables. The analysis of the combined dataset showed recurring relationships between undernourishment, poverty levels, food price volatility, and dietary energy adequacy, supporting the use of a multidimensional approach to food security. From a technical standpoint, the main result is an operational interactive dashboard built with a FastAPI backend and a React frontend, designed to make complex global data easier to explore and interpret. Project progress and tasks were monitored using Trello, which helped coordination and also contributed to clear improvements in the authors' analytical, technical, and project management skills over time.

Achievements and limitations

Due to the inherent complexity of measuring consistently and systematically hunger and food Security dimensions world wide we encountered some limitations. First, this model is a simplified version of the project focused on delivering analytical insights rather than prescriptive solutions. Computational constraints and the academic timeframe also limit the implementation of more complex models.

In addition, the project is limited by the quality and availability of public datasets, which may contain missing values, inconsistent time ranges, or limited geographic coverage. It is relevant to add that, as any other model, this is a simplified representation of a complex problem.

This dashboard constitutes a solid foundation and data infrastructure to continue building upon. The indicators selected are a first round of data aiming to understand Food Security. However, we acknowledge the complexity of this phenomenon, which requires more layers of analysis.

What we provide here is a platform where more indicators and perspectives can be effectively added and incorporated into this project.

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