Food Security and Forest Access in the Colombian and Peruvian Amazon

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Abstract

Food security is vital for a decent life, particularly in early development and with lasting adult health effects. Forests have historically played a key role by offering essential ecosystem services and a direct source of diverse, nutrient-rich foods and medicines. This study explores the link between forests and food security in Colombian and Peruvian Amazon communities. We analyze the four dimensions of food security-availability, stability, access, and utilization-within the context of forest access. Panel data from households in each country was collected to calculate a multidimensional household-level food security index. Our findings reveal that households with forest access have higher food security. However, the impact varies across countries and communities. In Colombia, Indigenous households benefit more from forest access, while Peru showcases distinct dynamics due to a higher share of mestizo communities. Forest cover, biodiversity, ethnicity, and accessibility shape this relationship. Indigenous communities rely on less degraded forests for food security, underscoring the importance of forest preservation for ancestral practices and sustenance. These findings suggest that the impact of forests on food security depends on the quality of the forest, the ethnicity of those accessing the forest, and the proximity and ease of accessing the forest.

Keywords: Food security, Forest access, Amazon, Ethnicity

1 Introduction

It is increasingly recognized that many rural households depend on forests for their food security (Olesen, Hall, and Rasmussen 2022), income (Angelsen et al. 2014), poverty reduction (Mukul et al. 2016), and well-being (Kuhnlein et al. 2013). Forests contribute to rural food security by providing wild foods such as edible plants, nuts, seeds, wild meat, or bushmeat (Rasmussen, Watkins, and Agrawal 2017). There are roughly 1.6 billion people who are directly dependent on forests (FAO 2010), all of whom rely upon wild foods from forests for their dietary diversity, nutrition, and broader health (Ickowitz et al. 2014; Powell et al. 2015; T. Sunderland 2023).

This dependence on natural resources, particularly forests, is more substantial in highly forested areas over long distances from urban populated centers and markets (Sunderlin et al. 2005). Belcher, Achdiawan, and Dewi (2015) investigate the influence of forest proximity on the livelihoods of rural households in a poor region of India. The authors show how rural household income is more significant among communities closer to forests. However, as Miller and Hajjar (2020) show, forest proximity improves several components of well-being that cannot be easily monetized. This approach focuses on several measures of household well-being rather than a single-dimensional focus on income. It is more comprehensive to think of access to natural resources as a mechanism that improves household welfare in multiple dimensions, including food security.

Improving market access may be a mechanism that allows rural households to improve their food security (Belcher, Achdiawan, and Dewi 2015; Grieg-Gran, Porras, and Wunder 2005; Kamanga, Vedeld, and Sjaastad 2009). The literature emphasizes how markets enable rural households to improve their livelihoods by commercializing forest products and other natural resources. However, other studies on the Colombian Amazon have shown that changing diets from wild meat to industrial chicken poses a food security dilemma, as the former provides less nutritional balance (Van Vliet et al., 2015). Additionally, not all farmers have the same socio-economic characteristics or geographical locations, factors that affect the generation of income and economic activities of households.

However, focusing only on access to a forest obscures the importance of forest quality to food security. Recent evidence suggests that more biodiverse environments are linked with better nutrition outcomes (Dawson et al. 2019). For households that do not have access to markets and are therefore heavily reliant on forests, a healthy, biodiverse forest is crucial for the food security of these households (T. C. Sunderland and Vasquez 2020). Evidence for more tree cover leading to higher dietary diversity has been found in Malawi (Johnson, Jacob, and Brown 2013) and Indonesia (Ickowitz et al. 2016).

Much of the literature regarding natural resources and food security also focuses on empirical evidence based on qualitative data and case studies (Angelsen et al. 2014). In a literature review, Cruz-Garcia et al., (2016) found that the link between natural resources and food security was not rigorously proven, which makes it difficult to draw general conclusions. Second, much of the previous literature analyzes forest access statically. It supposes that it homogeneously affects all households within a community, region, or country (Zenteno et al. 2013) disregarding household seasonality and differences.

This research proposes to close these gaps in the literature by: (1) providing an empirical analysis that explores how forest access and tree cover affect the food security of rural households in the Amazon, considering the ethnicity and social characteristics of the households studied. Additionally, we (2) use panel data at the household level across two seasons (rainy and dry) to measure four dimensions of food security in Colombia and Peru. To study a multidimensional concept such as food security, we use a statistical index that captures the dimensions of availability, stability, access, and use. Subsequently, we utilize a causal identification strategy through instrumental variables that allow us to control endogeneity problems to estimate the causal effect of each of the forest dimensions on food security.

The document's structure is as follows: Section II describes the study area, data collection, and methodology; Section III sets out the empirical estimation strategy and outlines the results; and Section IV presents the document's conclusions.

2 Context and Methods

2.1 Study Site and Data Collection

This research is part of the "Attaining Sustainable Services from Ecosystems through Trade-Off Scenarios" project[1], which aims to comprehend the nexus between ecosystem services, food security, and health in economically challenged communities in diverse agricultural and forest contexts. Despite sharing the Amazonian geography, Colombia and Peru exhibit contrasting social, economic, and environmental attributes and varying relationships between their inhabitants and the surrounding natural resources.

Panel data at the household level were gathered from rural households across Colombia and Peru within the designated study areas. Data collection occurred over two periods and rainy seasons, from 2014 to 2015. A total of 303 household surveys were carried out in Peru, while 289 surveys were carried out in Colombia, with an equal number done each season. The comprehensive information was

[1] More information: http://espa-assets.org/

acquired through household-level surveys, encompassing education, health, time allocation, work dynamics, food consumption, food security, income sources, loans, livestock, hunting, fishing, production activities, and agricultural sales. The interviews were conducted face to face, directing the questions together to the men and women of the household. Notably, all production-related inquiries spanned six months for each data collection round.

2.1.1 Colombia

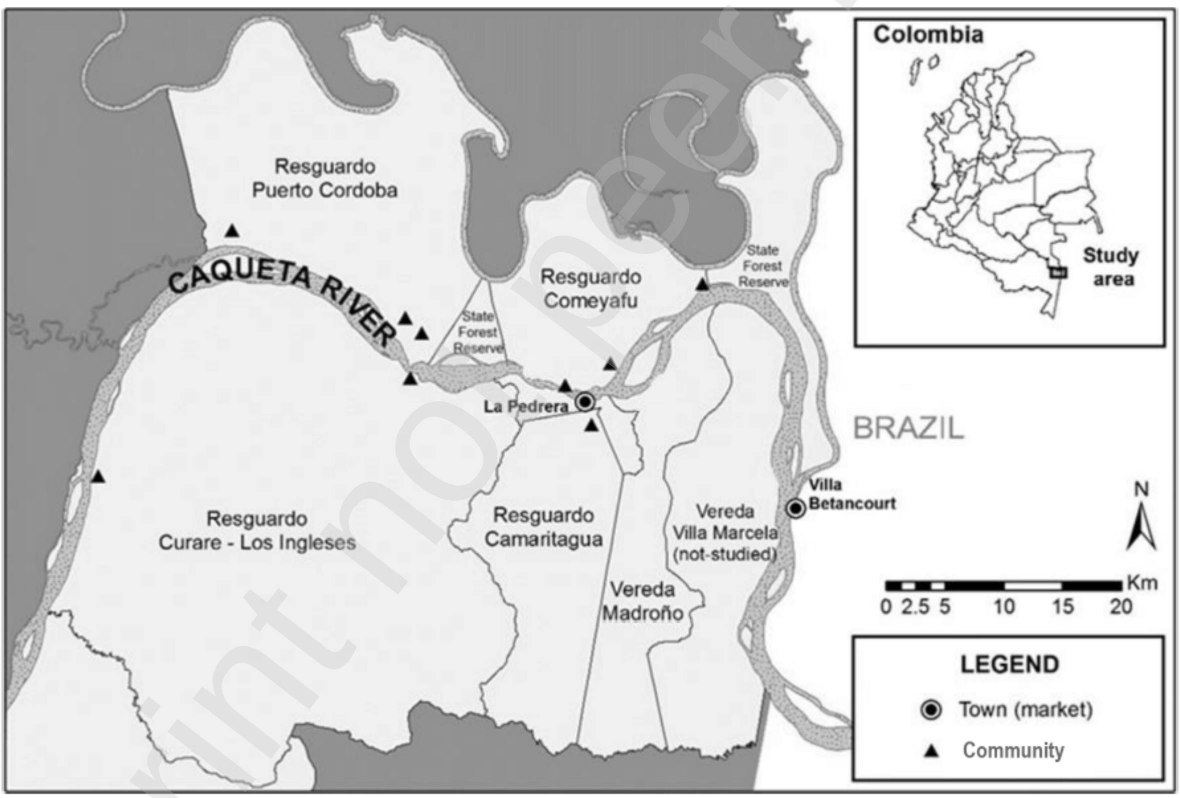


Figure 1: Study Area in Colombia, Caquetá-La Pedrera

In Colombia, our study site is La Pedrera district, located within the Amazonas department (Figure 1). La Pedrera comprises four Indigenous reserves containing ten communities and two *verandas.* This district has recently experienced continuous population growth, and most of the population belongs to an ethnic group. Spanning an area of 394,994 hectares (Ramirez-Gomez et al., 2015), from which, according to (Sánchez-Cuervo et al., 2012), 90% is covered by forest. Our study encompasses 11 out of the 13 Indigenous communities in the district (Table 1).

Table 1: Communities and Socioeconomic Characteristics of the Study Area in Colombia.

Indigenous Reservations	Communities	Population	Household Surveys Dry Season	Household Surveys Rain Season	Area (Ha)
Puerto Cordoba	Puerto Cordoba, Loma Linda, Bocas del Miriti	212	32	28	46,897
Curare	Curare, Borikada	263	30	28	237,643
Comeyafu	Tanimuca, Yacuna, Angosturas, Bacuri	520	79	71	19,023
Camaritagua	Camaritagua	64	10	6	8,456
Veredad Madrono	Veredad Madrono	56	8	6	20,351
Total		1,115	159	139	332,370

2.1.2 Peru

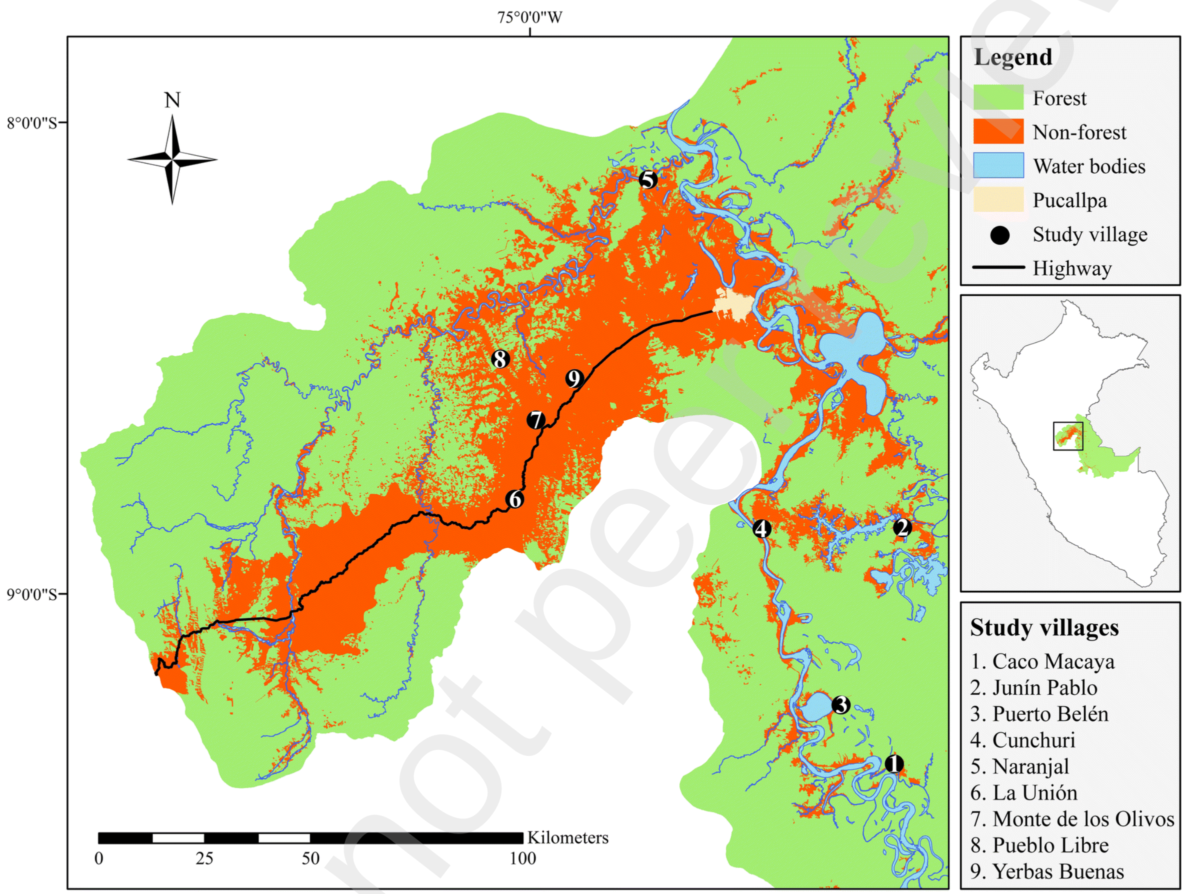


Figure 2: Study Areas in Ucayali, Peru

The study area in Peru is situated within the Amazon region, specifically in the Ucayali department. Ucayali is home to an estimated population of 490,000 individuals, with 75% residing in urban areas, including the capital city of Pucallpa, the second most populous city in the Peruvian Amazon (INEI 2011). Indigenous territories encompass approximately 20% of the land in the region (SICNA 2012), constituting a significant portion of the Ucayali population.

According to Bax et al. (2016), building a highway has increased deforestation in the region. Many mestizo settlers have established communities along the banks of the Ucayali River and its tributaries (Figure 2). Nine communities were surveyed to carry out the study: three Indigenous and six mestizo (Table 2).

Table 2: Communities and Socioeconomic Characteristics of the Study Area in Peru

Ethnic Group	Villages	Population	Household Surveys Dry Season	Household Surveys Rain Season	Area (Ha)
Indigenous	Caco Macaya	1,031	32	32	20
	Junin Pablo	922	21	21	8
	Puerto Belen	893	29	33	11
Mestizo	Chunchuri	604	21	21	35
	Naranjal	289	8	7	10
	La Union	959	27	28	55
	Monte de los Olivos	313	21	21	25
	Pueblo Libre	354	9	11	25
	Yerbas Buenas	337	31	30	20
Total		50,702	199	204	209

2.2 Food Security

Food security represents a state of complete physical and economic access to sufficient, safe, and nutritious food that meets a person's dietary needs for a healthy life and stability during periods of shortage and instability (Food and Agriculture Organization, 2006, Declaration 1996; Webb et al. 2006). Rural communities' livelihoods greatly depend on their natural resources (Ali and others 2018; Zavaleta et al. 2017), which are affected by the climatic seasonality of the regions in which they are located (Wunder, Noack, and Angelsen 2018). For these reasons, we propose to create a Multidimensional household-level food security index that captures the dimensions of access, availability, utilization, and stability (World Health Organization 2011).

This index is based on detailed information at the household level of food consumption, its sources, its use, and the strategies implemented to address food shortages. This information allows us to capture the different dimensions of household food security. Unlike previous research, we do not focus on a single size of the concept or based on a single context. As several authors mention (Delvaux and Paloma 2018; Headey and Ecker 2013; Leroy et al. 2015), food safety indicators focused on a single dimension and in particular case studies, tend to be criticized for having little external validity; mainly because food security is a concept that involves more than one dimension, reality, and evolution.

Within this index each dimension's approach is made through proxy variables at the household level. Specifically, for the concept of access, the number of food sources was used[2]. Availability is measured with the economic valuation of the total food consumed[3]. For the use dimension, several variables capture how food can be prepared so it is consumed, and its nutrients used. First, we use the energy source for cooking[4], and second, we start the water used for food consumption and processing[5] and the source used for food consumption and processing[6]. Finally, the concept of stability is analyzed, including the number of times households have carried out an activity to alleviate food shortages[7](Appendix A).

[2] The categories of household food sources are hunting, market, farm, and gifts. This variable is continuous and takes values from 0 to 4.

[3] This variable is created based on household food consumption in the last seven days and is added to the 6-month level. For both countries, the production used for self-consumption was assessed based on the information on the average price per community and per unit of measure to control community effects, scarcity, and market access in the imputation process. Once the total valuation of consumption in each country was carried out, the dollar rate was passed for the current year.

[4] The sources for cooking food are Firewood, Paraffin, Gas, Coal, and Electricity.

[5] Dummy variable that takes the value of 1 the water comes from a public water network or wells.

[6] Dummy variable that takes the value of 1 the water comes from a public water network or wells.

[7] Numerical variable from 0 to 5, where high values indicate a higher frequency with which the household has had to resort to a strategy against food shortages.

2.3 Forest Access

Recent studies establish a causal relationship between forest access and its effect on determining livelihoods and income (Ali and others 2018; Larson et al. 2023). They analyze data taken in a single moment and define access to the forest from proximity. In other words, they present the role of the forest from a static perspective that affects all households in the same community equally. However, these studies do not consider forest diversity, tree cover, or family differences.

In this investigation, we propose to measure access to the forest through two variables: i) household use of forest resources and ii) the distance per season that each household takes to reach the forest. Punctually, we use a dummy variable that takes one of the households accessing the forest to collect or hunt any natural resource (food, animals, medicinal plants, construction elements, etc.) and zero otherwise. To measure the concept of proximity, we take the minimum distance in minutes for the household to reach the forest.

In Colombia, our findings reveal that more than 85% of households can access the forest within an average of 12 minutes, both during dry and rainy seasons. However, during the rainy season, households face greater challenges due to issues with access roads, resulting in increased travel times[8](Table 3).

Table 3: Access to the Forest by Season in Colombia and Peru (Average time in minutes)

	Forest access	Rain Season	Dry Season	T-test (p-value)[*]

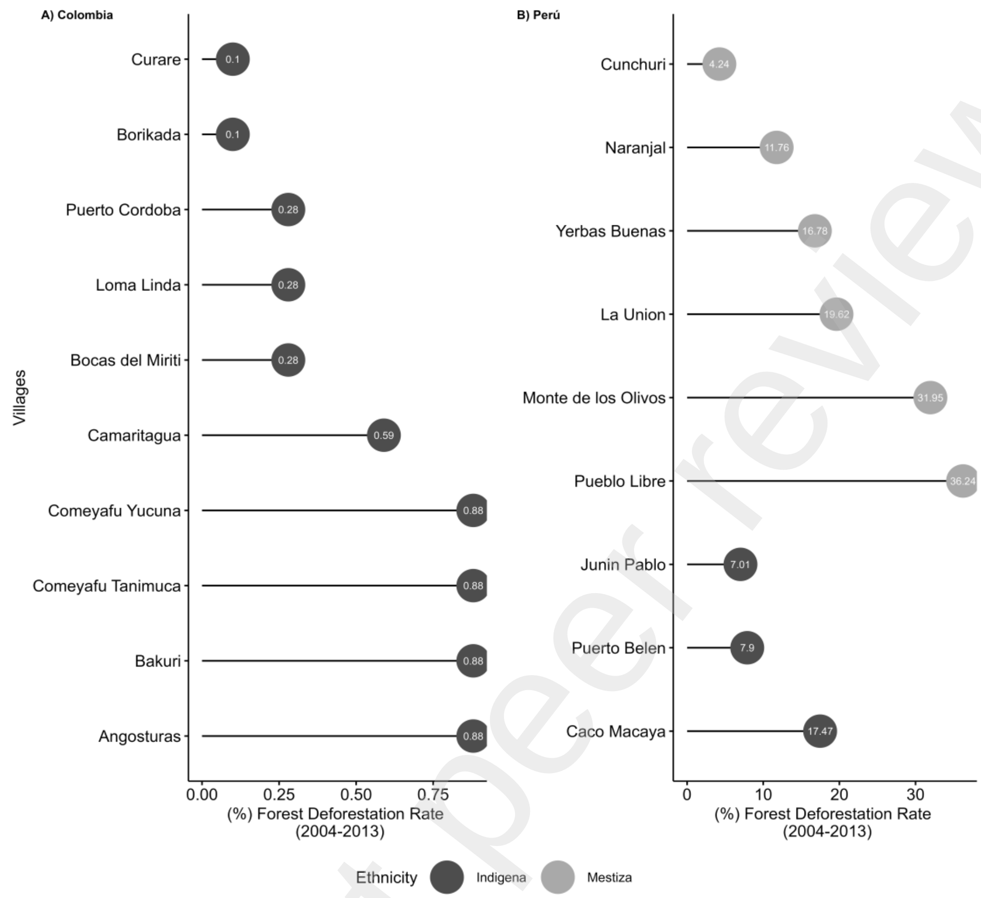
[8] For households that do not access the forest, we calculate the minimum travel time in minutes as if they were accessing and utilizing the forest during that season.

Colombia	**Yes**	16.3 (29.4)	7.4 (7.3)	0.001**
	No	94.4 (80.9)	23.6 (11.8)	0.033*
Perú (Indigenous)	**Yes**	35.4 (41.6)	39.3 (30.8)	0,6
	No	147.0 (76.6)	113.3 (45.5)	0,11
Perú (Mestizos)	**Yes**	30.0 (70.7)	23.0 (34.6)	0,7
	No	174.4 (116.3)	48.4 (41.3)	<0.001***

[*]Note: * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$

Conversely, in the rural households of our study area in Peru, we observe significant variations in forest use and travel times driven by ethnicity and seasonal factors. For example, 72% of Indigenous households have access to the forest with an average travel time of 37 minutes, while only 32% of mestizo households do so, with an average travel time of 27 minutes (See Table 3).

Households that use forest products live close to a forest, which takes them less time to travel. However, it is essential to highlight that forest biodiversity and tree cover exhibit substantial variations across countries and communities. In the Colombian study area, forests are less deforested than the Peru study area, resulting in higher-quality forests (Blundo-Canto et al. 2020). Moreover, there are significant differences between the two ethnicities represented in the Peru study area regarding deforestation rates. Over the past nine years, Indigenous communities have experienced an average deforestation rate of 11%, whereas mestizo communities have seen a higher deforestation rate of 19% (see Figure 3). These findings underscore the intricate relationship between forest access, socio-cultural factors, and environmental conditions, highlighting the need for a more comprehensive understanding of forest dynamics and their impact on livelihoods.



Note: Forest deforestation rate in Colombia is 0.58% and
16% in Peru; 11% in indigenous communities and 19% in mestizos.

Figure 3: Forest Deforestation by Country and Ethnicity.

2.5 Relationship between Forest Access and Food Security

To delve into the causal relationship between forest access and household-level food security, we adopt a robust estimation approach, employing ordinary least squares (OLS) specifications. Our model accounts for fixed effects related to households and seasonal variations while considering data from different countries. We formulate this analysis through the following equations:

$$FoodIndex_{(i,t)} = \beta * (ForestAcess_{(i,t)}) + \varphi * X_{i,t} + U_{i,t} + \upsilon_i + \omega_t + \delta_e \qquad (1)$$

Where $FoodIndex_{(i,t)}$ is the standardized principal component index that captures the level of household food security i over time t; likewise, $ForestAcess_{(i,t)}$ is a dummy variable that takes the value of 1 if the household i at the time t makes use of the forest and takes the value of 0 otherwise; $X_{i,t}$ is a vector of household-level control variables that vary over time . υ_i and ω_t are the fixed effects at the household and time levels The variable δ_e is a fixed ethnic effect. Finally, $U_{i,t}$ is the standard error term grouped at the household level that allows correlations between unobservable variables that could affect food security levels within the household i over time t.

However, equation (1) is potentially biased due to problems of simultaneity or joint determination since the causal relationship can go in two directions. A household's access to its forest could be determined by its level of food security since accessing the forest requires a physical effort when it is in remote or hard-to-reach areas.

We use a specification of instrumental variables to address the endogeneity in $ForestAcess_{(i,t)}$. This methodology seeks to estimate the causal effect through a variable that meets two statistical conditions i) relevance and ii) exogeneity; the condition of relevance tells us that the instrumental variable must be strongly correlated with the endogenous variable, while the condition of exogeneity requires that the only way that the instrument affects the dependent variable is through the endogenous one. The instrument proposed is the minimum average distance in minutes to the forest $TimeToForest_{(i,t)}$; since this variable contains a temporary variation and is also exogenous at the household level.

The instrument's relevance is based on two ideas. First, various investigations have proven that the user's geographical distance to the place that provides a service affects their access and use (Eckel et al. 2011; Pedrosa and Do 2011; Popradit et al. 2015). Second, the climatic season of the year (rainy or dry) affects the forms of access to the forest, so having the minimum time in minutes allows for capturing this heterogeneity at the household level.

The exclusion condition indicates that conditional in the variables control the minimum average distance in minutes to the forest $Timsubscription$ not correlate with the error term in equation (1). From the economic perspective, the instrument is exogenous but not necessarily from an econometric standpoint, so it is necessary to control for possible factors that confuse the effect. It should be considered that covariates potentially correlated with the instrument and could impact the food security index. We control market access, positively affecting food security and well-being (Stifel and Minten 2017). Therefore, we use a specification of the instrumental variable with fixed effects of home and time, which is given by the following equations:

$$FoodIndex_{(i,t)} = \beta * (\widehat{ForestAcess}_{(i,t)}) + \varphi * X_{i,t} + U_{i,t} + v_i + \omega_t + \delta_e \qquad (2)$$

$$\widehat{ForestAcess}_{(i,t)} = \phi * (TimeToForest_{(i,t)}) + \varphi * X_{i,t} + U_{i,t} + v_i + \omega_t + \delta_e \qquad (3)$$

In short, the coefficient β of equation (2) captures the causal effect of forest access to the food security index among households that access the forest according to their distance in minutes.

3 Results

3.1 Estimating Food Security Index.

Estimating the food security index allows us to capture the season's effect on household food security. The Colombian Amazon households are highly dependent on their surrounding natural resources, so it is expected that their food security will be affected during the rainy season since it is more difficult to carry out collection, hunting, and fishing activities during this time. Table 4 shows a statistically significant difference in the food security index of seven percentage points less in the rainy season compared to the dry season.

Table 4: Estimation of Food Security Index (Colombia and Peru)

	Colombia			Perú		
Food Security Dimension	**Rain Season**	**Dry Season**	**T-test (p-value)[*]**	**Rain Season**	**Dry Season**	**T-test (p-value)[*]**
Availability	2,469.00	4,801.00	0***	1,385.00	226	0.01**
Stability	1.34	2.56	0.37	2.26	2.53	0.22
Access	3.54	3.58	0.53	2.71	2.74	0.86
Utilization	5.46	1.6	0.09*	29.6	29.6	-
	69.53	65.62	0.51	87.5	86.18	0.73
Food Security Index[a]	62.36	69.88	0***	11.55	12.62	0.13

[*]Note: * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$; [a]Food Security Index in Percentage (0-100); [b]Household percentage (%)

Among rural households in Peru, food security is lower during the rainy season than during the dry season, although this difference is not statistically significant. On average, the household food security index in the rainy season is 1.1 percentage points less than in the dry season (Table 4).

Ethnicity has a preponderant role in livelihood dynamics and strategies implemented by rural households (Belcher, Achdiawan, and Dewi 2015). In Peru, Table 5 shows that, on average, the Indigenous population has a higher food security index than the mestizo population, primarily explained by a more significant number of food sources. Simultaneously, the Indigenous population's food consumption and number of food sources are more stable across seasons than the mestizo population.

Table 5: Components Food Security Index-Peru by Ethnics and Season.

	Indigenous				Mestizo				
Variables	**Rain Season [1]**	**Dry Season [2]**	**Annual [3]**	**T-test (1-2) (p-value)[*]**	**Rain Season [4]**	**Dry Season [5]**	**Annual [6]**	**T-test (4-5) (p-value)[*]**	**T-test (3-6) (p-value)[*]**
Economic valuation Amount of food consumed in the household ($ US)	1,218.00	1,711.00	1,464.00	0.15	1,585.00	3,903.00	2,113.00	0***	0.07*
Food scarcity intensity	2.78	2.94	2.86	0.62	1.93	2.24	2.03	0.23	0***

	Indigenous				Mestizo				
Variables	**Rain Season [1]**	**Dry Season [2]**	**Annual [3]**	**T-test (1-2) (p-value)[*]**	**Rain Season [4]**	**Dry Season [5]**	**Annual [6]**	**T-test (4-5) (p-value)[*]**	**T-test (3-6) (p-value)[*]**
Number of Food Sources	2.67	3.15	2.91	0.01**	2.75	2.50	2.58	0.01**	0***
Source Energy Kitchen (Gas)[b]	0.00	1.49	2.38	0.32	57.63	51.28	54.47	0.33	0***
Public Water Source[b]	77.61	95.52	86.57	0***	95.76	80.34	87.06	0***	0.9
Food Security Index[a]	13.66	13.39	13.52	0.68	9.53	13.62	10.95	0***	0***

[*]Note: * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$; [a]Food Security Index in Percentage (0-100); [b]Household percentage (%)

3.2 Socioeconomic characteristics

In this section, we descriptively explore households' socioeconomic characteristics and their relationship with forest access and food security. In general, we observe that families with access to the forest and who live far from a forest have a higher food security index in both countries.

In Colombia, rural households that access the forest have a statistically significant average differential of 13.8 percentage points higher on the food security index than households that do not. Additionally, those who access the forest have larger families with larger *chacras* (Table 6). As the literature mentions (Torres et al. 2018), many Indigenous communities rely heavily on bushmeat and forest products for food security. Households that do not access forests and are longer distances from the forest use their social capital as a source for food, through donations or food gifts.

Table 6: Descriptive Socioeconomic variables by forest access in Colombia

Variables	Forest Access	No Forest Access	T-test (p-value)[*]
Food Security			
Food Security Index (0-100)	67.36	53.57	0***
Percentage of Total Foods that come from the Farm	0.39	0.32	0.21
Percentage of Total Foods that come from Hunting or Collection	0.31	0	0***
Percentage of Total Foods that come from Gifts or Donations	0.12	0.38	0***
Household Socioeconomic Variables			
Households that own at least one canoe (Dummy Variable)[a]	0.56	0.39	0.13
Total Hectares of the Farm (Ha)	1.47	0.44	0***
Average Household Age	23.78	29.81	0.16
Number of persons in the Home	6.22	4.48	0***
Credit Access (Dummy Variable)[a]	0.29	0.26	0.79
Market Access Index (0-100)	13.29	18.4	0.35
Number of Subsidies	1.04	0.87	0.37
Average distance to the Forest (Minutes)	11.7	72.83	0***

Variables	Forest Access	No Forest Access	T-test (p-value)[*]
N			
Observations	233	33	

[*]Note: * p < 0.05. ** p < 0.01. *** p < 0.001; [a]Household percentage

As in Colombia, rural households in Peru that access the forest and live a shorter distance in terms of travel time from a forest have a higher food security index on average. This differential is positive for Indigenous and mestizo households but is only statistically significant for mestizo households. This positive relationship is explained by the percentage of total household food from hunting and gathering wild forest foods (Table 7). However, mestizo households, unlike many Indigenous households, have greater market access, which explains why, on average, they have a higher food security index[9].

Table 7: Descriptive Socioeconomic variables by forest access in Peru

	Indigenous			Mestizo		
Variables	**Forest Access**	**No Forest Access**	**T-test (p-value)[*]**	**Forest Access**	**No Forest Access**	**T-test (p-value)[*]**
Food Security						
Food Security Index (0-100)	13.84	12.726	0.19	14.698	9.209	0***

[9] Previous literature has found that market access is positive with the well-being of households through agricultural production (Stifel and Minten 2017).

	Indigenous			Mestizo		
Variables	**Forest Access**	**No Forest Access**	**T-test (p-value)[*]**	**Forest Access**	**No Forest Access**	**T-test (p-value)[*]**
Percentage of Total Foods that come from the Farm	0.218	0.144	0.04**	0.206	0.158	0.11
Percentage of Total Foods that come from Hunting or Collection	0.241	0	0***	0.148	0	0***
Percentage of Total Foods that come from Gifts or Donations	0.12	0.327	0***	0.105	0.086	0.52
Household Socioeconomic Variables						
Households that own at least one canoe (Dummy Variable)[a]	0.417	0.342	0.43	0.204	0.034	0***
Total Hectares of the Farm (Ha)	1.872	1.286	0.03**	8.657	11.695	0.2
Average Household Age	23.694	23.926	0.91	32.538	34.653	0.43
Number of persons in the Home	6.25	6.474	0.66	4.352	4.207	0.63
Credit Access (Dummy Variable)[a]	0.073	0.079	0.91	0.315	0.233	0.28
Market Access Index (0-100)	4.213	4.625	0.6	25.391	57.461	0***
Number of Subsidies	0.615	0.658	0.78	0.167	0.043	0.03**

	Indigenous			Mestizo		
Variables	**Forest Access**	**No Forest Access**	**T-test (p-value)[*]**	**Forest Access**	**No Forest Access**	**T-test (p-value)[*]**
Average distance to the Forest (Minutes)	37.385	131.053	0***	27	107.069	0***
N						
Observations	96	38		54	116	

[*]Note: * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$; [a]Household percentage

3.3 Estimation results: Forest Access and Food Security

Tables 8 and 9 show the results of equation (2) for each country and ethnicity using two-stage least squares (OLS) and instrumental variables (IV). Column 1 in both tables shows the result of the OLS estimate, assuming that access to the forest is exogenous, while column 2 shows results from the regression with instrumental variables.

Table 8: Access to Forest Effect on Food Security in Colombia

	Food Security Index	
Variables	**OLS (1)[*]**	**IV (2)[*]**
Forest Access)	9.86**	11.56*

Variables	Food Security Index	
	OLS (1)[*]	IV (2)[*]
	[4.73]	[6.03]
Observations	256	256
First-Stage (F-Statistic)		47.75
Season F.E	Yes	Yes
Household F.E	Yes	Yes
Set of Controls	Yes	Yes

[*]Note: * p < 0.05. ** p < 0.01. *** p < 0.001

In Colombia, access to the forest has a positive effect on household food security. The coefficient using the OLS model (column 1) is small and statistically significant ($p < 0.05$). In contrast, the instrumental variable methodology shows that the effect is more important and maintains the same significance level. The difference between the OLS and IV estimators confirms that the forest access variable has an attenuation bias in the OLS model due to double causality. On average, it is found that households that access the forest have a food security index of 11.56 percent points higher than households that do not access the forest (Table 8).

Consistent with what was shown in previous sections, households in Peru differ across cultures in how they access the forest and determine their food security. Among Indigenous communities, columns 1 and 2 show the OLS and IV estimators, respectively. As in Colombia, Indigenous communities that access the forest have greater food security, although the effect is smaller than in Colombia. The IV estimator shows that accessing the forest has an average effect of 3.45 percentage points more among households that access the forest than households that don't (Table 9). On the other hand, for both OLS and IV estimates, among mestizo households, there is no positive effect from accessing the forest on the food security index[10].

Table 9: Access to Forest Effect on Food Security in Peru

	Food Security Index			
	Indigenous		Mestizo	
Variables	**OLS (1)**[*]	**IV (2)**[*]	**OLS (3)**	**IV (4)**
Forest Access	1.65*	3.45**	0.89	-9.78
	[0.97]	[1.59]	[2.46]	[11.96]
Observations	134	134	170	170
First-Stage (F-Statistic)		31.42		2.97
Season F.E	Yes	Yes	Yes	Yes
Household F.E	Yes	Yes	Yes	Yes
Set of Controls	Yes	Yes	Yes	Yes

[*]Note: * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$

Therefore, the hypothesis that access to forests positively affects household food security holds among Indigenous communities and for communities living in or near biodiverse, healthy forests. The results show that forests are a significant

[10] The OLS estimator has an almost null and negative effect, the IV estimator is invalid since the relevance condition is violated by having an F statistic in the first stage of less than 10.

food source for rural households regardless of the year, season, market access, or location.

4 Conclusions

In this paper, we have conducted an in-depth analysis of the relationship between forest access and food security among households residing in the Colombian and Peruvian Amazon regions. Our investigation is based on panel data collected at the household level, spanning two seasons (rainy and dry), allowing us to empirically explore the influence of forests on a multidimensional food security index at the household level. This research holds particular significance considering the growing body of literature emphasizing the crucial role of forests in ensuring food security. To mitigate the challenge of selection bias, we have employed a rigorous identification strategy that uses an instrumental variable approach. Our estimates can be interpreted as causal relationships by accounting for observable and unobservable heterogeneity.

Our findings reveal a nuanced relationship between forest access and household food security. Notably, the impact of forest access is contingent upon factors such as deforestation rates and the overall health of the forest. In Colombia, where most households reside near forests with relatively low deforestation rates, access to these forests during both rainy and dry seasons is associated with higher levels of food security. In stark contrast, households in Peru exhibit lower levels of forest access and correspondingly lower food security, a situation attributed partly to the region's higher deforestation rates in recent years. Importantly, we observed variations in the magnitude of these results across different ethnic groups.

Moreover, our analysis challenges the conventional assumption that increased market access leads to improved food security among these households. Notably, Mestizo Peruvian households, despite having superior market access when compared to Colombian and Indigenous Peruvian households, paradoxically exhibit lower levels of food security. This observation underscores the critical role natural products from forests play in the food security of these communities.

In conclusion, our research strongly suggests that households with access to forests characterized by low deforestation rates enjoy higher levels of food security. From a policy perspective, it becomes evident that facilitating access to forests and their resources is paramount for enhancing the livelihoods and overall well-being of households in our study area. Additionally, urgent measures are needed to strengthen institutional capacity in Colombia and Peru to prevent escalating deforestation rates, given the profound repercussions on the food security of forest-dependent communities.

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Appendix

Appendix A. Estimation Food Security Index

Based Utilizing the statistical methodology of main components for mixed data, known as Factor Analysis for Mixed Data (FAMD), the Food Security Index for Colombia and Peru is computed for both seasons (Rain and Dry). Descriptive and econometric index analysis standardizes the values to a range of 0 to 100. The following formula is applied for this purpose:

$$FoodSecurityIndex = \frac{(\mathrm{x} - x_{min})}{(x_{max} - x_{min})} x100 \qquad (A.1)$$

For households in Colombia, the first component of estimating mixed principal components is used to create the food security index. This component, exhibiting the highest eigenvalue and capturing the most significant variation in the data (Table A.2), primarily reflects the dimensions of availability and access positively, while being negatively influenced by the dimension of utilization, particularly if households do not utilize water from a public source and cook with gas as an energy source (Table A.2).

Table A.2: Estimation Food Security Index-Colombia.

Food Security Dimension	Variables	Comp1	Comp2	Comp3	Comp4	Comp5
Availability	Economic valuation Amount of food consumed in the household ($ US)	0.713	0.185	0.001	0.154	0.658
Stability	Food scarcity intensity	-0.126	-0.783	0.303	0.512	0.133
Access	Number of Food Sources	0.634	0.230	0.405	0.321	-0.526
Utilization	Source Energy Kitchen (Firewood)	0.095	-0.096	0.040	-0.111	-0.009
	Source Energy Kitchen (Gas)	-3.038	3.069	-1.268	3.541	0.275
	Do not use Water Source (Public)	-0.642	0.469	1.091	-0.210	0.281
	Yes use Water Source (Public)	0.336	-0.245	-0.571	0.110	-0.147
FAMD	Eigenvalues	1.311	1.079	0.960	0.870	0.780
	Variance (%)	26.230	21.590	19.170	17.340	15.670

The negative impact of using gas as a source of energy for food preparation on the index is contextualized within households in the Colombian Amazon. Table A.3 illustrates that few families in this region use gas as a source of energy for food consumption, and these households tend to have the lowest economic valuation in food consumed.

The estimation of mixed principal components confirms that the multidimensional concept of food security is specific to the study area. The results explain each dimension of food security differently, attributable to ethnic, environmental, and institutional effects specific to each study area.

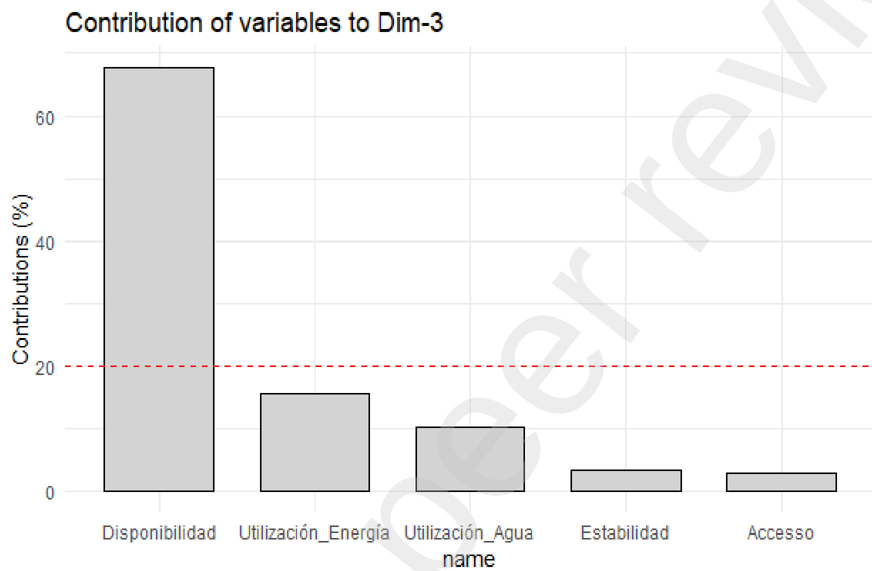

Figure A.3: Contribution of each Food Security Dimension in the First Component of the FMAD-Perú Index

In Peru, the first three components of the estimate capture the greatest data variance (Table A.4). Although the first component exhibits a negative relationship with the availability dimension and a positive one with the stability dimension, the third dimension is utilized to create the food security index for rural households in Peru, as it predominantly captures the concept of availability (Figure A.3).

The food security index in Peru demonstrates a positive relationship with the economic valuation of total food consumption and the number of food sources, while exhibiting a negative relationship with the intensity of scarcity, the energy source, and water used for food preparation.

Table A.4: Estimation Food Security Index-Colombia.

Food Security Dimension	Variables	Comp1	Comp2	Comp3	Comp4	Comp5
Availability	Economic valuation Amount of food consumed in the household ($ US)	-0.466	0.078	0.797	0.373	0.053
Stability	Food scarcity intensity	0.570	0.286	-0.181	0.715	0.222
Access	Number of Food Sources	0.139	0.816	0.167	-0.420	0.333
Utilization	Source Energy Kitchen (Firewood)	0.613	0.085	0.256	-0.062	-0.285
	Source Energy Kitchen (Gas)	-1.289	-0.178	-0.537	0.131	0.599
	Do not use Water Source (Public)	1.572	-1.651	0.752	-0.456	0.907
	Yes use Water Source (Public)	-0.251	0.263	-0.120	0.073	-0.145
FAMD	Eigenvalues	1.405	1.146	0.938	0.874	0.637
	Variance (%)	28.092	22.921	18.766	17.479	12.742