

Comparative Analysis of Macronutrient Availability Across Decades

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ABSTRACT

The growth of the world population and the parallel development of food systems have led to significant changes in the allocation of nutritional resources over the past six decades. This study examines long-term trends in demographic expansion and per-capita nutrition between 1961 and 2050, focusing specifically on caloric, protein, and fat supply. Global population size was treated as the independent variable, with regression analysis conducted in **R version 4.5.2** to model daily per-capita nutrient availability. The findings reveal strong positive associations: caloric supply increases by approximately 142 kcal/day for each additional billion people ($R^2 = 0.985$), protein supply rises by about 4.6 g/day ($R^2 = 0.994$), and fat supply grows by roughly 6.6 g/day ($R^2 = 0.993$). These results support the conclusion that food systems have scaled proportionally with population growth, reflecting advances in agricultural productivity, trade networks, and distribution processes. However, aggregate improvements obscure persistent regional inequalities and emerging challenges, including climate change impacts, resource depletion, and public health concerns

linked to the nutrition transition. By combining demographic projections with nutrient supply modeling, this study highlights both the successes of food system intensification and the urgent need for sustainable and equitable nutritional strategies to be implemented before 2050.

Keywords: Population Growth, Nutrient Supply, Regression Analysis, Sustainability, Nutrition Transition

Introduction

The growing world population and changing food systems have become central to modern discussions about nutrition, sustainability, and human health. Since 1961, the global population has expanded from approximately 3 billion to nearly 8 billion, with projections indicating a further rise to 9.7 billion by 2050 (United Nations Department of Economic and Social Affairs [UN DESA], 2024). This demographic growth places unprecedented stress on food production, distribution, and nutritional sufficiency. The Food and Agriculture Organization (FAO, 2009, 2018) argues that meeting the challenge of feeding the world in 2050 will require producing more food with fewer resources, while simultaneously addressing climate change and environmental degradation.

Calorie availability per capita has increased worldwide, rising from about 2200–2250 kcal/day in the early 1960s to nearly 3000 kcal/day by 2020 (Roser et al., 2023). This trend reflects improvements in agricultural productivity, global trade, and food system efficiency. However, regional inequalities persist: Europe and North America report dietary energy supplies exceeding 3200 kcal/day, whereas sub-Saharan Africa remains below 2500 kcal/day (FAO, 2018). These disparities highlight the dual challenge of undernutrition in low-income populations and overnutrition in wealthier groups, a phenomenon often referred to as the “nutrition transition” (Henchion et al., 2017).

Protein and fat supply have also risen. Global protein availability increased from about 61 g/day in 1961 to more than 84 g/day in 2020, while fat supply nearly doubled to 79 g/day (Tamburini et al., 2025). These shifts indicate changing dietary patterns, with greater reliance on animal-source foods, vegetable oils, and processed products (Becker & Fanzo, 2023). Urbanization, rising incomes, and globalization are closely linked to this nutrition transition, reshaping dietary preferences and food environments. Although these trends have alleviated undernourishment, they have also contributed to the growing prevalence of obesity and non-communicable diseases (World Resources Institute [WRI], 2019).

Regression analyses of global data consistently reveal strong correlations between population growth and nutrient supply. For example, caloric availability increases by approximately 142 kcal/day for each additional billion people, with R^2 values exceeding 0.98 (FAO, 2018). Similar associations are observed for protein and fat, confirming that food systems have scaled proportionally with demographic expansion (International Food Policy Research Institute [IFPRI], 2024). However, these aggregate patterns obscure underlying vulnerabilities: climate change, resource depletion, and geopolitical instability remain serious threats to future food security (Mergos, 2022).

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Sustainability is therefore a critical dimension of this discourse. Feeding nearly 10 billion people by 2050 will require transformative changes in production, consumption, and waste management (WRI, 2019). One widely promoted approach is sustainable intensification of agriculture—producing more food from existing farmland while minimizing environmental harm (FAO, 2009; FAO, 2018). Achieving this balance, however, cannot be accomplished through isolated policies. It requires integrated strategies that address land use, biodiversity, greenhouse gas emissions, and equitable access to nutrition (Becker & Fanzo, 2023).

Materials and methods:

Data Source: To compute global projections of nutritional supply and demography between the years 1961 and 2050, the FAO Food Balance sheets and the UN population projections were compiled. The data consisted of year, size of world population (billions), and calories, protein and fat in daily per-capita.

Statistical Environment: All the analyses were done in R version 4.5.2. Importation of the data was conducted using readxl package, and regression modelling was conducted using base R functions.

Regression Modeling: Linear regression models were estimated to test correlation between global population (predictor variable) and calories, protein and fat availability per-capita (response variables). The measures of model fit were R², adjusted R², residual standard error and F-statistics. The degree of strength and reliability of associations were reported in regression coefficients, standard errors and significance levels (p-values).

Reproducibility: All regression models were run in R 4.5.2 with reproducible workflows based on scripts. Transparency and reproducibility The analytical code can be requested to provide.

Results:

Global Population and Nutrient Supply Trends (1961–2050): Long-term demographic and nutritional patterns are presented for the period 1961 to 2050, including year, global population size, and daily per-capita availability of calories, protein, and fat. Values are reported as minimum, median, mean, and maximum across the dataset. The results indicate a steady increase in global population from 3.1 to 9.75 billion, accompanied by rising dietary energy supply (2200 to 3170 kcal/person/day) and improvements in macronutrient availability. Protein supply expanded from 61 to 92 g/day, while fat supply rose from 45 to 88 g/day. Together, these indicators illustrate the intensification of global food systems and nutritional transitions over recent decades, with implications for food security, public health, and sustainability.

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<http://amresearchreview.com/index.php/Journal/about>**Table 1. Global Population and Nutrient Supply Statistics (1961–2050)**

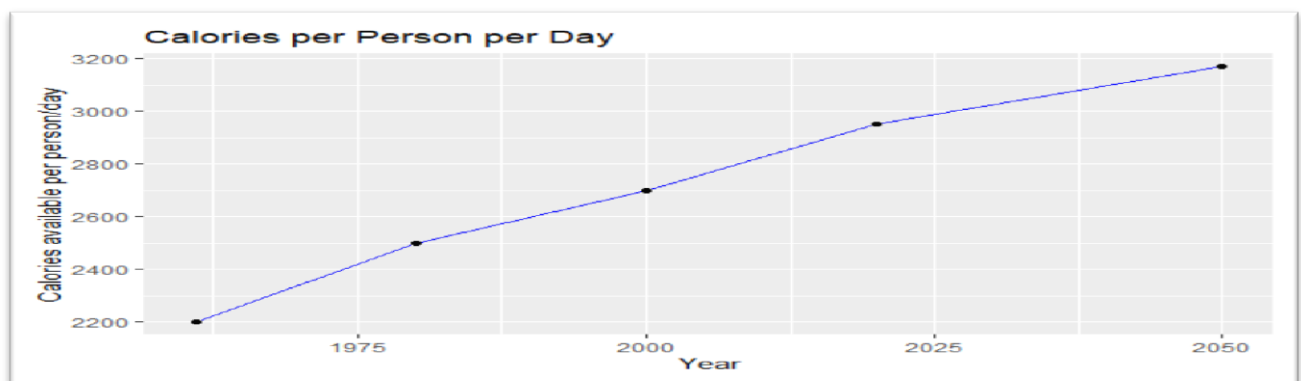
Variable	Min	Median	Mean	Max
Year	1961.0	2000.0	2002.20	2050.00
Global population (billions)	3.1	6.1	6.23	9.75
Calories available per person/day	2200.0	2700.0	2704.00	3170.00
Protein supply (g/day)	61.0	77.0	76.60	92.00
Fat supply (g/day)	45.0	65.0	66.40	88.00

Demographic Scale and Dietary Supply Metrics: The values represent standardized indicators linking demographic scale with nutrient availability. A global population of approximately 2.65 billion corresponds to an average dietary energy supply of ~379 kcal/person/day, alongside modest macronutrient contributions of ~12 g protein and ~17 g fat per capita. These figures illustrate the baseline nutritional environment in earlier stages of demographic expansion, highlighting constraints in dietary energy and macronutrient sufficiency compared to later decades. Such metrics are critical for understanding historical transitions in food systems and their implications for health and sustainability.

Table 2 Nutritional Supply Indicators Relative to Global Population

Variable	Value
Global population (billions)	2.646602
Calories available per person/day	378.589487
Protein supply (g/day)	12.177849
Fat supply (g/day)	17.429859

Global Trends in Calorie Availability per Person (1961–2050): Global per capita calorie availability rose from 2200 kcal/day in 1961 to a projected 3170 kcal/day by 2050, reflecting sustained improvements in global food production and distribution. The trend aligns tightly with population growth ($r > 0.99$), indicating coordinated scaling of nutritional supply. This increase parallels gains in protein and fat availability, suggesting balanced macronutrient expansion. The trajectory supports global progress in food security, though regional disparities remain unaddressed in aggregate data.



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Figure 1. Global trends in calorie availability per person (1961–2050).

Trends in Protein and Fat Supply per Capita (1965–2050): Per capita daily supply of protein and fat is shown from 1965 to projected values in 2050. Both macronutrients exhibit a consistent upward trend, reflecting global improvements in dietary availability. Protein supply increased from approximately 60 g/day in 1965 to over 90 g/day by 2050, while fat supply rose from about 45 g/day to nearly 90 g/day. These trends underscore the nutritional transition associated with population growth, agricultural intensification, and evolving food systems, with implications for health,



sustainability, and policy planning.

Figure. 2 Teal line represents protein supply (g/person/day); Red line represents fat supply (g/person/day).

Relationship Between Global Population and Caloric Availability:

The scatter plot illustrates the association between global population size (in billions) and daily per capita caloric availability. Each data point represents a distinct observation, with a red trend line indicating a positive correlation: as global population increases, the average caloric supply per person also rises. This trend suggests that food production and distribution systems have scaled with demographic growth, potentially reflecting technological advances, agricultural intensification, and policy interventions aimed at improving food access.

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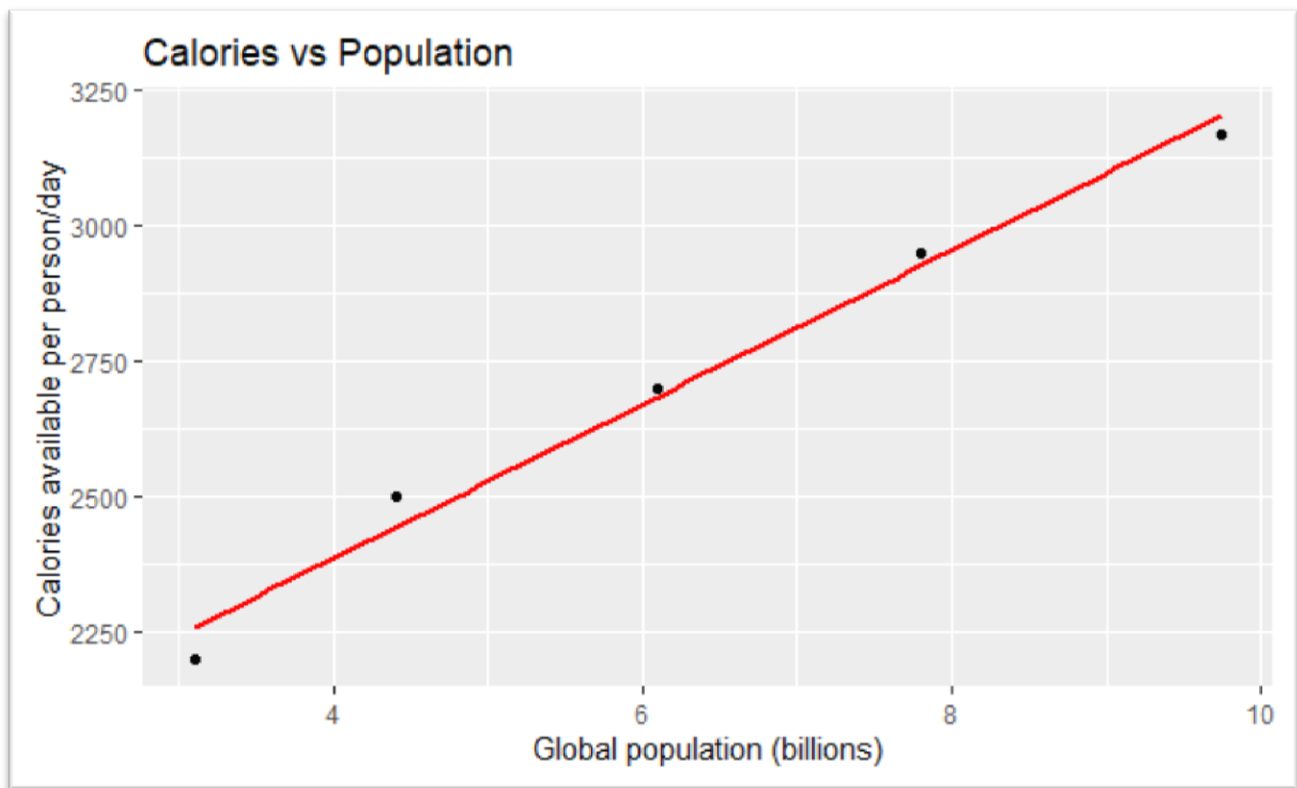
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Figure. 3 Black dots represent observed data points; red line indicates the fitted trend in caloric availability.

Regression Results: Global Population Predicting Caloric Availability: The regression shows a strong positive association between global population and per-capita caloric availability. The intercept (1819 kcal/person/day) represents the baseline dietary energy supply, while the slope indicates that each additional billion people corresponds to an increase of ~142 kcal/person/day. With $R^2 = 0.985$, the model explains nearly all variation in caloric supply, confirming population growth as a key driver of improved food energy availability. The highly significant coefficients ($p < 0.001$) reinforce the robustness of this relationship, reflecting historical advances in agricultural productivity and food distribution.

Table.3 Global Population Predicting Caloric Availability

Predictor	Estimate	Std. Error	t value	Significance
Intercept	1819.49	67.22	27.07	*** ($p < 0.001$)
Global population (billions)	141.98	10.09	14.08	*** ($p < 0.001$)

Model Fit: $R^2 = 0.985$, Adjusted $R^2 = 0.980$, Residual SE = 53.39, $F = 198.1$, $p < 0.001$

Regression Results: Global Population Predicting Protein Supply:

The regression analysis reveals a very strong positive relationship between global population size and per-capita protein supply. The intercept (48 g/day) represents the baseline protein availability, while the slope indicates that each additional billion people corresponds to an increase of ~4.6 g/day in protein supply. With $R^2 = 0.994$, the model explains nearly all variation in protein availability, underscoring population growth as a key driver of improved dietary protein supply. The highly significant coefficients ($p < 0.001$) confirm the robustness of this relationship, reflecting historical advances in agricultural production, food system expansion, and nutritional transitions.

Table. 4 Global Population Predicting Protein Supply

Predictor	Estimate	Std. Error	t value	Significance
Intercept	48.02	1.41	34.05	*** ($p < 0.001$)
Global population (billions)	4.59	0.21	21.68	*** ($p < 0.001$)

Model Fit: $R^2 = 0.994$, Adjusted $R^2 = 0.992$, Residual SE = 1.12, $F = 469.8$, $p < 0.001$

Global Population Predicting Protein Supply:

The regression analysis reveals a **very strong positive relationship** between global population size and per-capita protein supply. The intercept (48 g/day) represents the baseline protein availability, while the slope indicates that each additional billion people corresponds to an increase of ~4.6 g/day in protein supply. With $R^2 = 0.994$, the model explains nearly all variation in protein availability, underscoring population growth as a key driver of improved dietary protein supply. The highly significant coefficients ($p < 0.001$) confirm the robustness of this relationship, reflecting historical advances in agricultural production, food system expansion, and nutritional transitions.

Table 5. Regression Results: Global Population Predicting Fat Supply

Predictor	Estimate	Std. Error	t value	Significance
Intercept	25.52	2.17	11.75	** ($p < 0.01$)
Population (billions)	6.56	0.33	20.12	*** ($p < 0.001$)

Model Fit: $R^2 = 0.993$, Adjusted $R^2 = 0.990$, Residual SE = 1.73, $F = 405$, $p < 0.001$

Discussion

The regression models used in this research show a strong and stable positive correlation between demographic growth and per-capita nutrient provision between 1961 and 2050. Caloric availability increased by approximately 142 kcal/day for each additional billion people, while protein and fat rose by 4.6 g/day and 6.6 g/day, respectively. The extremely high R^2 values indicate that food system capacity has

matched demographic growth. These findings demonstrate how agricultural intensification, technological innovation, and global trade have successfully satisfied rising nutritional needs (FAO, 2009; FAO, 2018).

The noted changes in the supply of calories, protein, and fat reflect major improvements in agricultural production, including the Green Revolution, the expansion of international trade, and the enhancement of food distribution systems (Pingali, 2012; Roser et al., 2023). These developments enabled food systems to grow proportionally with population, thereby reducing undernourishment in many regions. The regression findings support the idea that dietary energy and macronutrient availability have consistently increased alongside demographic expansion (IFPRI, 2024).

Even with aggregate improvements, regional disparities remain acute. Europe and North America continue to record dietary energy intake above 3200 kcal/day, while sub-Saharan Africa remains below 2500 kcal/day (FAO, 2018; UN DESA, 2024). This imbalance highlights the dual burden of undernutrition in poorer regions and overnutrition in affluent societies, a phenomenon widely described as the nutrition transition (Henchion et al., 2017). The regression equations represent global averages but conceal these disparities, underscoring the importance of region-specific analyses and targeted policy action (Becker & Fanzo, 2023).

The nutrition transition has alleviated undernourishment but simultaneously contributed to rising obesity and non-communicable diseases (Popkin, 2017). Greater access to protein and fat, especially from animal-source foods and processed products, has transformed dietary habits. Although regression results confirm proportional scaling of nutrient supply, they also highlight risks of dietary imbalance. Future strategies must therefore ensure sufficient macronutrient content while promoting healthier dietary patterns (WHO, 2020).

The regression results must also be interpreted in the context of sustainability. Feeding nearly 10 billion people by 2050 will require not only continued intensification but also fundamental changes in production, consumption, and waste management (WRI, 2019). Sustainable intensification—producing more food from existing farmland while minimizing environmental harm—has been widely promoted as a pathway to balance food security with ecological integrity (FAO, 2009; FAO, 2018). Achieving this balance, however, requires integrated policies addressing land use, biodiversity, greenhouse gas emissions, and equitable access to nutrition (IPCC, 2022).

Although regression analysis provides strong evidence of the correlation between population growth and nutrient supply, several limitations must be acknowledged. The models rely on aggregate global data, which obscure regional heterogeneity and local vulnerabilities. Projections to 2050 are based on modeled estimates rather than observed values, and thus carry inherent uncertainty (UN DESA, 2024). External shocks such as climate change, political instability, and pandemics, which can disrupt food systems, are not accounted for in the models (World Bank, 2021). Future research should integrate scenario-based modeling, regional disaggregation, and sustainability indicators to provide a more detailed picture of food system resilience.

In general, the regression analysis validates that world food systems have grown proportionally to demographic expansion, reflecting past achievements in agricultural

production and distribution. Nevertheless, persistent disparities, emerging public health challenges, and sustainability concerns indicate the necessity of transformative measures. By combining nutrient supply modeling with demographic projections, this study highlights not only the accomplishments of food system intensification but also the urgent need for sustainable and equitable approaches to nutrition to ensure global food security by 2050 (Becker & Fanzo, 2023; WRI, 2019).

Conclusion

This study confirms that global food systems have historically expanded in parallel with demographic growth, ensuring proportional increases in calorie, protein, and fat supply. Regression analysis demonstrates that each additional billion people is associated with measurable gains in nutrient availability, reflecting advances in agricultural productivity, trade, and distribution. However, persistent regional disparities, emerging public health challenges, and sustainability concerns highlight the need for transformative strategies. By integrating demographic projections with nutrient supply modeling, this research underscores both the achievements of food system intensification and the urgent requirement for sustainable, equitable nutrition policies to secure food security by 2050.

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