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RESEARCH ARTICLE

COVID-19 pandemic exacerbated food insecurity in South American countries

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Abstract
The COVID-19 pandemic triggered unparalleled political, economic, and social ramifications, exacerbating global food insecurity (FI). To understand the overall impact of the pandemic and how different socio-economic groups were affected, we assessed prevalence and severity of FI in a sample of 18,997 households across seven countries in South America. We employed the Food Insecurity Experience Scale developed by the FAO. Our results showed that pre-pandemic, 4.5% of the sampled population across the entire continent faced Moderate FI, while 0.6% experienced severe FI. During the pandemic, Moderate FI increased to 16.9% (+12.4%), and Severe FI to 2.7% (+2.1%). By country, pre-pandemic households in Venezuela had the highest prevalence of Moderate FI (9.7%), with Peru experiencing the highest Severe FI frequency (1.1%). Peru had the greatest rise in Moderate (+23.9%) and Severe FI (+4.6%) during the pandemic. Low-income households, defined as those earning < 2 minimum wages per month, were most susceptible to FI. Uruguayan low-income families exhibited the most significant rise (+40.4%) in Moderate FI, while those in Peru experienced an increase of +9.1% in Severe FI. This study measures the profound and far-reaching impact of the COVID-19 pandemic on FI in South America. Our findings also emphasise the critical importance of implementing effective public policy interventions to improve resilience against future shocks. This would enable policymakers to develop targeted strategies that address the immediate challenges posed by pandemics as well as laying the groundwork for a more resilient and sustainable food security landscape in the region.

Keywords Food security · Nutrition · Covid-19 · Hunger · South America

1 Introduction

Many countries worldwide have been profoundly impacted by the COVID-19 pandemic, caused by the SARS-CoV-2 virus (Hiscott et al., 2020). This global health crisis has had far-reaching effects on the economies, political structures, and social fabric of those countries grappling with its consequences. The COVID-19 has also exacerbated food insecurity (FI), due to the restrictive measures aimed at controlling the virus' spread (Laborde et al., 2020a, 2020b). This threatened access to food mainly through losses of income and assets that prejudice the ability to buy food. Globally, this was more severe in poorest households, who on average spend around 70% of their incomes on food and have limited access to financial markets, making their food security

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particularly vulnerable to income shocks (Laborde et al., 2020a, 2020b).

Food insecurity (FI), a pervasive issue globally, affects millions of people, particularly in low- and middle-income countries with high inequality and limited social support. FI arises when individuals or households lack reliable access to enough affordable nutritious food leading to uncertainty about their ability to acquire adequate food for a healthy and active life (World Food Summit, 1996). FI can manifest in various degrees, ranging from occasional uncertainty about obtaining food to more severe and chronic conditions where hunger and malnutrition become prevalent.

Measuring FI is intricate due to its subjective nature, influenced by cultural variations and diverse factors such as economic conditions and climate changes. The dynamic and multidimensional aspects of food security, ranging from availability to access and utilisation, require comprehensive assessment tools. Limited access to accurate data and the interconnected nature of food security with various indicators pose challenges to obtaining a precise understanding. Despite these complexities, ongoing efforts to refine measurement tools and embrace multidimensional approaches contribute to a more nuanced assessment of food insecurity globally (Manikas et al., 2023).

Research on the influence of COVID-19 on food insecurity often neglects to consider variations in food access related to individuals' income levels (Bloem & Farris, 2022), despite income being a recognized central factor influencing FI (IFPRI, 2016). Another notable drawback in the field is the prevalent dependence on cross-sectional studies, which fail to track changes in an individual's food security status over time (Gebeyehu et al., 2023). Despite these limitations, existing research suggests that the impact of COVID-19 on food insecurity varied among countries, primarily mirroring their economic status. However, it may also reflect socioeconomic differences within each nation and the effectiveness of mitigation measures implemented by their respective governments (OECD, 2020). Notably, Indonesia, Mexico, Bangladesh, Lebanon, and the USA witnessed an increase in FI, while a study in Iran indicated improved household food security and dietary diversity linked to government assistance policies (Gebeyehu et al., 2023; Pakravan-Charvadeh et al., 2021). Currently, there are few studies that analyze the impact of the COVID-19 pandemic on FI in several (Benites-Zapata et al., 2021; Hernández-Vásquez et al., 2022, Novoa-Sanzana et al., 2024), or particular countries (Manfrinato et al., 2021; Zila-Velasque et al., 2022) in the entire South America.

It is estimated that Latin America and the Caribbean is the region with the second highest figures for FI globally, with a prevalence of 40.9% in the entire region (Hernández-Vásquez et al., 2022). South America in particular is characterized by income disparities, inequalities in the opportunities to access goods and public services, as well as high rates of poverty, unemployment, and high inflation. In South America, the wealthiest 10% concentrate 58.6% of the population's average income and over 75% of agricultural lands (Bauluz et al., 2020; Espinosa-Cristia et al., 2019; Otsuka, 2013; World Inequality Lab, 2022). This resource imbalance has historical roots in the colonial origins of South American countries and persists (Frankema, 2010). The current food production model favours large producers and agribusiness corporations while diminishing the capacity of small farmers and local communities to produce their own food (Clapp & Moseley, 2020; Gonzalez, 2004; Mares & Alkon, 2011). As a result, despite the pandemic pushing 33.7 million South Americans into hunger (FAO, 2021), food exports increased by 2%, and the agricultural sector's Gross Domestic Product (GDP) grew by 1.1% during that period. Additionally, a country's dependence on agricultural commodity exports can result in reduced food availability in the domestic market and heightened food prices, disproportionately affecting poorer and more vulnerable families (Nkurunziza et al., 2017; UNCTAD, 2021).

Our study's main objective was to assess the magnitude of changes in FI across seven countries in South American, with a particular focus on comparing conditions before and during the COVID- 19 pandemic. We also assessed FI at the household level and thereby improved the understanding of the impact of the COVID- 19 pandemic on families with various income levels.

2 Material and methods

2.1 Sample size

We employed the EpiInfo7 program (Dean et al., 2011), to determine the required sample size. The calculation, based on an expected response frequency of 50% and a 10% margin of error, indicated the need for a total of 16,640 households to be sampled. The study was implemented across seven countries (Brazil, Colombia, Ecuador, Paraguay, Peru, Uruguay, and Venezuela), encompassing a total of 18,997 households (Fig. 1; Suppl. Table 1).

2.2 Data collection

We developed an online form using Google Forms to gather information on socioeconomic and food security aspects within households. Participants were asked to supply information on number of residents, total monthly income (in national currency) and the status of food and nutritional security (FNS) by using the Food Insecurity Experience Scale (FIES) (Cafiero et al., 2018) developed by FAO (Suppl. Table 1). The FIES method consists of eight

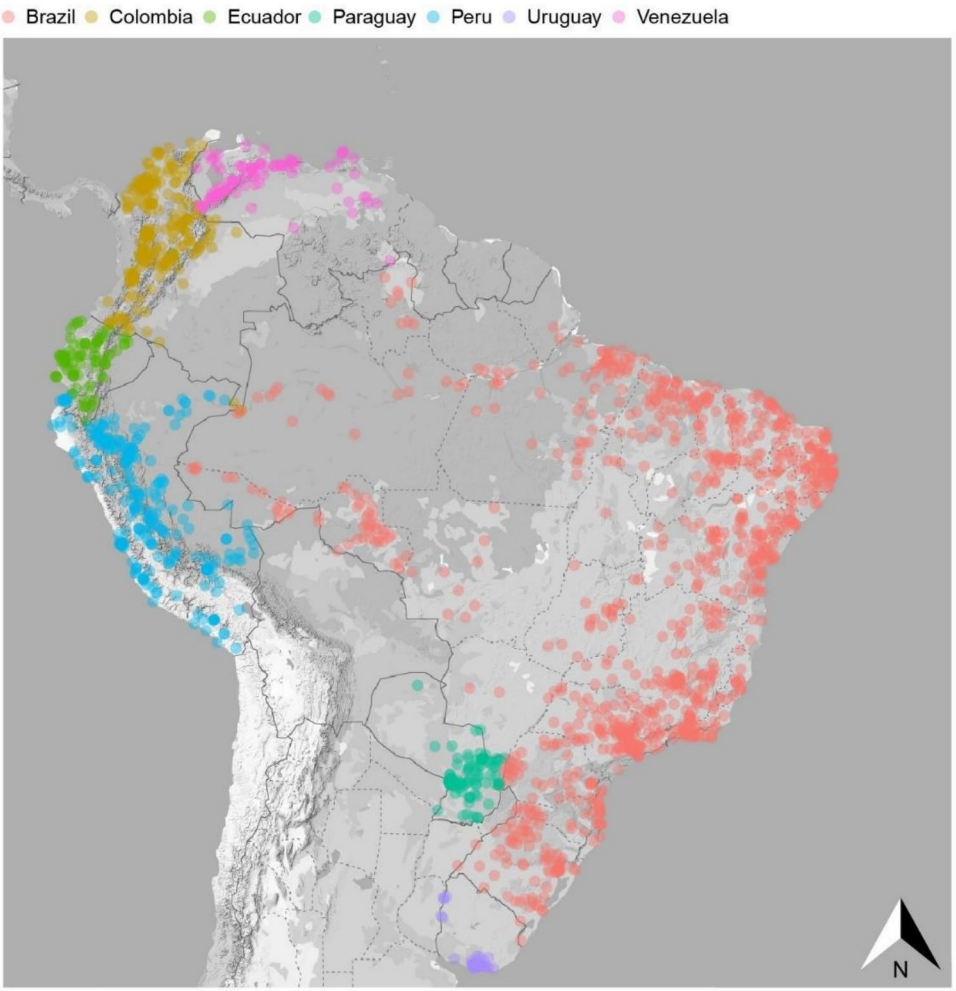

Fig. 1 Human settlements surveyed on food insecurity levels in each South American country during the data collection carried out throughout the year 2020

questions containing a graded FI severity scale (Mild: 1–3; Moderate: 4–6; and Severe FI: 7–8). To capture the effects of the pandemic, respondents were asked about the level of FI in their households during two time periods: A) pre-pandemic (November—December 2019); and B) during the pandemic (May—December 2020). To ensure clarity, questions were translated and adapted to the primary language spoken in each country (Portuguese for Brazil, Spanish for the remaining countries).

Data collection was supervised by a group of 49 regional coordinators, aiming to have at least one representative from each state or region in the countries sampled. These coordinators recruited volunteers and coordinated data collection in their respective areas. A total of 330 volunteers participated in the research, recruited through university websites, social media groups, and announcements offering voluntary internships for research with the issuance of participation certificates. Volunteers were responsible for disseminating the survey link and attracting participants to the research. Weekly reports were shared on the progress of data collection to identify and prioritize areas with fewer interviews. The survey was distributed by volunteers through messaging apps and social media. Participants were encouraged to become volunteers and share the research link within their networks after completing the questionnaire, thus integrating the snowball sampling recruitment method.

Sampling was limited to areas with internet access since health and safety regulations precluded in-person interactions during the data collection period. In 2020, about 74% of the population in South America had internet access (World Bank, 2021). A stratified sampling technique was employed to address potential selection bias, with increased sampling density in urban areas. The average internet connectivity in rural regions is roughly half that in urban locations (Ziegler et al., 2020). Therefore, only 22% (n = 4,179) of households were sampled in municipalities with fewer than 50,000 inhabitants, with proximity and influence from rural areas.

The survey was targeted to persons aged 18 years or older. Google Forms was chosen for its free accessibility and its versatility and not requiring high-speed internet

connection. The form could be filled out on both computers and smartphones.

Each country sampled had specific rules regarding the Research Ethics Committee, though in general authorization was not required if participant anonymity was maintained. Research transparency and adherence to medical research ethics protocols as established by the Declaration of Helsinki ('World Medical Association Declaration of Helsinki', 2013) was adhered to and no personal information enabling participant identification was collected. The project description, outlining objectives, expected outcomes, and coordinator contact information, was provided before accessing the questionnaire. Participants were informed of the option to withdraw at any time and invited to sign an informed consent form if choosing to respond to the survey. This study was considered exempt from requiring ethical approval because the nature of the Internet-based questionnaire always protected anonymity and ensured the possibility that the interviewee was free to decide to discontinue the questionnaire.

Households surveyed were classified according to country and income level and information on the person who completed the household survey, including age, gender and educational attainment (Suppl. Table 2).

2.3 Statistical analysis—Rasch Model

Because FIES questions have a gradual severity scale, a positive response to a later question, e.g., question five, is anticipated to be accompanied by positive responses to all preceding questions. However, in practice, not all respondents would follow this, leading to response patterns deemed erroneous. To reduce the impact of this bias on the results, we built a Rasch Model using income as a predictor variable and estimated the probability of each household experiencing Moderate or Severe FI, thereby enhancing the precision and reliability of our analysis:

Let y_{itq} be the binary response of individual i to question q at time t. Our Rasch model assumes that:

$$y_{itq} \sim Bernoulli\left(\frac{exp\left(\theta_{it}-\phi_q\right)}{1+exp\left(\theta_{it}-\phi_q\right)}\right)$$

where θ_{it} is the position of individual i at time t in the severity of food insecurity scale. Similarly, ϕ_q is the position for question q. We assume that:

$$\phi_q \sim N(0,1)$$

In relation to the position of each individual at each time, we assume that:

$$\theta_{it} \sim N\left(\gamma_i + x_{it}^T\beta, 1\right)$$

where γ_i is an individual-level random effect, x_{it}^T is a vector of covariates, and β is a vector with the corresponding slope parameters. We rely on these individual-level random effects to account for correlation given that respondents replied twice (once referring to the period prior and once referring to the period during the pandemic) to the eight questions that comprise the food insecurity scale. These random effects were modeled as $\gamma_i \sim N\left(0,\sigma^2\right)$. The covariates within the vector x_{it}^T included a binary period variable (t = 0 for prior to pandemic; t = 1 for during pandemic), an income variable, and the interaction between these variables. The income variable was discretized into three categories based on the number of minimum wages per month (MW) in each country (Low: < 2 MW; Medium: 2–4 MW, and High: > 4 MW). To estimate prevalence for each country and period regardless of income status, we dropped the income variable and the interaction terms before fitting the model.

Since this model is implemented within a Bayesian framework, it is necessary to define our priors. These priors serve as the initial beliefs or assumptions about the parameters of the model before observing the data. These priors are given by:

$$\beta_p \sim N(0,1)$$

$$\sigma \sim Unif(0,100)$$

2.4 Model fitting

To conduct our analysis, a separate Rasch model was fitted for each country utilising a Gibbs sampler implemented in JAGS (Plummer, 2003) within the R programming environment (R Core Team, 2021). We employed three chains, each consisting of 5,000 iterations. Following a burn-in period, the first 1,000 iterations were discarded, and we retained every 5th sample from the posterior distribution. Convergence of the algorithm was assessed using the Rubin and Gelman *Rhat* statistic (Gelman & Rubin, 1992). Successful convergence was confirmed as all parameters exhibited an *Rhat* statistic below 1.1.

2.5 Estimation of the prevalence of moderate and severe FI for each country and income level

Following the FAO guidelines (Cafiero et al., 2018), we estimated the prevalence of Moderate or Severe FI for country k (M_k) by calculating the mean probability of positively answering the question "Still thinking about the last 12 MONTHS, was there a time when you ate less than you thought you should because of a lack of money or other resources?". This is the question 5 in the FAO questionnaire

(i.e.,"ATELESS" question) and therefore this quantity was calculated as:

$$p(x_{itk}) = \frac{exp(E[\theta_{itk}] - \phi_{5k})}{1 + exp(E[\theta_{itk}] - \phi_{5k})}$$

where $E[\theta_{itk}] = x_{itk}^T \beta$, thus excluding the individual-level random effects.

Similarly, we estimated the prevalence of Severe FI for country k (S_k) by calculating the mean probability of positively answering the question "During the last 12 MONTHS, was there a time when you went without eating for a whole day because of a lack of money or other resources?". This is the question 8 in the FAO questionnaire (i.e.,"WHOLEDAY" question) and therefore this quantity was calculated as:

$$p(x_{itk}) = \frac{exp(E[\theta_{itk}] - \phi_{8k})}{1 + exp(E[\theta_{itk}] - \phi_{8k})}$$

Subsequently, we calculated the increase of FI by comparing M_k (and S_k) for 2019 and 2020.

2.6 Estimation of the prevalence of moderate and severe FI for South America

To compute the prevalence of Moderate and Severe FI for South America (M_{LA}), we utilised on the following equation to combine the results from each country:

$$p(M_{LA}|T = t) = \sum_k p(T = t)p(Country = k)$$

for before and during the pandemic periods. In this expression, $p(Country = k) = \frac{N_k}{\sum_q N_q}$ where N_k is the population of country k in 2020 (ONU, 2022). Similarly, we calculated the prevalence of Severe FI for South America (S_{LA}) using:

$$p(S_{LA}|T = t) = \sum_k p(T = t)p(Country = k)$$

3 Results

The median age of surveyed persons was 29 years (Q1 = 22, Q3 = 41), with a sex ratio of 59.2% females, 40.4% males and 0.4% not declared. The average monthly income was 2.5 (± 2.1 SD) minimum wages relative to the respective measure in each country. The higher educational level of surveyed people was a university degree (40.5%), followed by secondary education (35.3%). Supplementary Table 2 shows the demographic characteristics of the households surveyed overall and per country.

Our calculations reveal that before the pandemic, 4.5% and 0.6% of our sampled households in the studied South American countries were already experiencing Moderate and Severe FI, respectively (Suppl. Table 3). Severe FI was most prevalent in Paraguay (1.7%), followed by Peru (1.1%), Ecuador (0.8%), Colombia (0.7%), Brazil (0.5%), Venezuela (0.3%), and Uruguay (0.3%); whereas Moderate FI was most prevalent in Venezuela (9.7%), followed by Peru (7.7%), Paraguay (6.6%), Colombia (5.8%), Ecuador (5.7%), Uruguay (5.6%), and Brazil (2.7%) (Fig. 2; Suppl. Table 3).

The pandemic had an unprecedented overall impact on FI among our sample population, more than tripling and quadrupling the prevalence of Moderate (from 4.5% to 16.9%) and Severe (from 0.6% to 2.7%) FI, respectively (Suppl. Table 4). This increase in Severe FI represents an additional 53.4 million people experiencing hunger in South America. All countries studied experienced exacerbated increase in FI prevalences; however, Peru experienced the greatest increase in Moderate and Severe FI (Moderate FI 23.9%/Severe FI 4.6%), followed by Ecuador (22.9%/4.2%), Venezuela (21.8%/1.1%), Colombia (20.1%/3.3%), Uruguay (16.1%/0.9%), Paraguay (8.7%/2.5%), and Brazil (6.9%/1.3%) (Fig. 2; Suppl. Table 3).

At the household level, low family income was associated with a higher likelihood of food insecurity (FI), with an increased risk of +28% for moderate and +5% for severe FI, compared to high-income families. Among the countries surveyed, Low-income families in Uruguay were the most vulnerable (Moderate FI 59.2%/Severe FI 5.1%), followed by Peru (49.9%/11.5%), Colombia (44.1%/8.5%), Ecuador (39.9%/8.1%), Venezuela (36.1%/1.7%), Paraguay (17.7%/5.1%) and Brazil (13%/2.4%) (Fig. 3; Suppl. Table 4).

4 Discussion

In this study, we measured the state of food insecurity in seven South American countries before and during the COVID-19 pandemic, carrying out the most extensive collection of FI data in South America during the pandemic. We also undertook novel analytical methods by using Bayesian statistics to improve the FAO's Food Insecurity Experience Scale to allow inferences at the household level. By doing so, we identified a tripling and quadrupling trend in Moderate and Severe FI during the pandemic.

In comparison to previous government data (GAIN, 2023) for the same South American countries, our pre-pandemic data showed lower levels of Moderate and Severe FI. The latter indicated that the combined prevalence of Moderate and Severe FI was 37%, 29%, 25% and 14% for Ecuador, Brazil, Paraguay and Uruguay, respectively. Data for Venezuela, Peru and Colombia were not available. As far as we

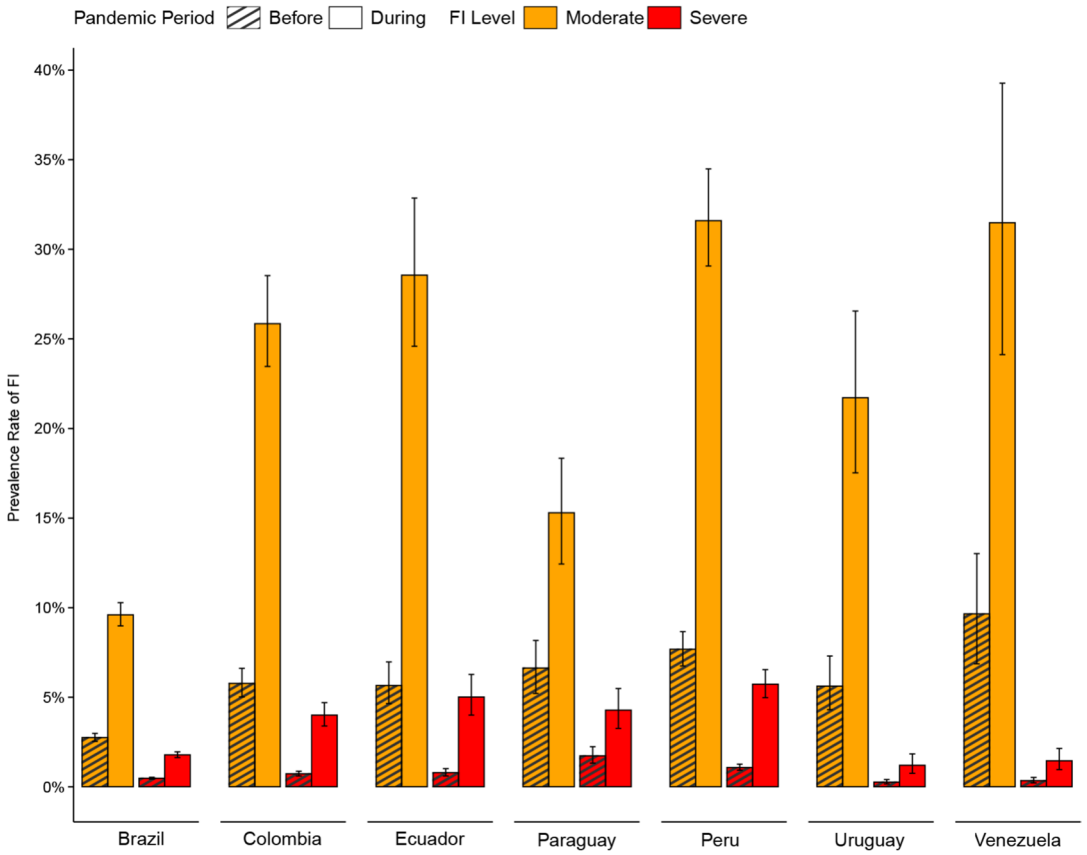

Fig. 2 Prevalence Rate of FI calculated by country, pandemic period, and FI level. The error bars represent the 95% credible Confidence Intervals

know, the available regional information focuses mainly on Latin America. Studies carried out in various Latin American countries during the COVID- 19 pandemic reported 40.9%, 41.8% and 75.7% FI, respectively (Benites-Zapata et al., 2021; Hernández-Vásquez et al., 2022; Novoa-Sanzana et al., 2024). Some studies suggest that the combined prevalence of Moderate and Severe FI before the COVID-19 pandemic in particular South American countries was between 23 and 37% in Peru (Curi-Quinto et al., 2021; Zila-Velasque et al., 2022), 40% in Colombia (Sinclair et al., 2022), and 47% in Brazilian favelas (Manfrinato et al., 2021).

Estimates of FI in South America have been influenced by a history of economic crises in the region. From 2000–2008, South American countries enjoyed a period of economic prosperity, characterized by high GDP growth, low inflation, and reduced poverty rates (Moreno-Brid & Garry, 2016). This period experienced significant advancements in food security and nutrition policies and initiatives (Piñeiro et al., 2010). However, the food crisis of 2006–2008 and the subsequent economic crisis of 2008–2009 led to food price inflation, particularly impacting the poorest due to the loss of purchasing power (Piñeiro et al., 2010). The economic crisis that unfolded in 2014–2017 further exacerbated FI levels (Sousa et al., 2019a, 2019b), potentially contributing to the scenario uncovered by our study in 2019. Therefore, the South American population already had important rates of FI, although unequal based on economic income, before the outbreak of the COVID-19 pandemic.

Our results reveal the vulnerability of food security in South America by showing how the onset of the COVID-19 pandemic exposed a significant portion of the initially food-secure population to rapid and severe FI, without a gradual evolution of the situation. The disparities observed in this study are markedly larger compared to baseline population data for countries in the South American region. For instance, according to the data from the Food System Dashboard (GAIN, 2023), the prevalence of Moderate and Severe FI in Uruguay rose by only 1% due to the pandemic, more than 15 times smaller than in our observations. In general, prevalence studies are not adept at capturing changes in FI within the same sample units, a limitation we attempted to address here. Stability is a crucial dimension of FNS, and the rapid shift in access to food conditions underscores the low resilience of food systems in South America to ensure future food security.

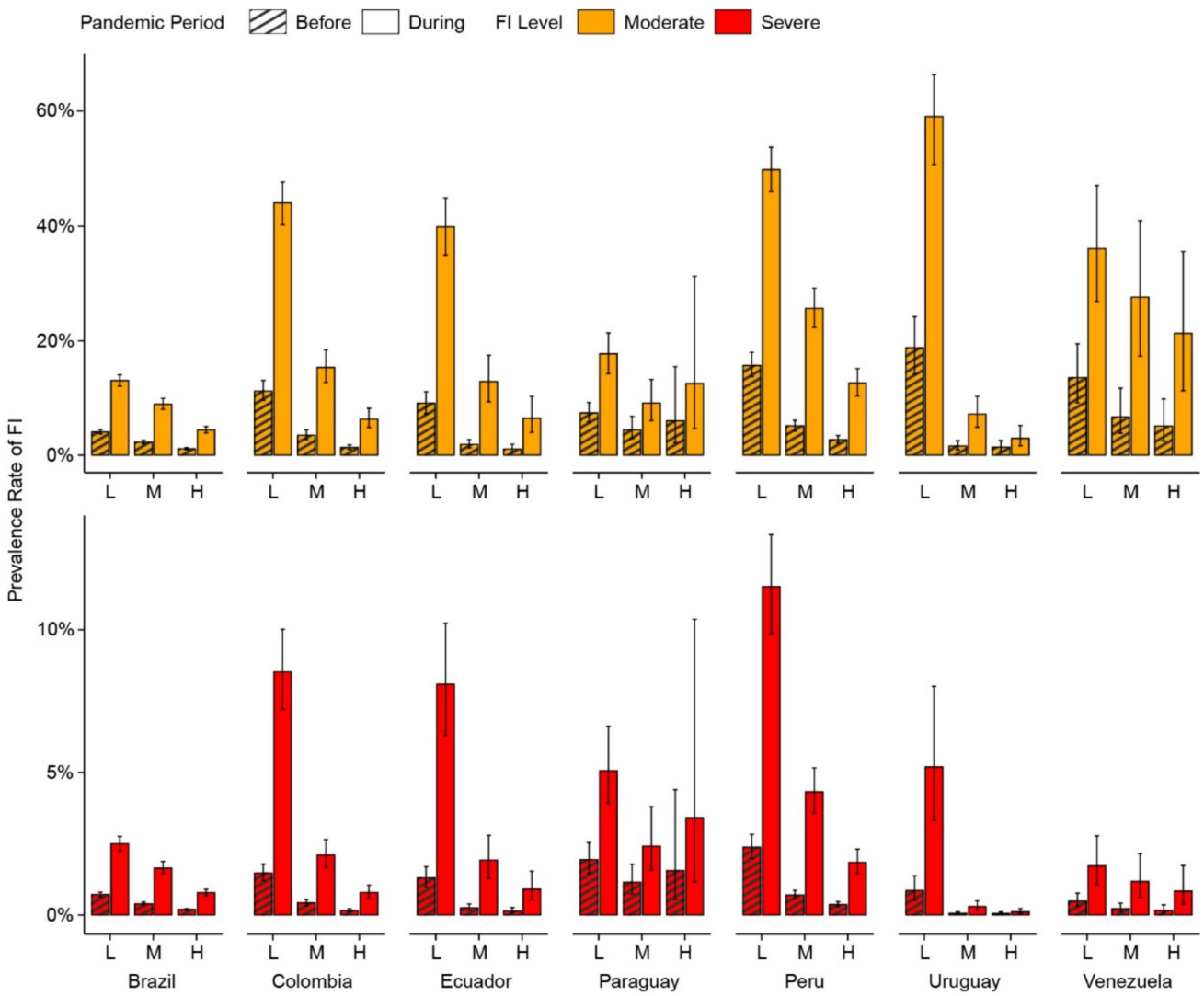

Fig. 3 Prevalence rate of households from different income classes experiencing Moderate and Severe FI based on income and pandemic period in each country. The error bars (vertical lines inside the bars on Y-Axis) represent 95% credible Confidence Intervals

Historical trends (Sousa et al., 2019a, 2019b) and specific Food Security and Nutrition (FSN) policies and actions developed by each country (Espinosa-Cristia et al., 2019; Farrow et al., 2005; Gómez Perazzoli, 2022; Vargas & Penny, 2010; Vasconcelos et al., 2019) suggest pre-existing problems and vulnerabilities in South America (Clapp & Moseley, 2020). Countries with less social support and higher inequality rates, as in South America, tend to be more impacted (Myers, 2006; Ohnsorge & Yu, 2022; Rosen & Shapouri, 2009), mainly because the fiscal adjustments implemented to contain the crisis usually prioritize cutting resources for strategic social programs that fight hunger and poverty (Sousa et al., 2019a, 2019b). While these austerity measures proved incapable of containing the negative effects of previous crises, fiscal incentives and investment in social policies not only mitigated the harmful effects on the population but also accelerated the recovery of the economy (Farnsworth & Irving, 2015; Starke, 2013).

Existing studies on the impact of the COVID-19 pandemic lack clear narratives regarding how changes in FI may vary among socioeconomic groups (Bloem & Farris, 2022). In this study, we demonstrate that in South America the lower-income families experienced a greater impact of FI after the onset of the pandemic. It may seem plausible that poorer families have been more vulnerable due to limited access to financial safety nets and a lower capacity to protect themselves from disruptions caused by the pandemic. Contrary, wealthier families more integrated into the national or global economic system, could be less directly affected by disturbances related to the pandemic (Aggarwal et al., 2020; Mahmud & Riley, 2021).

South America is among the most unequal regions in the world in terms of wealth concentration, where the richest 10% of the population hold around 58.4% of income (World Inequality Lab, 2022). A positive, albeit nonlinear, correlation exists between economic development and the enhancement of resilience capacities within the food system. On average, countries with a higher per capita GDP exhibit higher scores in terms of food system sustainability. The increase in per capita GDP is associated with induced improvements in FNS (Béné et al., 2022).

The COVID-19 pandemic in 2020 resulted in a global 30.7% rise, from 88 to 115 million, in the population living in extreme poverty (defined as individuals earning less than US$1.90 per day) (World Bank, 2020), paralleled by the emergence of 5.2 million new millionaires (Credit Suisse, 2021). The increase in unemployment during the pandemic boosted informality and precariousness, and restriction and flexibility of laws and labour rights (Acevedo et al., 2021; Huang, 2022; Lima & Durán, 2021; Llop-Gironés et al., 2021; McNamara et al., 2021; Parwez, 2022). In this context, conditional cash transfer programs should play a pivotal role in mitigating the negative effects of inequality (Kabeer & Waddington, 2015; Molina-Millan et al., 2016).

Simultaneously with these shifts in population income levels, food prices experienced an upward trajectory. Despite the pandemic having negatively affected GDP growth worldwide, the economic contribution of the agricultural sector in South American countries increased and food exports grew by an average of +5% (World Bank, 2022b). The region is among the largest food producers in the world, contributing 8.9% of GDP (World Bank, 2022a) and employing 14% of the population (International Labour Organization, 2022). Thus, South American countries have production chains that are strongly connected to the global market, with a focus on exports, strongly hindering food self-sufficiency and leaving the population exposed to fluctuating financial market prices and inflation, thereby reducing access to food (Baer-Nawrocka & Sadowski, 2019; Khoury et al., 2016). This dramatic scenario questions whether food systems, at least in South America, have as their primary objective to provide enough food for their population, or simply to trading food.

In addition, the devaluation of South American currencies against the US dollar (OECD, 2022) further boosted food exports and accentuated inflation in the price of the basic food basket, which reached 21.9% in 2020 (FAO, 2021). Among the countries studied, Uruguay (13.8%) and Brazil (9.1%) showed the largest price increases, while Paraguay (1.2%) and Ecuador (0.8%), the smallest (FAO, 2021). Any increase in the price of food should affect the poorest population more intensely by committing a greater percentage of income to food alone (Smith et al., 2017; Sousa et al., 2019a, 2019b). For example, in Peru, the country with the greatest increase in FI according to our results, the cost of a basic food basket corresponds to 34.8% of the minimum wage (INEI, 2020), while in Paraguay (lower increase in FI) the cost is 12.0% (INE, 2020).

Macroeconomic indicators appear to be linked to the low resilience of food systems and the sudden increase in FI during the COVID-19 pandemic. Countries with the worst FI prevalence had a greater proportion of informal workers, and lower GDP growth and GNI PPP (Gross National Income per Purchasing Power Parity). Peru and Ecuador were also the countries with the highest percentage of informal labour (70.1% and 68.6%, respectively) and agricultural labour force (27.4% and 29.7%). In 2020, the countries that in our study had the highest levels of Moderate and Severe FI, Peru and Ecuador, had the biggest declines in GDP (− 10.9% and − 7.8%, respectively); while Paraguay and Brazil, with the smallest declines in GDP (− 1.2% and − 2.1%), showed the least dramatic FI levels, reinforcing the relationship between economic indicators and loss of FNS. In addition, Peru and Ecuador had the lowest social protection coverage (29.3% and 31.7%) and recorded the greatest increase in the Gini Index between 2019–20 (+ 2.2 and + 1.6, respectively) (World Bank, 2022c; Suppl. Table 5).

There is no way to fully assess the effectiveness of measures aimed at reducing the impacts of future pandemics or other major food security shocks based solely on economic indicators, without considering the numerous variables associated with the environmental, cultural, geographic, historical, political, and social complexity of each country. Specifically, it is necessary to take into account how each country has developed and implemented its policies to combat hunger, poverty, and inequality over the years (Espinosa-Cristia et al., 2019; Piñeiro et al., 2010). Several authors have emphasised the need for FSN programs to be integrated with policies across multiple government sectors (Mavridis & De Walque, 2022; Piperata et al., 2011, 2016). Brazil was one of the most organized countries in this regard, having established a food and nutritional security management council (CONSEA) composed of members from different political and social spheres. This council has implemented interconnected actions in the agrarian, educational, economic, and health sectors (Vasconcelos et al., 2019). For example, the School Feeding Program (PNAE) is based on sourcing 30% of food from local small farmers, ensuring access to high quality food for children (Campos, 2013). This policy not only contributes to reducing FI, but also to providing a stable income to ~400 thousand small-family farmers. Additionally, it increases the diversity of the food supply and may, potentially, reduce the carbon footprint by lowering the costs of food distribution. In Brazil alone, the closure of schools meant that around 40 million children were left without food due to the interruption of meals (WFP, 2020). This has particularly affected poorer families by putting pressure on an already tight monthly budget.

Our study faces some limitations that are important to discuss as they may result in bias in our results. Firstly, the sampling strategy through virtual platforms likely conditioned homogeneous access of the population and representativeness, not only by economic class strata but also by region and age. FI scales should be administered by trained professionals, but due to the preventive health safety regulation during the pandemic, we opted for an online approach, limiting our sample to those areas with reliable internet access, and restricting the participation of people living in rural and isolated localities due to lower internet coverage. It is estimated that 74% of the population of South America has access to the Internet, and that this access is double in urban areas (World Bank, 2020). To address this limitation, we established a wide collaborative network tasked with disseminating our research, since Internet access is more common among young people, as an intermediate access route to the heads of households responsible for food. Since these rural communities, and even in urban settlements, have higher extreme monetary poverty levels, lower coverage of these areas may have led to an underestimation of FI in our study. Secondly, the network of participating researchers influenced the countries included in the study, so the results cannot be extended to the entire continent. The results of our study should be interpreted with caution within particular social, economic, and geographic contexts. Thirdly, another limitation of the study is the recall period. The data reported by respondents may be subject to recall or social desirability biases because a single-point questionnaire was conducted to refer to specific events that occurred in a past health and economic crisis. Therefore, we face a possible recall bias and a telescoping effect that can affect the quality of the data, and generally tends to overestimate food consumption estimates in the recall (Abate et al., 2022; Beegle et al., 2012). This limitation may have implications that must be considered since households could exaggerate food consumption, then they could indicate lower FI levels than they really are. Fourthly, we acknowledge the inherent trade-off in using individual FIES items as proxies for overall food insecurity. While the full FIES scale offers a more nuanced perspective, cross-cultural comparability using the full scale presents significant challenges. Therefore, we adopted these specific indicators, recommended by the FAO for global comparisons (Cafiero et al., 2018), to ensure internationally comparable measures of food insecurity prevalence. Although these indicators do not capture the full spectrum of food insecurity, they provide reliable insights into critical aspects of food deprivation across diverse contexts. Diagnostic analyses supporting the assessment of our findings are available in the Supplementary Table 6. Finally, the cross-sectional design does not allow establishing causal relationships between the emergence of the COVID-19 pandemic and FI. Our study uses a before and after approach to compare the prevalence and severity of FI. Furthermore, although the main global change between both periods is the appearance of the COVID pandemic, we cannot establish an exclusive causal relationship, since other variables or trends unrelated to the pandemic could be affecting the results. However, despite the abovementioned restrictions and the need to be cautious when generalizing and interpreting the results, our extensive sample size allowed for robust statistical analyses, yielding essential insights into the impact of the COVID-19 pandemic on FNS in South America. This information is highly useful in addressing current FNS challenges in South America, and even during future crises, including potential pandemics.

We shed light on the complex challenge of tackling FNS. In this regard, the imperative lies in policymakers crafting anti-hunger initiatives underpinned by multifaceted strategies, bolstering agrarian reform policies, alleviating poverty, and labour precariousness, and above all, executing effective measures for curbing food price inflation and socioeconomic inequalities. The post-pandemic phase should result in key changes within the food systems with emphasis on strengthening resilience to address the inequality of accessing healthy food (Mardones et al., 2020), and adopt risk-based approaches to target interventions and policies to mitigate future shocks. We need to develop further studies that allow for the implementation of a multilevel, person-centered framework to understand how people living in food-insecure households cope with inadequate access to food themselves and within their households, communities, and the broader food system. Many of these coping strategies can have an adverse impact on health, particularly mental health conditions when maintained over time (Fang et al., 2021, Kolovos et al., 2020). The improvement of opportunities to improve access to programs and policies that support food security is essential to support better health outcomes, both in terms of quantity and quality of diet. Additionally, existing food assistance programs themselves could be used as a platform to monitor FI. We need to accelerate progress towards the Sustainable Development Goals and by strengthening local and global food systems. Locally produced food may be an opportunity for a new low-cost for better production agri-food system that would reduce long-distance transportation and distribution by third parties with significant carbon footprints (Weber & Matthews, 2008). Finally, food security requires a "One Health" and "Planetary Health" approach, to cut across traditional domains to address the challenge posed by COVID-19 (Mardones et al., 2020). The pandemic demonstrated our increasingly global, interdependent, and environmentally constrained societies. Crises in food systems, such as COVID-19, go beyond a single-sector approach and require the mobilization and integration of knowledge and skills across geographic, institutional and disciplinary boundaries. These findings underscore the

urgency of implementing comprehensive and coordinated approaches to address the multifarious aspects of the food security challenge.

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Data Availability Data will be made available on request.

Declarations

Conflict of interest The authors declared that they have no conflict of interest.

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Willandia A. Chaves is a conservation social scientist working with the human dimensions of fish and wildlife conservation, using tools and methods from different fields, including Conservation Psychology, Economics, Human Geography, Wildlife Management, and Education. She is an Assistant Professor in the Department of Fish and Wildlife Conservation at Virginia Tech. Her research aims to understand how people make decisions about their use of natural resources and, in turn, use this understanding to foster more sustainable behaviors and influence policy. She is interested in wildlife trade, how urbanization affects people and biodiversity, broadening participation in STEM education, and cutting-edge approaches to collecting sensitive information on natural resource use (e.g. illegal wildlife trade).

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Marcela Oliveira holds a bachelor's degree in Biological Sciences from the Federal University of Rondônia (2006), a master's degree in Ecology and Natural Resources Management from the Federal University of Acre (2012) and a doctorate in Biodiversity and Biotechnology from Rede Bionorte from the Federal University of Rondônia (2022). She is currently a lecturer on various courses at the Metropolitan College of Rondônia (UNNESA) and the Aparício Carvalho University Centre (FIMCA), and a permanent lecturer and advisor on the Postgraduate Program in Conservation and Use of Natural Resources (PPGReN) at the Federal University of Rondônia (UNIR). She is a researcher with the Research Network on Diversity, Conservation and Use of Amazonian Fauna and a volunteer with the Association for Ethno-Environmental Defense. She is a post-doctoral fellow linked to the Saúde Única project in the areas of urban and peri-urban streams in Porto Velho (SUIg). She has experience in the areas of human ecology, ethnoecology and mammal ecology, working mainly on the following topics: game fauna, subsistence hunting, sport hunting, linear transects, mastofauna, road ecology and exotic species. Above all, she is Pietra's mother.

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Valéria Raiana Fonseca Ferreira is a veterinarian, a graduate from the State University of Maranhão (2017). She holds a master's degree in Animal Health and Production in the Amazon, from the Federal Rural University of the Amazon (2022), where she researched food security during the COVID-19 pandemic. She has been working for 7 years in the field of small animal medicine.

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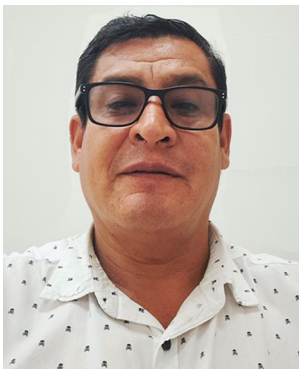
Joe S S Rojas. Forestry Engineer from the National University of the Peruvian Amazon (2005). Magister Scientiae in Management and Conservation of Tropical Forests and Biodiversity of the Tropical Agricultural Center of Research and Teaching – CATIE -Costa Rica (2015). Professional with 5 years of research experience in management and conservation of flora and fauna of the Peruvian Amazon. He has 3 years of work with native and peasant communities of Loreto and Ucayali on forest tenure of the territory. Additionally, he worked supervising forest concessions in Madre de Dios region. Currently, since 2020, he is a specialist in Administration Contracts, a mechanism that supports the co-management of the Natural Protected Areas of SINANPE.

Marco Antonio Arenas Aspilcueta. Agricultural Engineer with a Master in Biodiversity Management and a Master in Public Management; with specialty and experience in conservation and management of biodiversity (protected natural areas), strategic planning and articulation of the territory, project management, financial sustainability, governance and participation in the territory with Indigenous Organizations and/or Local Population; works in adaptive management, territory management; ecosystem management in the Andes and the Amazon In recent years in terms of participation and governance, with emphasis on populations, on issues associated with forms of conservation and management, legal security, territorial management, food security, health, and Indigenous Population in Isolation and Initial Contact.



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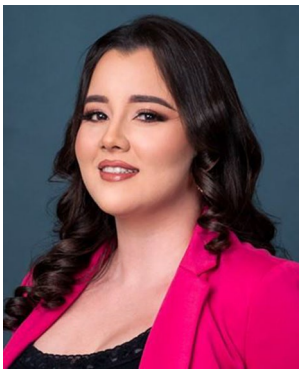

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