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Foundations for emissions reduction and improved nutrition in conflict-affected areas: the case of Colombia's Cauca and Putumayo food environments

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Acronyms

ADR	Agencia de Desarrollo Rural
AICMA	Acción Integral Contra Minas Antipersonal
APM	Antipersonnel Mine
ART	Agencia de Renovación del Territorio
CAA	Climate Advantage of Alternatives
CAS	Climate Advantage of Specialization
CIAT	International Center for Tropical Agriculture
CO₂	Carbon Dioxide
CONPES	Consejo Nacional de Política Económica y Social
COP	Colombian Pesos
CV	Coefficient of variation
DANE	Departamento Administrativo Nacional de Estadística
ENA	Encuesta Nacional Agropecuaria
ENSIN	Encuesta Nacional de Situación Nutricional
EPINER	Environmental Peacebuilding for Improved Nutrition and Emission Reductions in Cauca and Putumayo
FAO	Food and Agriculture Organization of the United Nations
FARC-EP	Fuerzas Armadas Revolucionarias de Colombia – Ejército del Pueblo
FEDEGAN	Federación Colombiana de Ganaderos
FEDEPALMA	Federación Nacional de Cultivadores de Palma de Aceite
FIES	Food Insecurity Experience Scale
FINAGRO	Fondo para el Financiamiento del Sector Agropecuario
FONTAGRO	Fondo Regional de Tecnología Agropecuaria
GDP	Gross Domestic Product
GHGs	Greenhouse Gas Emissions
HLPE	High Level Panel of Experts on Food Security and Nutrition
ICA	Instituto Colombiano Agropecuario
ICBF	Instituto Colombiano de Bienestar Familiar
IDEAM	Instituto de Hidrología, Meteorología y Estudios Ambientales
IPCC	Intergovernmental Panel on Climate Change
IUCN NL	National Committee of The Netherlands
MADS	Ministerio de Ambiente y Desarrollo Sostenible
MADR	Ministerio de Agricultura y Desarrollo Rural
PDET	Programas de Desarrollo con Enfoque Territorial
SIPSA	Sistema de Información de Precios y Abastecimiento del Sector Agropecuario
SSP5-8.5	Shared Socioeconomic Pathway 5 – Representative Concentration Pathway (RCP) 8.5
UNODC	United Nations Office on Drugs and Crime
UPRA	Unidad de Planificación Rural Agropecuaria
WASD	Weighted Average Shortest Distance

Executive Summary

Food systems in conflict-affected regions face interconnected challenges related to environmental degradation, market disruptions, and persistent food and nutrition insecurity. This study characterizes the food environments of Cauca and Putumayo, two conflict-affected departments in Colombia, using a food system approach that integrates indicators of food consumption, agricultural production, distribution, transport-related emissions, and security dynamics. We combine household survey data, agricultural statistics, food mobilization records, spatial analyses, and climate and land-use suitability information to identify the gaps, bottlenecks, and inequalities shaping food availability, accessibility, affordability, and desirability. Study results show that Cauca has a diversified, commercially integrated agricultural sector with strong linkages to regional and national markets, but with apparent disconnects between local production and household consumption of nutrient-dense foods. Putumayo exhibits a more subsistence-oriented production system based on local consumption, as a result of limited infrastructure, market integration, and technical capacity. In both departments, perishable products dominate the short food supply chains, while long-distance flows reflect differentiated market demand. Extensive cattle ranching remains a key driver of deforestation risk, whereas diversified smallholder systems offer opportunities for improving dietary diversity and climate resilience. The findings highlight priority areas for intervention in infrastructure, market access, extension services, and governance, and provide policy-relevant insights for integrating food and nutrition security, climate mitigation, and peacebuilding agendas in conflict-affected territories.

1. Introduction

The current food system imposes unsustainable environmental and economic costs (Van Nieuwkoop, 2019). Biodiversity loss, climate change, and conflict are eroding the natural and social capital upon which food systems depend. The sustainability of the food system relies, among other factors, on the *food environment*—representing the interface between the consumer and the food production and supply chain—which shapes key conditions such as the availability, affordability, convenience, and desirability of food (Downs et al., 2020). Characterizing these elements is crucial for identifying gaps, prioritizing interventions, promoting collective action, and tracking changes within the system, all of which are essential for informing effective responses to its challenges.

The agriculture, forestry, and fishery sectors provide livelihoods for 50% of the world's workforce and form the foundation of global food and nutrition security (Mohieldin & Cabellero, 2015; Food and Agriculture Organization of the United Nations [FAO], 2018). However, the food system is both a contributor to and a victim of climate change. It accounts for one-third of global greenhouse gas emissions (GHGs) (Crippa et al., 2021; Tubiello et al., 2021), while changing climate patterns, including droughts and floods, are increasingly threatening food security (Berlin et al., 2024). Furthermore, rising atmospheric carbon dioxide (CO₂) levels compromise the nutritional quality of staple crops, reducing essential nutrients,

such as zinc, iron, protein, and key vitamins. This decline presents a serious global public health challenge, as plants are the primary dietary sources of these nutrients (Myers et al., 2014; Semba et al., 2022). When combined with climate change-induced crop-yield reductions, the result is a significant decrease in nutrient availability in the global diet (Smith & Myers, 2018).

Despite global food production being sufficient to feed the planet's entire population, approximately 800 million people suffer from hunger, with severe impacts in regions such as Sub-Saharan Africa and South America (FAO, 2022). In 2021, half of global child deaths were linked to nutritional deficiencies, and 34,000 women died from pregnancy-related malnutrition (Ritchie, 2024). Food and nutrition insecurity are particularly prevalent in low-income countries (ibid) and are exacerbated by ongoing conflicts in these regions. In these contexts, food environments are affected in multiple ways, including through reduced investment, shifts in production orientation, population displacement, infrastructure damage, and mobility restrictions, among others (Arias & Ibáñez Londoño, 2012; FAO et al., 2017; Iglesias et al., 2024).

Colombia is one of the countries where these challenges converge. The armed conflict has significantly impacted agriculture (Iglesias et al., 2024), disrupting the dynamics of the food system and its environment. For instance, while cattle ranching is a key sector of the national agricultural economy, it is equally a major driver of deforestation and GHGs, it has been used as a means for land grabbing, and is associated with illegal economies (Consejo Nacional de Política Económica y Social [CONPES], 2020; Murillo-Sandoval et al., 2020). Furthermore, cattle ranching does not necessarily contribute to local food and nutrition security, as higher rates of child malnutrition have been documented in livestock-dominated areas (Pérez Marulanda & Castro-Nunez, 2023). The connection between cattle ranching, deforestation, and conflict in Colombia is well-documented (Ganzenmüller et al., 2022; González et al., 2018; Vanegas-Cubillos et al., 2022), yet its link to malnutrition remains insufficiently explored. The "Environmental Peacebuilding for Improved Nutrition and Emission Reductions in Cauca and Putumayo" (EPINER) project aims to bridge this knowledge gap while promoting environmental sustainability and improved nutrition in both of these conflict-affected areas.

Here, we contribute to broadening the understanding of the food environment of conflict-affected and deforestation-prone regions by characterizing three food system stages in Cauca and Putumayo: consumption, production, and distribution. To this end, we have analyzed indicators related to each stage in both departments and presented additional insights into conflict issues and agriculture scenarios. The report aims to: (1) Identify gaps, barriers or imbalances that may affect people's capacity to access, acquire, and consume sufficient, nutritious, and culturally-appropriate food; (2) Provide insights into target areas for prioritized interventions (e.g. infrastructure, market access, subsidies); and (3) Inform policy decisions related to climate-change mitigation and peacebuilding agendas to better address food system sustainability and food and nutrition security concerns.

1.2 Overview of Cauca and Putumayo Departments

1.2.1 Cauca

Cauca Department is located in southwestern Colombia, spanning the Andean, Amazonian foothills, and Pacific regions. It consists of 42 municipalities and covers an area of 29,308 km² (Gobernación del Departamento del Cauca, 2024). The department features diverse climatic zones, ranging from warm conditions along the Pacific slope and Patía Valley to temperate and cold climates in the central and higher-altitude areas (Oficina Asesora de Planeación Gobernación del Cauca, 2020). Approximately 40% of Cauca's land is designated as agricultural frontier, while the remaining 60% comprises natural forests, non-agricultural areas, and conservation zones (Gobernación del Departamento del Cauca, 2024).

In 2023, public administration and defense accounted for the largest share (19.8%) of Cauca's gross domestic product (GDP), followed by agriculture, livestock, and fisheries (17.1% in total) (Oficina de Estudios Económicos MINCIT, 2024a). In 2022, Cauca ranked 12th in Colombia for deforested area, with 2,454 ha affected, reflecting a general deceleration in deforestation rates (Instituto de Hidrología, Meteorología y Estudios Ambientales [IDEAM] & Ministerio de Ambiente y Desarrollo Sostenible [MADS], 2023). Land-use conflicts persist, with agricultural and livestock activities occupying 22.9% and 19.7% of the territory, respectively, despite only 7.3% and 1.6%, respectively being officially recognized as suitable for such purposes (Gobernación del Departamento del Cauca, 2024).

Cauca's Multidimensional Poverty Index (MPI) was 15.8 in 2023, surpassing the national average (12.1). The most significant deprivations were in employment, education, and access to public services, with rural areas experiencing the greatest deficits (Oficina de Estudios Económicos MINCIT, 2024a). Food insecurity affected 25.1% of households in 2022 (Gobernación del Departamento del Cauca, 2024).

Due to conflict, high poverty levels, weak state presence, and illicit crop cultivation, 20 of Cauca's 42 municipalities were prioritized under Colombia's Development Programs with a Territorial Approach (PDET is the Spanish acronym)¹. These municipalities are distributed across two subregions: Alto Patía and Norte del Cauca (17 municipalities) and Pacífico Medio (3 municipalities). In the former, 54% of municipalities are at a high or extremely high risk of armed conflict, while in the latter, this figure reaches 100% (Agencia de Renovación del Territorio [ART], 2023a, 2023b). Between 2018 and 2022, illicit crop cultivation increased by nearly 52% in Alto Patía and Norte del Cauca, whereas Pacífico Medio saw a 10% reduction between 2021 and 2022 (ART, 2023a, 2023b).

1.2.2 Putumayo

Putumayo Department is situated in southern Colombia within the Amazon region. It consists of 13 municipalities spread across 24,885 km². Its climate is predominantly warm, with thermal

¹ As part of the peace agreement in Colombia, 170 municipalities grouped into 16 subregions were prioritized for socio-economic assistance through the "Programas de Desarrollo con Enfoque Territorial – PDET" (Ministerio de Agricultura y Desarrollo Rural [MADR], 2017). Further information on the PDET can be found at https://www.renovacionterritorio.gov.co/especiales/especial_PDET/.

variations ranging from tropical lowlands to páramo ecosystems at higher elevations. More than 70% of the department's land is covered by natural forests, non-agricultural areas, and conservation zones (Secretaría de Planeación Gobernación de Putumayo, 2024).

In 2023, the mining and quarrying sector contributed the largest share (29.3%) of Putumayo's GDP, whereas agriculture, livestock, and fisheries ranked fourth, with a 7.7% contribution (Oficina de Estudios Económicos MINCIT, 2024b). In 2022, Putumayo ranked fourth in deforested area, with 10,852 ha affected, and is home to one of Colombia's nine active deforestation hotspots, driven by extensive cattle ranching (IDEAM & MADS, 2023).

Putumayo's MPI was 13.2 in 2023, placing it in the middle of the national ranking. The most severe deprivations were in employment, education, and access to public services, particularly in rural areas (Oficina de Estudios Económicos MINCIT, 2024b, p. 20). In PDET municipalities, child mortality due to malnutrition increased by 1.7 points between 2018 and 2021 (ART, 2023b).

Putumayo has been heavily affected by armed conflict, particularly in its lowland areas, due to drug trafficking (Centro de Memoria Histórica, 2012). Nine municipalities in Putumayo belong to one of the 16 PDET subregions, where 77% of municipalities are classified as at a high or remarkably high risk of armed conflict. Additionally, illicit crop cultivation increased by 82% between 2018 and 2022 (ART, 2023b).

2. Applying a Food Systems Approach

A food system comprises all the elements and activities involved in the production, processing, marketing, distribution, preparation, and consumption of food (High Level Panel of Experts on Food Security and Nutrition [HLPE], 2014). It includes not only the tangible components—such as people, resources, infrastructure, and institutions—but also the environmental, social, and economic outcomes resulting from these activities. Likewise, the latter elements provide the context that shapes the food environment.

According to the HLPE (2017), the food environment is defined as “the physical, economic, political, and socio-cultural context in which consumers engage with the food system to make their decisions about acquiring, preparing, and consuming food.” This environment encompasses multiple dimensions that are shaped by a wide range of socio-economic, environmental, institutional, technological, cultural, demographic, and biophysical factors influencing the broader food system (Béné et al., 2019; FAO, 2022).

As outlined by Turner et al. (2018), the key dimensions of the food environment include, but are not limited to:

- I.** Availability – the presence of specific foods or food groups in each location.
- II.** Accessibility – physical and temporal access to food or food vendors in markets.
- III.** Affordability – the relationship between food prices and individual purchasing power.

- IV. Convenience – the time and effort required to obtain, prepare, and consume food.
- V. Desirability – the social and cultural factors that shape food preferences.

In this report, we characterize the food environments of Colombia’s Cauca and Putumayo Departments by exploring variables related to three stages of the food system: production, distribution, and consumption, which provide insights into the five dimensions described above and other relevant contextual data. Figure 1 illustrates this approach. Data from this webpage² was used to analyze indicators on: (a) Food purchasing and consumption; (b) Agricultural production, cattle inventories, tree cover loss, food supply, food mobilization, and derived GHGEs; c) Finance and security issues; and (d) Health, nutrition, and future crop suitability. As the data originate from multiple sources, such as the National Statistics Department (DANE), the Colombian Agricultural Institute (ICA), and the Rural Agricultural and Livestock Planning Unit (UPRA), not all are available at the municipal level. In such instances, regional or departmental data was utilized. Data on other indicators, such as prices, income, and markets, among others, were not available.

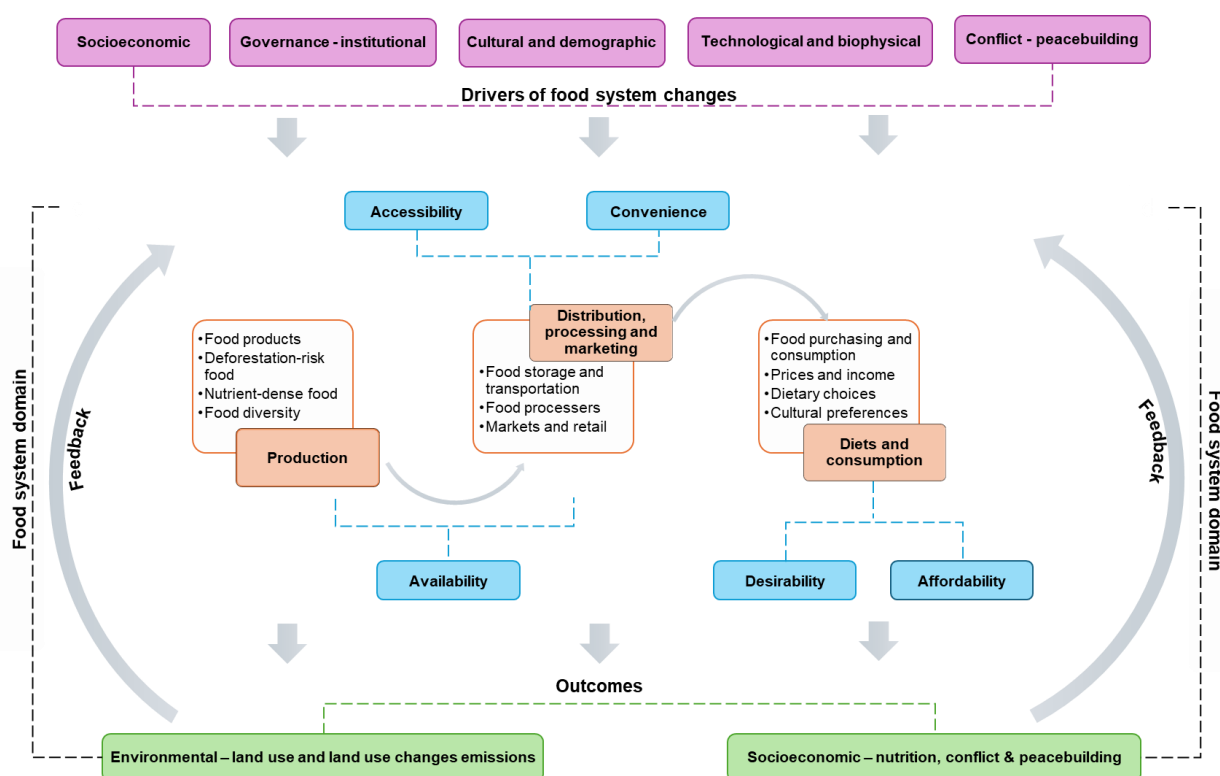


Figure 1. Food system approach for characterizing the food environment.

The orange-colored boxes indicate the *stages of the food system* and the indicators used to approximate the *food environment dimensions* presented in the blue-colored boxes (note that not all known indicators are included in this figure). The plum-colored boxes indicate *factors driving food system changes*, while green boxes indicate the *food system outcomes*, which focus on contextual issues relevant to the target departments. Source: Authors’ own elaboration.

² <https://epiner.alliance.cgiar.org/explora-epiner/>. Information is available at municipal and/or department level for Colombia.

This approach serves as a foundation for identifying gaps, bottlenecks, and inequalities, prioritizing investments, promoting collective action, and tracking changes within the food system. These findings will inform debates among researchers, civil society members, and policymakers involved in overcoming environmental and food and nutrition challenges.

In the following four sections, we first explore Cauca's and Putumayo's food environments through the lens of three food system stage metrics: purchase and consumption, production, and distribution. Next, in Section 4, we focus on the links between financing and security, given their influence on agricultural production and local market dynamics, followed by Section 5 on the food and nutrition security perspectives; and lastly, Section 6 examines the policy implications of these findings on food and nutrition security in both departments.

3. Cauca and Putumayo Food Environments

The interplay of multiple factors influences key aspects of the food environment, such as market access, prices, productivity, food availability, and dietary preferences, among others. In Colombia, for example, armed conflict has had a particularly significant impact on the functioning of food systems and environments. Between 1995 and 2017 alone, it is estimated that agricultural production in Colombia declined by 29% as a result of the conflict (Iglesias et al., 2024). Violence discourages investment, hinders the adoption of new technologies, and undermines human capital development. It also encourages the cultivation of illicit crops (Iglesias et al., 2024) or shifts in production toward crops that are less vulnerable to the effects of violence, such as short-cycle crops and pasture for livestock (Arias & Ibáñez Londoño, 2012).

Displacement of communities and the degradation of natural resources further reduce access to land and the local availability of traditional foods, increasing reliance on external and processed food products (Hurtado-Bermúdez et al., 2020; Vélez-Torres et al., 2013). Damage to infrastructure and restricted mobility also limit market access.

While conflict remains a major driver of food system disruption in Colombia, global market forces also play a critical role in shaping agricultural production and pricing. In departments such as Cauca and Putumayo, agro-industrial expansion has displaced small-scale farming, threatening traditional food systems centered on crops like beans and maize (Hurtado-Bermúdez et al., 2020; Vélez-Torres et al., 2013). These transformations affect both livelihoods and local diets, as such crops are considered essential for food sovereignty and are deeply rooted in the cultural identity of many communities (Bernal Galeano, 2019; Calderón Farfán et al., 2023).

In some communities within these departments, there are ongoing efforts to promote agroecology as a means of safeguarding food sovereignty and preserving traditional practices, knowledge, and seed varieties (Jiménez Reinales & Arias Naranjo, 2020). Farmers' markets and agroecological initiatives serve as platforms to promote these products, with women playing a central role in preserving ancestral knowledge and managing household plots (Gallego, 2023;

Hernández et al., 2023; Hernández García & Daza Alfonso, 2024). Nevertheless, challenges such as limited technical assistance and the lack of institutional incentives persist (Reyes Benavides & Sánchez Castillo, 2024), while global market trends continue to strengthen the dominance of agroindustry (Vélez-Torres et al., 2013).

In this context, government intervention is essential to support small-scale agriculture, secure access to land, and ensure the safety and stability of territories still affected by conflict (Carpena & Bejarano, 2023; Iglesias et al., 2024).

This section explores the food environment using metrics across three food system stages. Although these stages are arranged sequentially—production, distribution, and consumption—in this section, we will address the final stage first. This will allow us to contextualize the results of the other two stages when necessary. First, we examine factors such as food purchasing and consumption in Cauca and Putumayo Departments to learn about the affordability and desirability of food. Next, we analyze each department's agricultural production by crop type to understand food availability. We then present estimates on food transportation across different levels, which inform the availability, accessibility, and convenience of acquiring specific foods in these territories.

3.1 Food purchasing and consumption

Colombia currently lacks an updated version of the National Survey on the Nutritional Status of Colombia (ENSIN) that captures recent household consumption trends. While food purchases do not fully reflect consumption patterns, given the influence of factors such as home production, food exchange, and transfers (Utsunomiya et al., 2025), we used data from the Quality of Life Survey (DANE, 2025b) as a proxy to approximate household food access and consumption dynamics.

Figure 2 shows that in 2024, households in both Cauca and Putumayo purchased most food items with a weekly frequency (40%) or every two weeks (~30%). In Cauca (both rural and urban) and in urban areas of Putumayo, a higher proportion of households reported purchasing eggs, dairy products, fruit, meat, tubers, and vegetables on a weekly basis. Fruit, vegetables, and dairy products are highly perishable, making frequent purchases expected. However, the higher purchase frequency of eggs, meat, and tubers—foods with a longer shelf life—suggests that other drivers are at play, such as a cultural preference for fresh products, high market turnover due to local availability (e.g., livestock and tubers), and economic or storage limitations that prevent bulk purchasing.

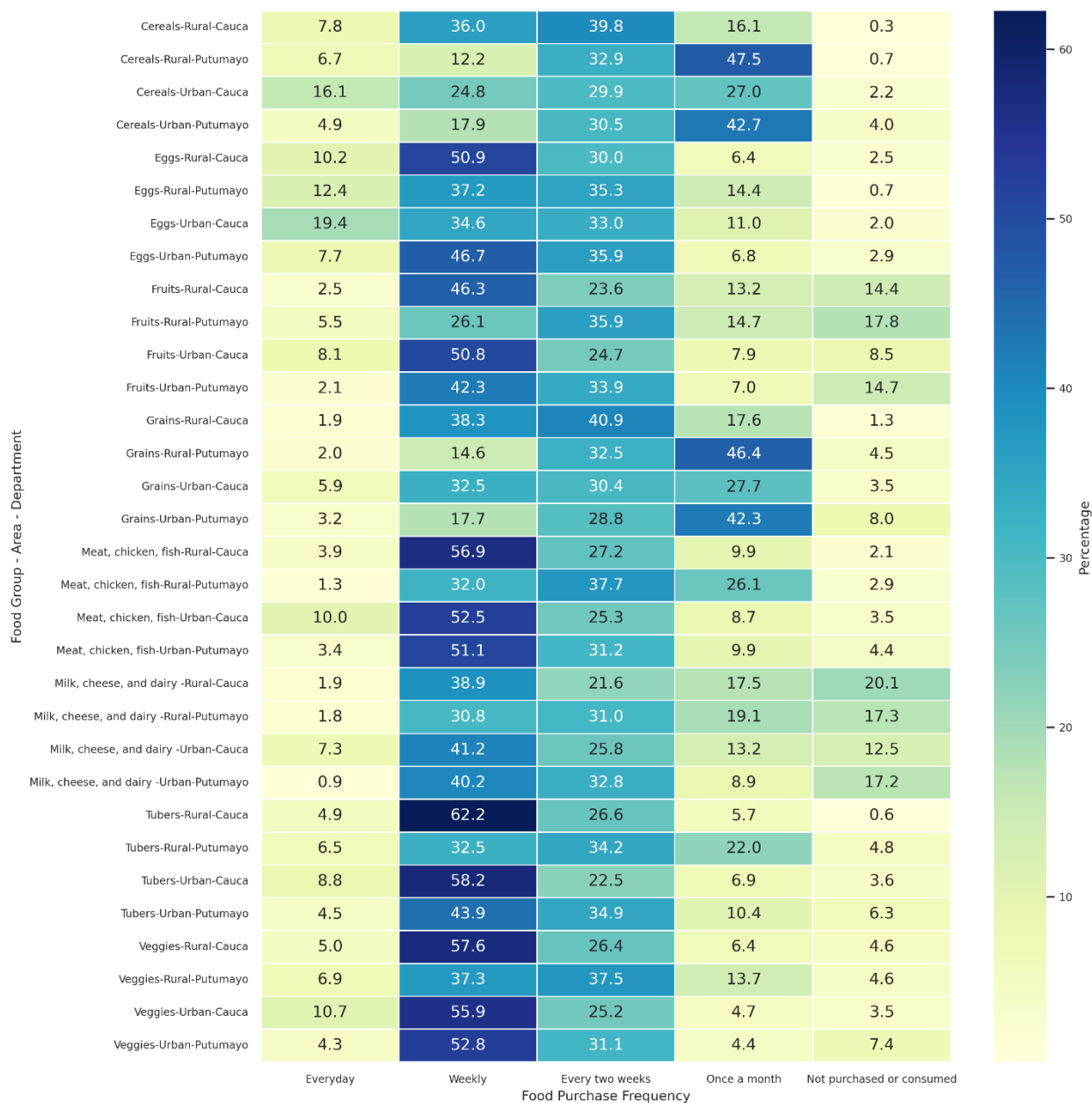


Figure 2. Food purchase frequency average by residence type, food group, and department in 2024.

Source: Authors' own elaboration, based on data from the Quality of Life Survey 2024 (DANE, 2025b).

Purchase frequency can also reflect convenience. For instance, in municipal centers, neighborhood supermarkets, and traditional markets are the primary sources of fresh foods in both departments, particularly cereals, fruit, grains, tubers, and vegetables (Figure 3). Consumers typically purchase meat at traditional markets in Cauca and neighborhood supermarkets in Putumayo. In both departments, dairy products and eggs are most frequently purchased in supermarkets.

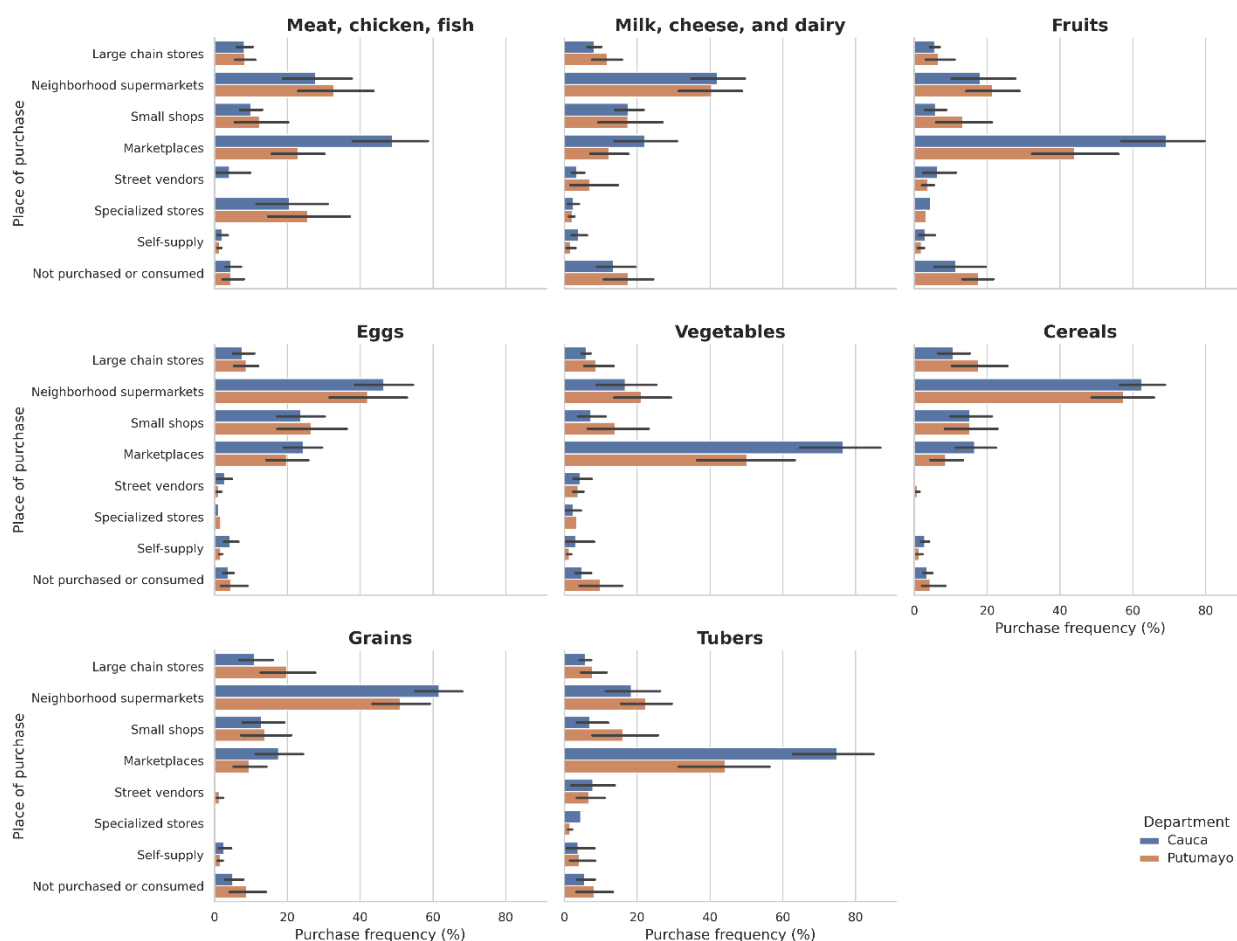


Figure 3. Food purchase sources by food group in Cauca and Putumayo in 2024.

Source: Authors' own elaboration, based on data from the Quality of Life Survey 2024 (DANE, 2025b).

More than 42% of households in Putumayo purchase grains and cereals only once per month (see Figure 2). Given their long shelf life, this pattern is expected. Yet, on average, 51% of the households surveyed acquire grains and cereals more frequently than once a month. In the case of beans, a dietary staple in the department, being purchased more frequently may reflect their productive and cultural importance, thus a higher household turnover. There are no apparent differences between rural and urban areas.

Even though 40% of households in Cauca purchase dairy weekly, overall consumption remains limited compared to other food groups. About 20% and 12.5% of rural and urban households, respectively, reported not buying dairy because they do not consume it. Similarly, in Putumayo, around 17% of rural and urban households do not consume dairy products. This could represent a nutritional gap, given the high nutrient value of dairy, and suggests that barriers are more likely economic than cultural, especially in a cattle-producing department such as Cauca, where dairy produce is widely available.

A similar restriction is observed in fruit consumption: on average, 11.5% of respondents in Cauca and 16.3% in Putumayo reported not purchasing fruit because they do not consume it. Considering that fruit production is significant in both departments, such limitations point to

either cultural preferences or economic constraints. However, this still suggests an improvement over earlier data; the ENSIN 2010 survey reported that 65.5% of households in the Pacific and Amazon regions consumed fruit (Instituto Colombiano de Bienestar Familiar [ICBF], 2010), indicating that although persistent barriers remain, gradual progress has been made.

Despite this, the disconnect between local production and household consumption raises concerns about the desirability and affordability of nutrient-rich foods in both departments, pointing to potential nutritional vulnerabilities. According to the Food Insecurity Experience Scale – FIES³ (DANE, 2025a), 41% of households in Cauca and 21.4% in Putumayo reported not consuming healthy and nutritious foods in the last year, while 46.5% and 30.5%, respectively, indicated consuming low-variety diets. ENSIN 2015 (ICBF, 2015) reported that only 17% of the population in Putumayo and 22% in Cauca consumed the five recommended food groups—(i) vegetables; (ii) fruit; (iii) starchy staples (grains and cereals); (iv) legumes or nuts (protein); and (v) meat products (protein)—in the previous 24 hours. This underscores persistent dietary diversity limitations in both departments.

These findings highlight the importance of examining equity and inclusiveness in local food systems. This reinforces the need to address not only the physical availability of foods but also economic access and cultural desirability, which ultimately shape dietary choices.

3.2 Production

3.2.1 Primary food products

This section identifies the primary agricultural products in Cauca and Putumayo by planted area (Figure 4) and volume (Figure 5), highlighting each department's production niche and its potential contribution to the local food environment. Overall, Cauca shows a more commercially oriented agricultural sector, whereas Putumayo's production is more limited in volume but includes exotic Amazonian fruits and spices. Both departments grow staple crops that are important for food security. Livestock is discussed separately in Section 3.2.2.

³ The Food Insecurity Experience Scale (FIES) is a tool for measuring access to food in terms of both quantity and quality. Through eight questions, the scale captures individuals' or households' experiences of food insecurity and provides a measure of its severity (DANE, 2025a).

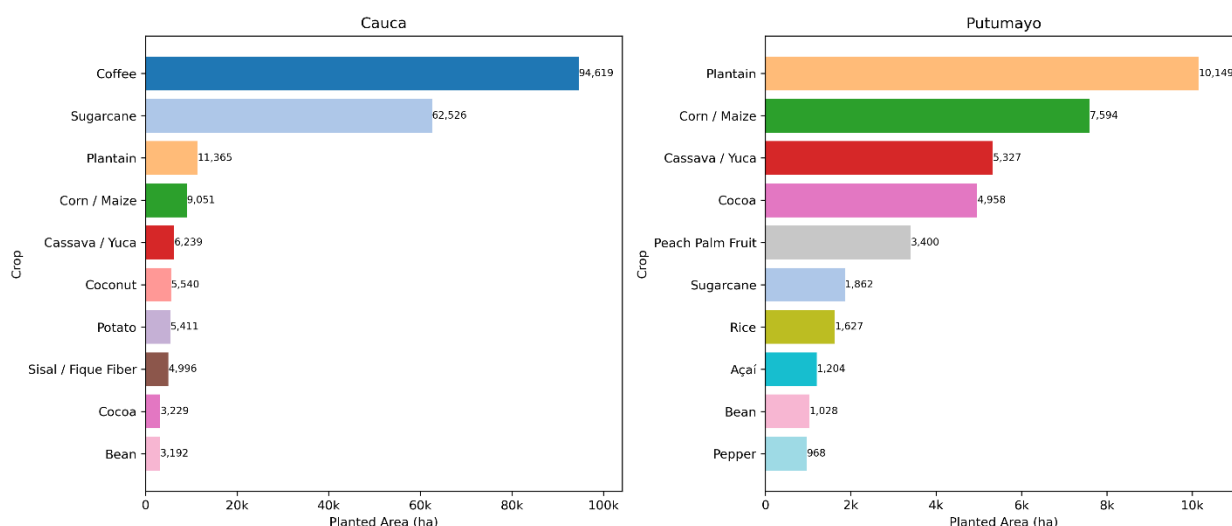


Figure 4. Top 10 crops by planted area (ha) in Cauca and Putumayo in 2024.

Source: Authors' own elaboration, based on (UPRA, 2024).

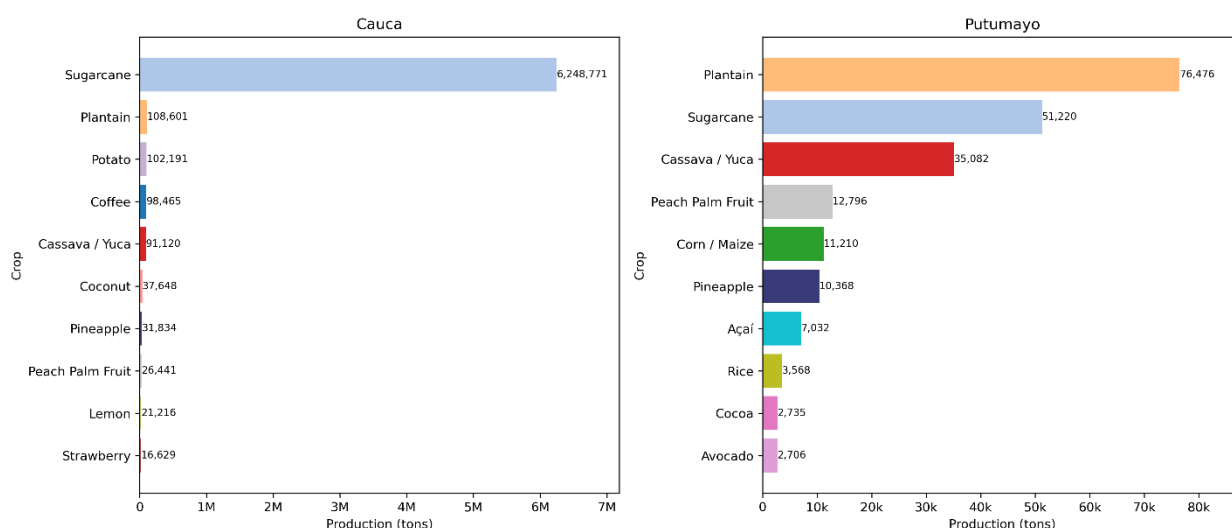


Figure 5. Top 10 crops by production volume (tons) in Cauca and Putumayo in 2024.

Source: Authors' own elaboration, based on (UPRA, 2024).

Cauca

Almost 40% (1.25 million ha) of Cauca's total area lies within Colombia's national agricultural frontier (UPRA, 2023a). Of this area, about 60.5% (754,545 ha) is considered suitable for agricultural activity, located in the eastern part of the department. Legally, around 19% (592,346 ha) of Cauca's territory is excluded from agricultural or livestock use. According to the 2023 National Agricultural Survey – ENA (DANE, 2025d), land use in Cauca is livestock-oriented, with an estimated 874,578 ha under livestock systems, of which 551,055 ha (63%) correspond to pastures and forage. However, these estimates carry considerable uncertainty, with coefficients of variation (CV) ranging from 19.3% to 25.3%. Agricultural land covers approximately 249,705 ha (CV = 12.5%).

Cauca has strong potential for food production driven by small-scale farming, which supplies most of the food consumed and traded within the department (FAO & Agencia de Desarrollo Rural [ADR], 2021a). Approximately one million hectares, about 32% of the department's total area, are dedicated to family farming (UPRA, 2023a). Despite this, Cauca's agricultural landscape is dominated by large-scale coffee and sugarcane production, which together cover around 157,000 hectares (see Figure 4). While these crops are important for the regional and national economy and traditions, their contribution to food security is limited. The combined area to which the remaining eight of the top 10 crops are planted barely exceeds 42,000 hectares, almost four times less than for coffee and sugarcane.

Sugarcane production is concentrated in the northern part of the department, where it has driven greater technological development and mechanization (Gobernación del Departamento del Cauca, 2024). In 2024, sugarcane production reached 6.3 million tons, whereas the next four largest ranking crops in terms of production ranged between 90,000 and 100,000 tons (Figure 5). Most sugarcane (about 85%) is processed into refined sugar, while roughly 15% is used for *panela* production—a traditional unrefined sweetener widely consumed in Colombian households.

Coffee, another key agricultural value chain in Cauca, positions the department as the fourth-largest coffee producer in the country (Gobernación del Departamento del Cauca, 2024). Although coffee occupies about 32,000 more hectares than sugarcane, it ranks fourth in total production volume after plantain and potato, two staple crops that are frequently purchased in local markets. Cassava, another major root crop, yielded approximately 91,000 tons in 2024. Around half of this production was sold fresh, while the other half was destined for industrial processing.

Given its extensive agricultural land and diverse productive landscapes, Cauca has the potential to supply nutritious and culturally appropriate foods to its own population and contribute to other national food environments. However, this potential remains largely unrealized due to structural constraints. Agricultural extension services remain insufficient, and producers have limited access to markets, finance, productive infrastructure, and transportation networks (FAO & ADR, 2021a). Fewer farmer organizations and low levels of participation, coupled with high informality and inequitable land tenure, further constrain agricultural development. These challenges are compounded by the presence of illegal economies and armed groups, which continue to affect the department's productive and social dynamics.

Putumayo

According to the UPRA (2023b), in 2022, 579,592 hectares (22.4% of its territory) in Putumayo were classified as part of Colombia's national agricultural frontier. Of this land, 92% is *conditionally suitable* for agricultural activities, meaning it is subject to various restrictions. Additionally, approximately 542,000 hectares (21%) are legally excluded from any form of agricultural use. Regarding land use, the 2023 ENA (DANE, 2025d) reported that 350,897 ha (CV = 17.2%) are dedicated to livestock activities, including 124,802 ha of pastures and forage (36%; CV = 21.7%). Agricultural land accounts for about 43,092 ha (CV = 15.3%).

Putumayo's agricultural production is smaller in scale compared to Cauca's but remains highly significant for household food self-sufficiency. The department is characterized by low-intensity production systems based on traditional crops, primarily destined for local consumption (FAO & ADR, 2021b). It is estimated that 256,357 hectares (10%) are managed under family farming systems (UPRA, 2023b).

In 2024, the largest planted areas corresponded to plantain and maize, while in production volume, plantain and sugarcane stood out. Plantain and sugarcane production is concentrated in the low Putumayo, while maize is cultivated in the mid-region of the department. All sugarcane is destined for *panela* production and local consumption, whereas maize is entirely produced for household consumption. Cassava, another major dietary staple, ranked next in both area and production, with about 35,000 tons in 2024, entirely sold fresh in local markets.

Peach palm (*Bactris gasipaes*), a nutrient-rich fruit with deep cultural relevance in southern Colombian diets, ranked fifth with 12,797 tons produced in 2024. Other essential foods in the departmental diet, such as rice (3,568 tons) and beans (1,602 tons), are also fully allocated to local consumption (FAO & ADR, 2021b).

Despite this high potential for self-sufficiency, the agricultural sector in Putumayo remains constrained by low productivity levels, limited infrastructure for processing, commercialization, and transport, and insufficient technical assistance and extension services (FAO & ADR, 2021b).

3.2.2 Deforestation-risk food

Agriculture remains one of the leading global drivers of forest loss, accounting for an estimated 43% of tree cover loss between 2001 and 2022, and as much as 88% in Africa, 73% in Latin America, and 72% in Southeast Asia (Sims et al., 2025). Commodity crops such as cocoa, oil palm, coffee, and livestock production continue to shape land-use transitions in biodiversity-rich regions, including Brazil, Côte d'Ivoire, and Indonesia (Goldman & Weisse, 2024).

In Colombia, extensive cattle ranching is a major direct cause of deforestation (IDEAM, 2025b). These systems are not only characterized by low productivity and large land requirements, but in some zones, cattle are also used as a mechanism for land grabbing and money laundering linked to illicit economies (CONPES, 2020; Peña, 2017). In contrast, official reporting suggests that approximately 98% of planted coffee and cocoa areas in Colombia are classified as deforestation-free (Ministerio de Comercio, Industria y Turismo, 2025). Yet evidence indicates the persistent overlaps between recent deforestation and perennial crop establishment. In Cauca, for instance, new coffee plots have been identified in recently cleared areas across municipalities such as Buenos Aires, El Tambo, Inzá, Páez, and Santa Rosa (Solidaridad, 2022).

Similarly, according to the National Federation of Palm Growers (Fedepalma), 99% of oil palm plots established between 2011 and 2024 are classified as deforestation-free (Fedepalma, 2024). Expansion has taken place on previously cleared land, and current estimates suggest that new plantations account for less than 1% of Colombia's deforestation (García & Uricoechea, 2023;

Vijay et al., 2016). Nevertheless, the potential for increased risk remains and, in some regions, oil palm cultivation intersects with complex social dynamics, land tenure issues, and local environmental pressures (National Committee of The Netherlands [IUCN NL] & AidEnvironment, 2023). Figure 6 presents the areas planted to and the production volume of coffee, cocoa, and oil palm commodities in Cauca and Putumayo.

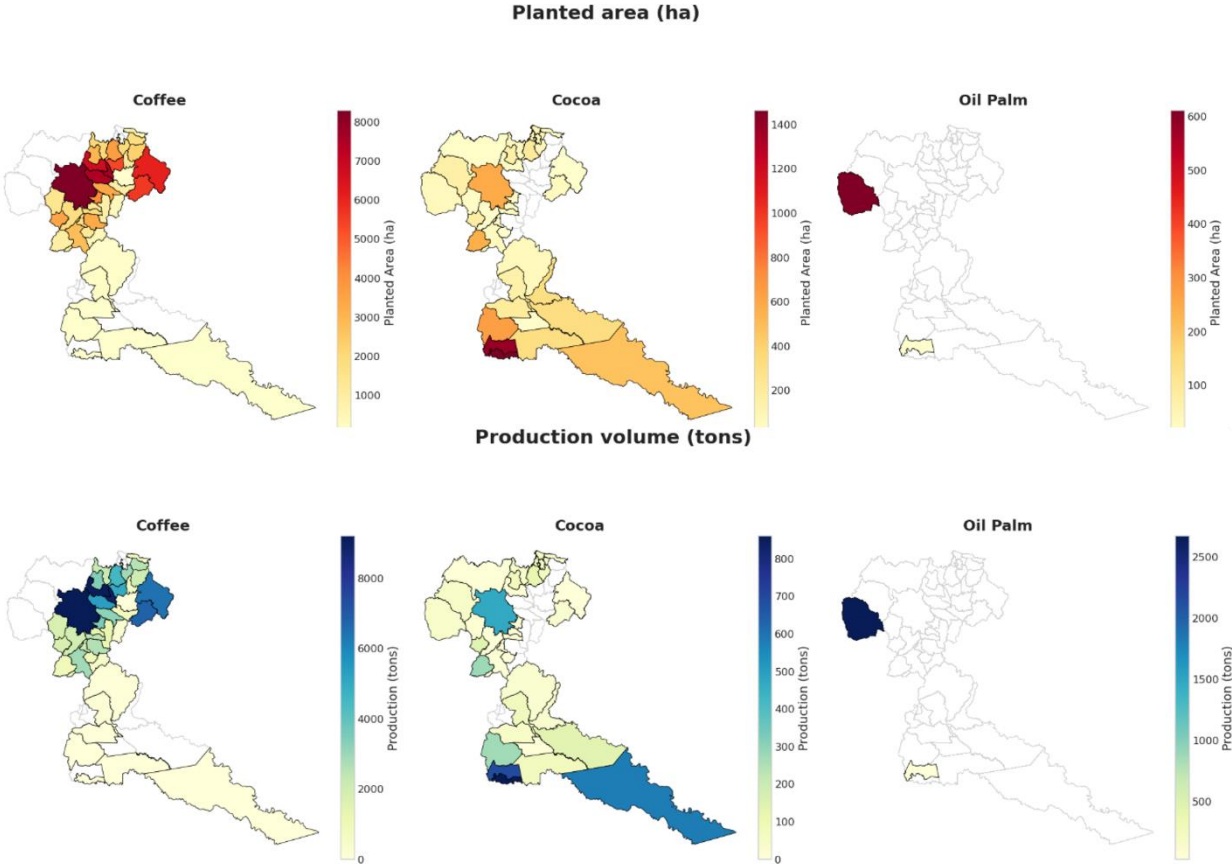


Figure 6. Spatial distribution of planted areas and production volume of coffee, cocoa, and oil palm crops in Cauca and Putumayo during 2024.

Source: Authors’ own elaboration, based on (UPRA, 2024).

Looking ahead, the level of risk for these commodities may intensify as climate change renders certain production zones less viable, pushing crops into new frontiers, or as political and socioeconomic dynamics reshape land-use pressures. However, Colombia has positioned itself as a leader in zero-deforestation value-chain commitments. Cocoa, coffee, bovine livestock, oil palm, and wood sectors have all adopted voluntary agreements that bring together public agencies, private companies, producer organizations, and civil society to curb deforestation within their supply chains and advance climate mitigation goals.

Since the bovine livestock sector is currently the only commodity that represents a high deforestation risk in the country, the following section provides a more detailed examination of its dynamics in Cauca and Putumayo.

Bovine livestock

As shown in Figure 7, in 2024, the highest cattle inventories in Putumayo were reported in Puerto Guzmán (127,136 head), Puerto Leguízamo (64,390), and Puerto Asís (33,470). In Cauca, inventories were highest in Patía (36,335), Puracé (23,393), and Mercaderes (18,727).

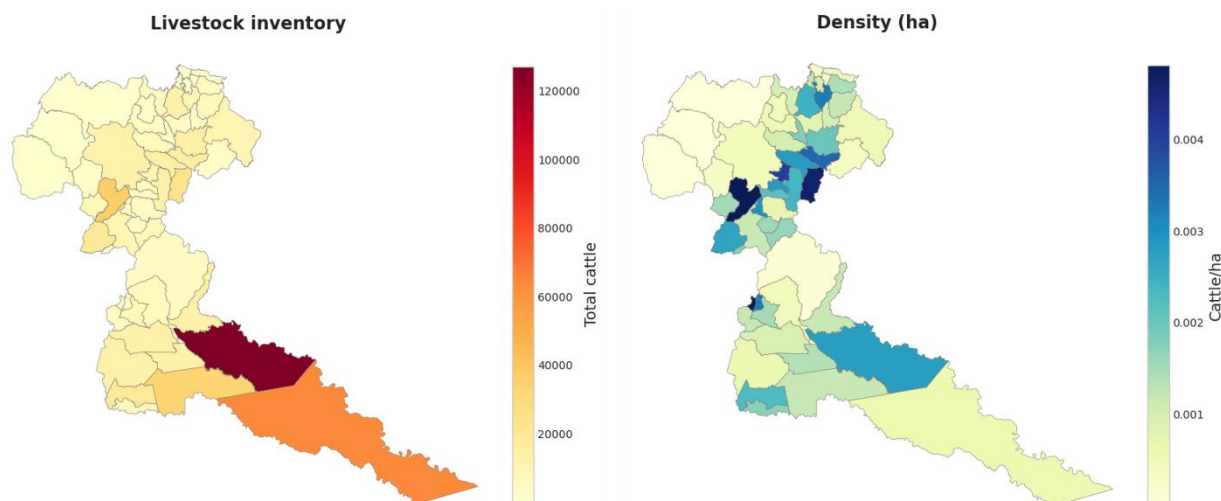


Figure 7. Livestock inventory and density in Cauca and Putumayo in 2024.

Source: Authors' own elaboration, based on (ICA, 2024).

Cattle production, in both departments, is dominated by small-scale systems. In Cauca, in 2024, an average of 93% of cattle farms held between 1 and 50 animals (ICA, 2024). Municipalities such as Piamonte (14%), Guachené (11%), and Patía (11%) showed a greater presence of farms with 51–101 head, while in Mercaderes, 16% of farms held herds of 101–500 animals. Patterns in Putumayo were similar: 87% of farms had 1–50 animals, whereas Puerto Guzmán and Puerto Leguízamo had the highest proportions of farms with 51–100 head (27% and 20%, respectively) and 101–500 head (20% and 26%, respectively). Puerto Leguízamo additionally registered 15 farms with more than 500 animals. These concentrations of medium and large herds overlap with municipalities characterized by vast territories and extensive forest cover. Both Puerto Guzmán and Puerto Leguízamo were among the 18 national high-deforestation hotspots identified during the first quarter of 2025, where extensive cattle ranching was reported as the main direct driver (IDEAM, 2025a).

Suitability maps (UPRA, 2025) indicate that 141,981 ha in Putumayo are classified as having high (30%) or medium (70%) suitability for beef production. For dairy systems, 181,961 ha fall within the high-to-medium suitability range, although 90% of this area is considered to have only medium suitability. In Cauca, suitability is substantially broader: 394,209 ha are identified as highly to moderately suitable for beef production, and 423,216 ha for dairy. In both cases, the distribution between high and medium suitability is even, with each category representing roughly 50% of the suitable area. While high levels of land-use conflict are presumed in both departments, official data to substantiate this is lacking.

Livestock production serves local consumption. In 2024, Cauca collected 16.3 million liters of milk, while Putumayo collected 2.7 million liters (Federación Colombiana de Ganaderos

[FEDEGAN], 2025). That same year, Putumayo slaughtered 7,311 cattle, an average of 609 animals monthly, yielding 1,687 tons of beef, all destined for internal consumption (DANE, 2025c). Milk production in Putumayo is also entirely consumed within the department (FAO & ADR, 2021b). Comparable disaggregated data are not available for Cauca, though supply records indicate that approximately 1,782 tons of dairy and dairy products were delivered from Cauca to cities such as Cali, Medellín, and Manizales in 2024 (Alliance Bioversity International & CIAT, 2025). However, it is not possible to determine whether these products originated in the department or were routed through it as an intermediate storage point.

Given the modest scale of production and the importance of livestock-derived foods for nutrition, understanding the drivers behind the notable percentage of the population that does not consume dairy products in both departments is essential. In Putumayo, where all production is consumed locally, it remains unclear whether consumption gaps reflect limited availability or whether barriers are primarily economic or cultural. In Cauca, the absence of clearer information on how much production leaves the department further complicates the assessment. Strengthening this evidence base is critical to better characterize the local food environment for nutrient-dense animal-source foods and to identify the bottlenecks that need to be addressed at institutional, sectoral, and territorial levels.

3.2.3 Nutrient-dense food

The availability and accessibility of nutrient-dense foods, such as dairy, eggs, legumes, and meat, play a critical role in shaping food security and nutrition outcomes. As presented in the previous section, cattle production contributes significantly to the availability of animal-source and nutrient-dense foods, particularly meat and milk. Other species such as birds, fish, goats, pigs, and sheep are also produced in these departments (ICA, 2024) and contribute to their food and nutrition security, although information about their production (in volume) and commercialization within and outside these departments is scarce. This highlights the need for more detailed and disaggregated data.

While legume production is nutritionally important, it is relatively limited in scale. In Cauca, beans, chickpeas, and peas are produced in lower volumes compared to cereals or tubers. During 2024, 4,463 tons of beans were produced from crops mainly located in the municipalities of Paez (800 ha), Argelia (523 ha), El Tambo (480 ha), and Bolívar (350 ha). In Putumayo, bean production reached 1,602 tons in 2024, from production areas concentrated in Sibundoy (510 ha) and Colón (280 ha) municipalities (UPRA, 2024).

Suitability maps (UPRA, 2025) show that Cauca has about 429,988 ha with high and 273,082 ha with medium aptitude for bean cultivation. This contrasts with the modest 3,192 ha (less than 1% of highly suitable areas) that were established in 2024. Similarly, in Putumayo, 12,279 ha are considered highly suitable and 3,313 moderately suitable. However, cultivated areas in this department only occupied 1,028 ha (8.4% of the highly suitable area) during 2024. Given their protein and micronutrient content, legumes such as beans represent an important opportunity to improve dietary quality in both departments, particularly if production can be strengthened.

3.2.4 Food diversity

To better understand how agricultural production diversity varies across the EPINER project departments, an adapted Shannon Diversity Index was calculated using UPRA’s classification of food groups produced at the municipal level (UPRA, 2024). This index reflects the variety of food groups cultivated in each municipality, regardless of production volume, offering insights into the level of crop-type diversity within the local agricultural systems. Figure 8 presents the index across the EPINER municipalities. Higher values indicate production of a greater number of food groups.

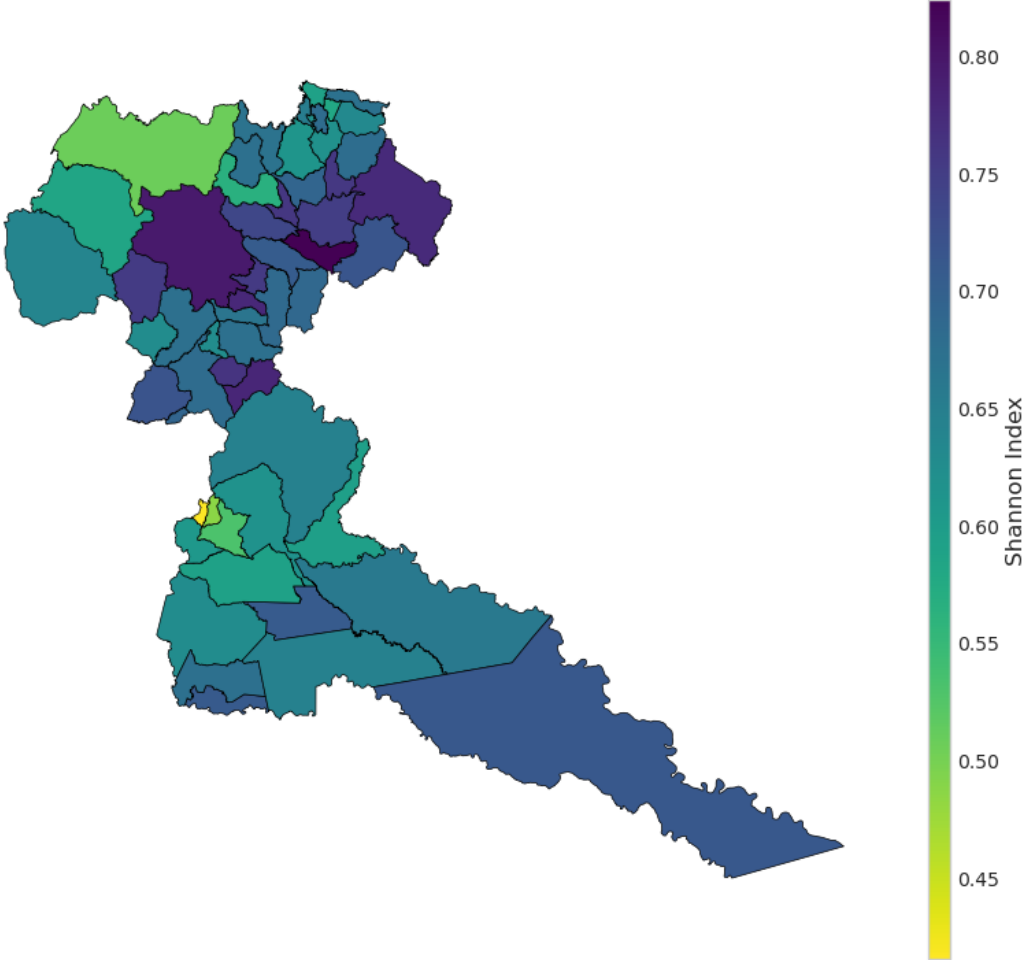


Figure 8. Shannon Diversity Index related to agricultural production diversity in Cauca and Putumayo in 2024.

Source: Authors’ own elaboration, based on (UPRA, 2024). Note: *The higher values correspond to more production from food groups reported by UPRA (not considering the production volume).*

As shown in Figure 8, food production is not evenly distributed across the territory. Some municipalities demonstrate greater crop diversity, an indicator often associated with agroecological resilience, subsistence-oriented systems, and a wider availability of food options at the local level. Others show a narrower range of products, which may reflect specialization in a few commercial crops, lower reliance on agriculture, or less diversified farming systems. Overall, Cauca cultivates a greater variety of crops per food group (Figure 9). Fruit is the most diverse group, with 27 and 32 crops produced in Putumayo and Cauca, respectively. Vegetables

are the second most diverse group in both departments, although Cauca’s vegetable crop diversity (19 crops) doubles that of Putumayo’s (9 crops).

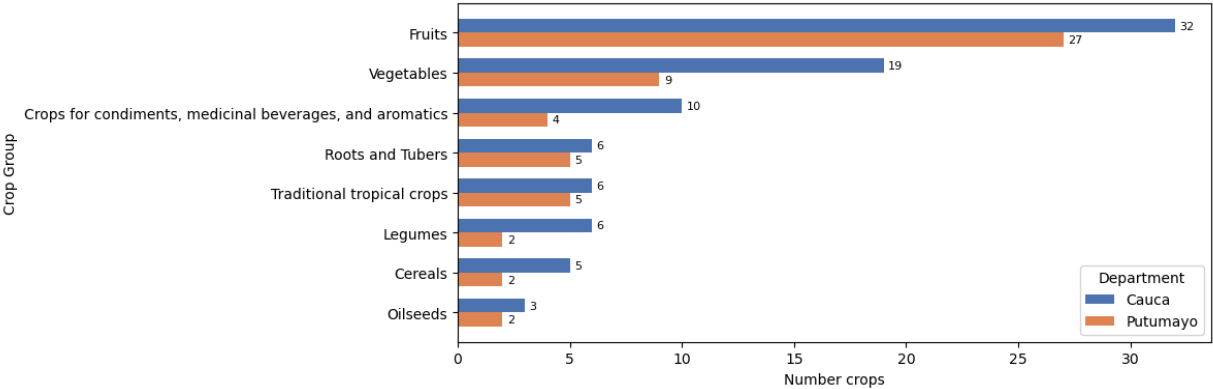


Figure 9. Number of crops per food group in Cauca and Putumayo during 2024. Source: Authors’ own elaboration, based on (UPRA, 2024).

In Cauca, municipalities with the highest Shannon Diversity Index values include Totoró (0.82), El Tambo (0.80), San Sebastián, Rosas, and Páez (0.78 each). Totoró, for example, is an area known for the presence of Indigenous communities and smallholder agriculture, often characterized by traditional practices and polycultures (Sarria et al., 2022). In contrast, municipalities such as López de Micay, Morales, Padilla, Puerto Tejada, and Timbiquí show the lowest diversity values (0.51 to 0.60). Some of these areas, particularly in the northern and central subregions, are more strongly associated with agro-industrial production, including sugarcane and coffee.

In Putumayo, the most diverse municipalities are Puerto Leguizamo, San Miguel, and Puerto Caicedo (0.71 each), which also have strong traditions of family farming, and rich and diverse agroecological landscapes. Meanwhile, Colón, Sibundoy, and San Francisco exhibit lower diversity scores (0.41 to 0.53), perhaps reflecting their specialization in a few crops (such as beans and maize) and their economic reliance on bovine livestock activities.

The diversity index serves two important purposes: it offers a snapshot of the variety in current production systems, and it provides a window into each territory’s adaptive capacity and resilience to market or climate shocks. Municipalities with more diversified production are better positioned to offer locally available, culturally appropriate, and nutritionally varied diets, though this depends on whether that production is accessible to the local population.

3.3 Distribution

This section examines how food supplied from Cauca and Putumayo is distributed across Colombia and analyzes the GHGEs associated with its mobilization. The analysis focuses on the spatial structure of food supply networks linking these two departments to regional and national markets, including the configuration of supply routes, the distances traveled, and the intensity of food flows across different food groups.

To support this analysis, data from Colombia's Agricultural Sector Price and Supply Information System (SIPSA) were used (DANE, 2024). SIPSA provides both temporally and food-type disaggregated data, thus allowing insights into the nationwide movement of key food groups. Supply route distances were calculated using the Google Maps API, while transport-related GHGEs were estimated based on distribution trucks' diesel consumption. These estimates were complemented with vehicle and fuel-use data from Colombia's Ministry of Transportation (Ministerio de Transporte, 2023).

3.3.1. Food flows

Figure 10 illustrates the mobilization of various food groups from Cauca and Putumayo to the rest of the country between 2018 and 2024, providing several notable insights. Firstly, we observe a disparity in flows across all food groups for both departments, with Cauca mobilizing more food than Putumayo. In Putumayo, total annual mobilization rarely reaches 20,000 tons across all categories and remains consistently low. This trend spans the entire period under examination—rather than being isolated occurrences that affect food distribution for shorter time periods—clearly indicating that Putumayo faces persistent challenges in food mobilization. This pattern may reflect longer-term logistical challenges, characterized by Putumayo's geographical isolation and poor road infrastructure, which hinder access to large food hubs, key food distribution centers, and markets such as Popayan and Cali.

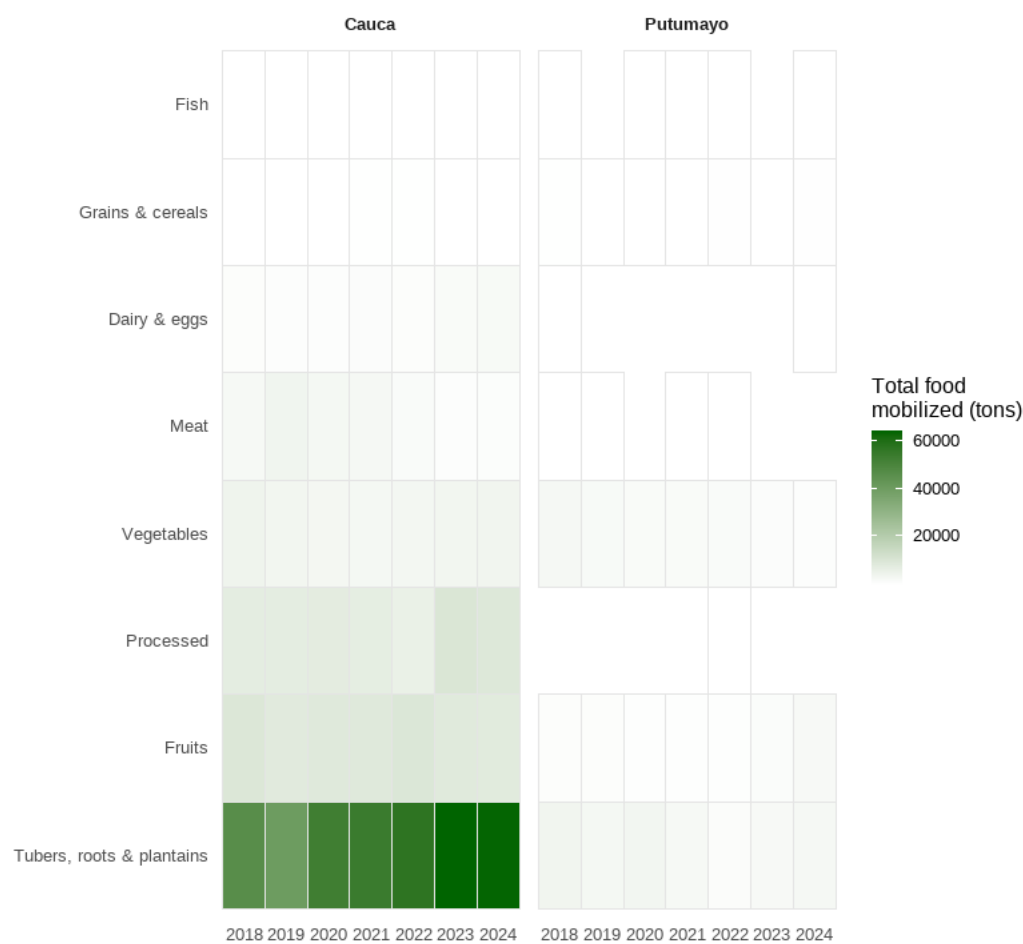


Figure 10. Total volume of food mobilized by food group from Cauca and Putumayo between 2018 and 2024.

Source: Authors' own elaboration based on (DANE, 2024).

Additionally, these findings reflect Putumayo's subsistence-oriented agricultural profile, described in Section 3.2, where production is largely directed toward self-consumption and local markets rather than regional trade; the roots, tubers, and plantains⁴ food group provides this insight. In 2024, Cauca and Putumayo jointly produced approximately 111,558 tons of plantain and cassava (UPRA, 2024); however, this distribution is not mirrored in inter-departmental food mobilization data. In the same year, roughly 60,000 tons of roots, tubers, and plantains were mobilized from Cauca, compared to around 10,000 tons from Putumayo, reflecting Cauca's larger production share for this crop. This finding aligns with additional evidence indicating that approximately half of Cauca's cassava production is industrially processed for trade, whereas Putumayo's cassava production is entirely consumed locally.

Finally, it is important to note that the mobilization data only captures food movements between formal distribution centers and does not account for flows from production sites to these centers or to processing facilities. As a result, local and intra-departmental movements are only partially

⁴ The roots, tubers, and plantains food group contains plantains, in addition to cassava and yuca and other tubers, including several types of potato, arracacha, turmeric, and ulluco. As such, the production data (representing just plantain and cassava) does not account for the entirety of the food 'flow'. However, this data may still be considered representative as the means of comparison.

reflected in these data, which constrains the interpretation of observed mobilization volumes. Nevertheless, the consistently low levels of food mobilization recorded for Putumayo suggest limited integration with broader food value chains, reinforcing evidence of weaker connectivity between local production systems and regional markets, and a trend towards local consumption.

These findings provide insights into the foods mobilized by both departments. The data highlights the broader complexities of the food system, showing that movement can be shaped by local production, in addition to market integration, infrastructure constraints, and household-level food access within the wider food system.

3.3.2 Food distances traveled

The food supply network in which each municipality participates is shaped by its geographic location and the food market, which responds to continuous demand for specific products. Accordingly, supplementary analyses examined the distances traveled, by food type, from the departments of Cauca and Putumayo to other municipalities in Colombia. A clear commonality between mobilized food volumes and distances traveled is that food transported from Cauca travels significantly greater distances than food from Putumayo, indicating that food items from Cauca are transported to distant areas of the country to meet national demand.

Figure 11 shows the total distance traveled, by food group, from Cauca (left) and Putumayo (right) between 2018 and 2024. Cauca exhibits greater transport distances across all categories and years, with processed foods and fruit reaching annual totals of 30,000–40,000 km. Meanwhile, the tubers, roots, and plantains, and the vegetables categories also show substantial flows exceeding 10,000 km/year. In contrast, Putumayo's totals remain notably lower, rarely surpassing 5,000 km annually per food group. Nonetheless, as with Cauca, the fruit and tuber categories mobilized from Putumayo are key contributors to distances traveled, reflecting strong national demand for these foods.

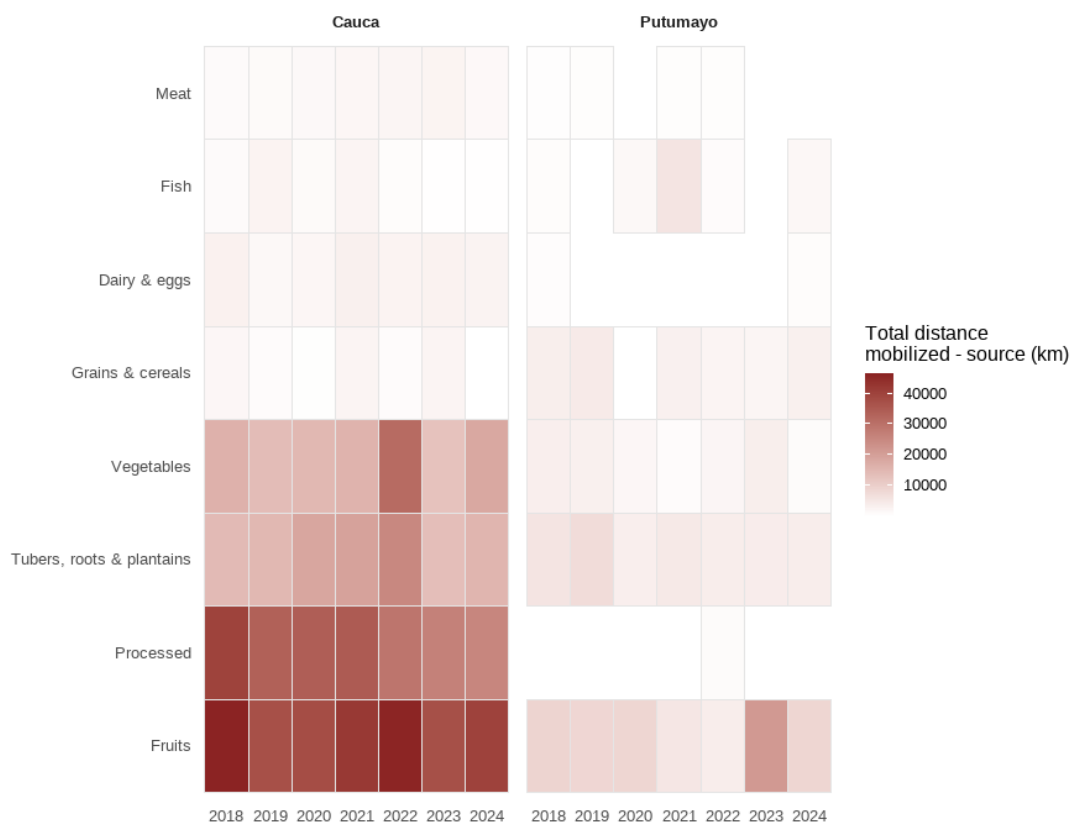


Figure 11. Total distance traveled, by food group, from Cauca and Putumayo between 2018 and 2024.

Source: Authors' own elaboration based on (DANE, 2024).

Figures 12 and 13 represent food travel patterns from Cauca and Putumayo, revealing contrasting dynamics in the organization of their supply networks. These figures also illustrate how perishability, demand structure, and the degree of regional market integration may shape spatial distribution beyond simple volume metrics. The visible differences indicate that food flows are not determined solely by availability, but also by the logistical and commercial configuration of each territory, shaping accessibility and convenience.

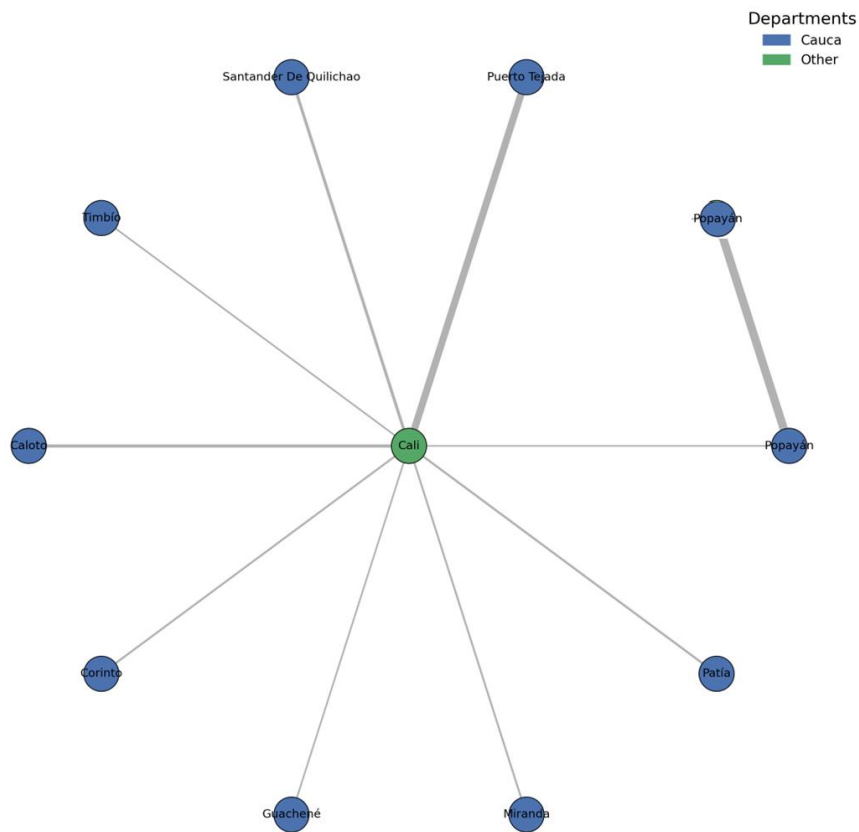


Figure 12. Destinations of meat products mobilized from Cauca during 2024.

Thicker lines represent a higher volume of mobilization. No data was recorded for meat product mobilization from Putumayo Department in 2024. Source: Authors' own elaboration, based on (DANE, 2024; Ministerio de Transporte, 2023).

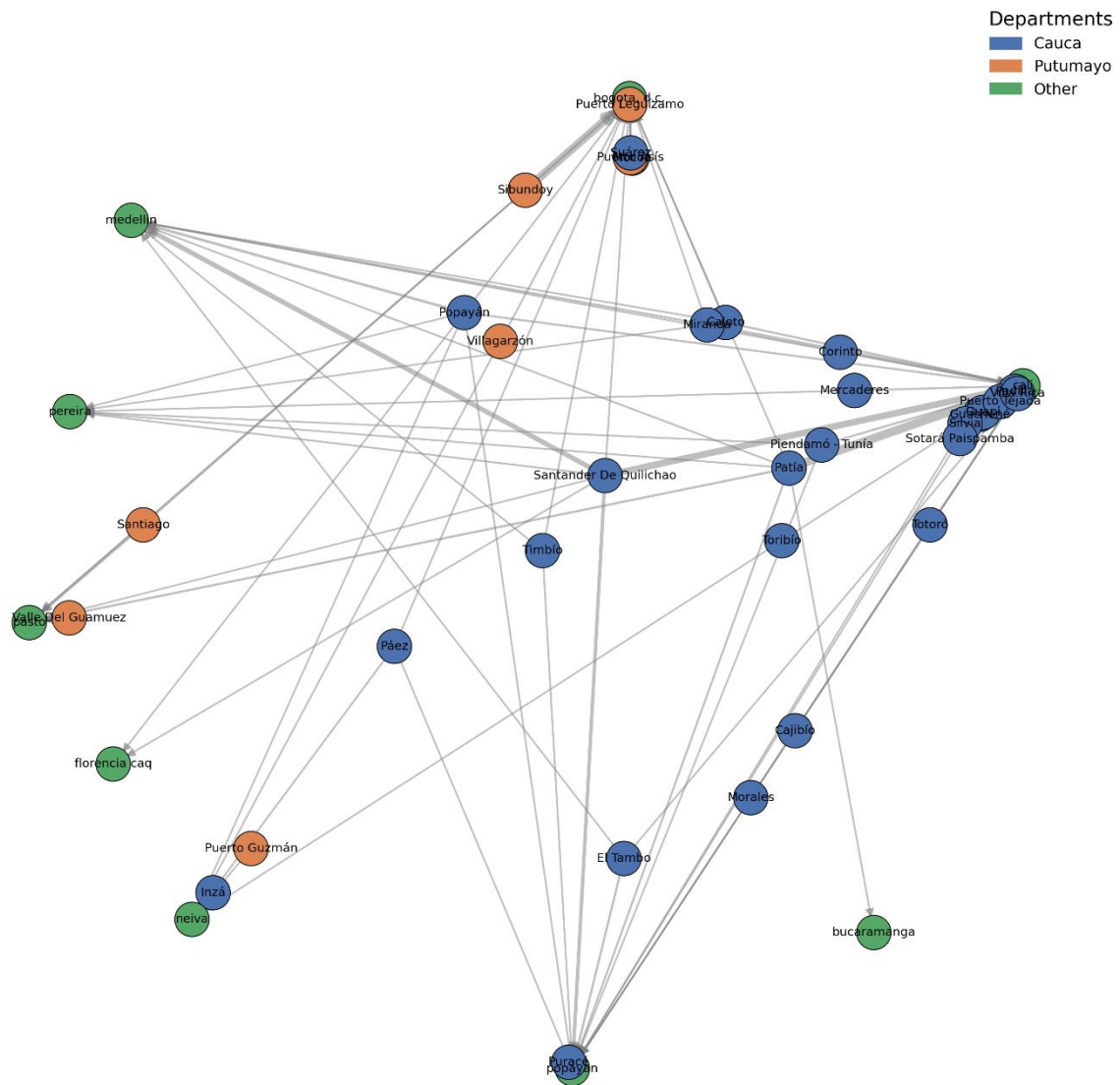


Figure 13. Destinations for fruit mobilized from Cauca and Putumayo during 2024. The thicker lines represent a higher volume of mobilization. Source: Authors’ own elaboration based on (DANE, 2024; Ministerio de Transporte, 2023).

For example, Figure 12 shows that, in 2024, meat mobilization was concentrated on short, intra-regional routes. The largest flows occurred within the same municipality (Popayán, 404 tons) or between nearby municipalities such as Puerto Tejada and Cali (331 tons in total). These patterns suggest that meat distribution is largely confined to Cauca’s immediate economic hinterland, indicating localized demand and short supply chains (Table 1). However, these estimates are based only on records from the country’s main supply centers, so the total volume mobilized may be underestimated.

Table 1. Top ten destinations by volume of meat mobilized from Cauca in 2024.

Source	Destination	Tons mobilized	Distance (km)
Popayán	Popayan	404.1	1.0
Puerto Tejada	Cali	331.3	33.6
Caloto	Cali	91.9	48.5
Santander De Quilichao	Cali	79.6	54.1
Patía	Cali	34.4	213.7
Corinto	Cali	23.4	58.5
Miranda	Cali	18.9	56.1
Timbío	Cali	6.1	152.0
Guachené	Cali	3.5	43.7
Popayán	Cali	0.8	139.0

Source: Authors' own elaboration, based on (DANE, 2024; Ministerio de Transporte, 2023).

Due to their strict cold-chain requirements, high logistical costs, and sanitary risks, meat products tend to supply nearby markets, particularly when strong regional demand can absorb local production (Stringer & Hall, 2007). Meat, therefore, falls within short food supply chains, defined by a limited number of intermediaries and close geographical and organizational proximity between producers and consumers (Marsden et al., 2000; Renting et al., 2003). This factor also influences the item's final price (Schwartz et al., 2009), making it more affordable than if it were to travel long distances and require more intermediation.

In contrast, fruit supply networks (Figure 13) show a wider spatial reach and a clearer integration into long food supply chains, accessing distant regional and national markets. Reardon et al. (2009) demonstrate that, despite their perishability, certain fresh products can be successfully integrated into long-distance supply circuits when differentiated demand, agroecological comparative advantages, or sufficiently high prices offset transportation costs and associated losses.

In megadiverse countries such as Colombia, fruit production associated with specific agroecological niches facilitates integration in distant markets (FAO, 2017). Table 2 illustrates this extended network. While regional corridors such as Patía–Cali (~1,765 tons) and Santander de Quilichao–Cali (~1,239 tons) anchor fruit distribution within the region, significant volumes are also mobilized toward distant consumption centers such as Bogotá (~1,642 tons) and Medellín (~792 tons). The presence of these long-distance flows, particularly from relatively remote origins, demonstrates how product differentiation and market demand can sustain extended supply chains despite higher transportation costs and logistical difficulties.

Table 2. Top ten destinations by volume of fruit mobilized from Cauca and Putumayo in 2024.

Source	Destination	Tons mobilized	Distance (km)
Patía	Cali	1764.6	213.7
Sibundoy	Bogotá, D.C.	1641.8	717
Santander De Quilichao	Cali	1238.5	54.1
Sotará Paispamba	Cali	881.5	172
Santander De Quilichao	Medellin	792.2	483
Padilla	Cali	526	50.6
Santander De Quilichao	Popayan	436.7	81.9
Santiago	Pasto	418.2	428
Miranda	Cali	354.4	56.1
Silvia	Cali	299.1	130

Source: Own elaboration based on (DANE, 2024; Ministerio de Transporte, 2023).

Beyond the intrinsic characteristics of the products, the geometry of the supply networks reflects territorial inequalities in market integration. Cauca exhibits stronger connectivity and articulation with regional and national markets, while Putumayo occupies a more peripheral position within the food system, where higher transportation costs and smaller commercial scale constrain the viability of long-distance flows. Nevertheless, the existence of large flows from remote territories to major consumption centers suggests that the desirability of differentiated products can, in certain cases, overcome traditional logistical barriers.

Taken together, these patterns highlight how geographic specificity, value chain structures, and demand interact to shape departmental contributions to national food security, confirming the systemic and relational nature of territorial food systems (Ericksen, 2008).

Weighted Average Shortest Distance

Building on the previous analysis of food flows by product type, the Weighted Average Shortest Distance (WASD) is introduced as a complementary indicator to quantify the spatial structure of food supply networks. While Figures 12 and 13 highlight the differences in distribution patterns between meat and fruit supply chains, the WASD provides a synthetic measure of how far food effectively travels, weighted by transported volumes, capturing both the intensity and spatial reach of supply relationships.

By weighting distances by the amount of food mobilized, the indicator highlights dominant supply corridors and allows the identification of short versus long supply circuits (Blanke & Burdick, 2005). In this context, lower WASD values indicate a stronger spatial proximity between production and consumption, whereas higher values reflect more extended and less localized supply networks.

Food Supply Weighted Average Shortest Distance from Cauca and Putumayo

Figure 14 presents the distribution of WASD values for food supplied from Cauca and Putumayo to other municipalities in Colombia. In both departments, there is a pronounced peak for short distances, where food production is distributed to nearby markets. This pattern confirms the predominance of short supply circuits, in which most of the food produced by each territory is consumed within a close range.

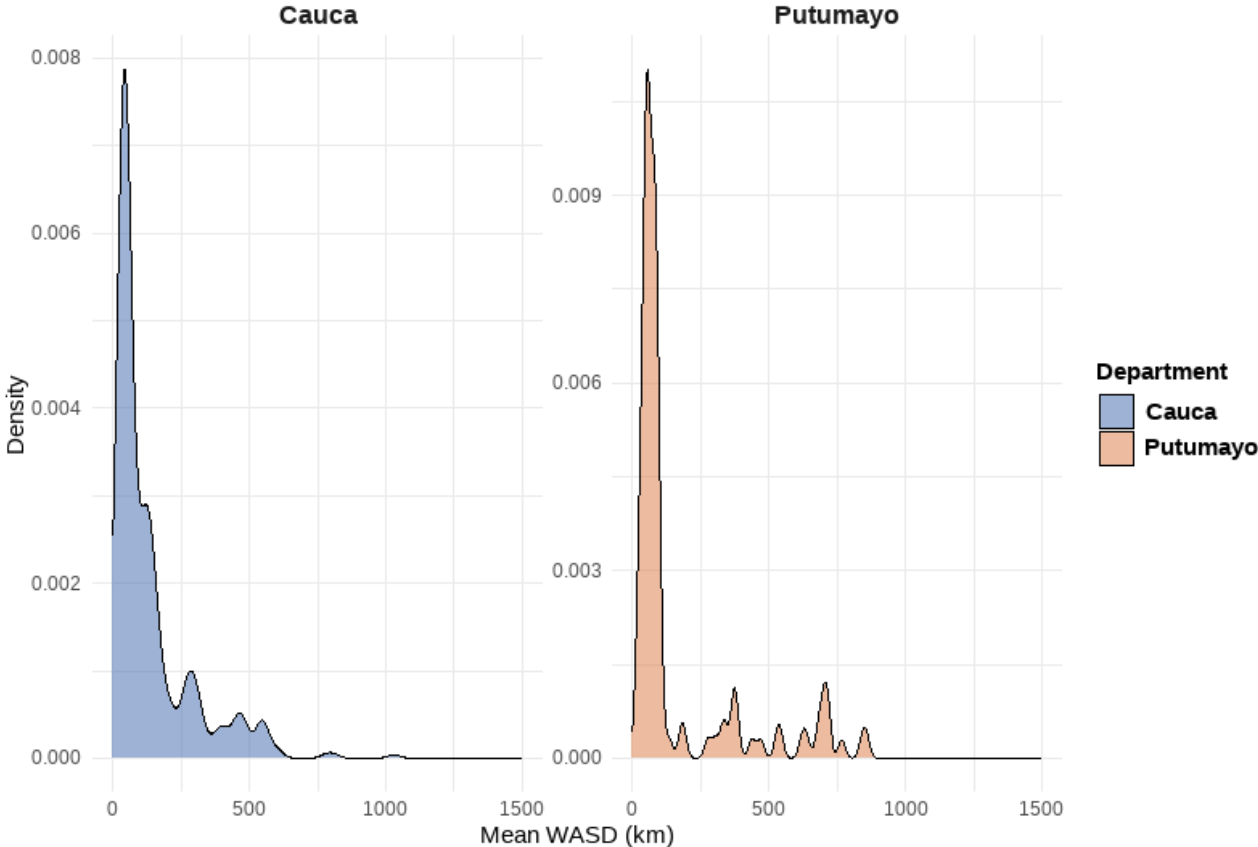


Figure 14. Weighted Average Shortest Distance of food supplied from Cauca and Putumayo Departments to other national municipalities in 2024.

Source: Own elaboration based on (DANE, 2024; Ministerio de Transporte, 2023).

Despite this common pattern, territorial differences emerge. Putumayo shows a wider range of distances, with WASD values reaching approximately 1,600 km, whereas from Cauca, the distances rarely exceed 1,000 km. Although Putumayo is less integrated into national markets, when long-distance connections do occur, they tend to span greater spatial extents, reflecting its peripheral geographic position and the need to reach distant consumption centers.

Food Supply Weighted Average Shortest Distance to Cauca and Putumayo

When considering the WASD of food entering Cauca from other territories (Figure 15), a similar pattern is observed. Most incoming food originates from nearby areas, as indicated by the dominant peak within the first few hundred kilometers. At the same time, the presence of a smaller secondary peak over longer distances shows that Cauca maintains selective connections

with more distant suppliers. This combination of short- and long-distance sourcing reflects a diversified supply structure that balances localized supply networks with external linkages, as discussed in the previous section. Comparable data are not available for Putumayo.

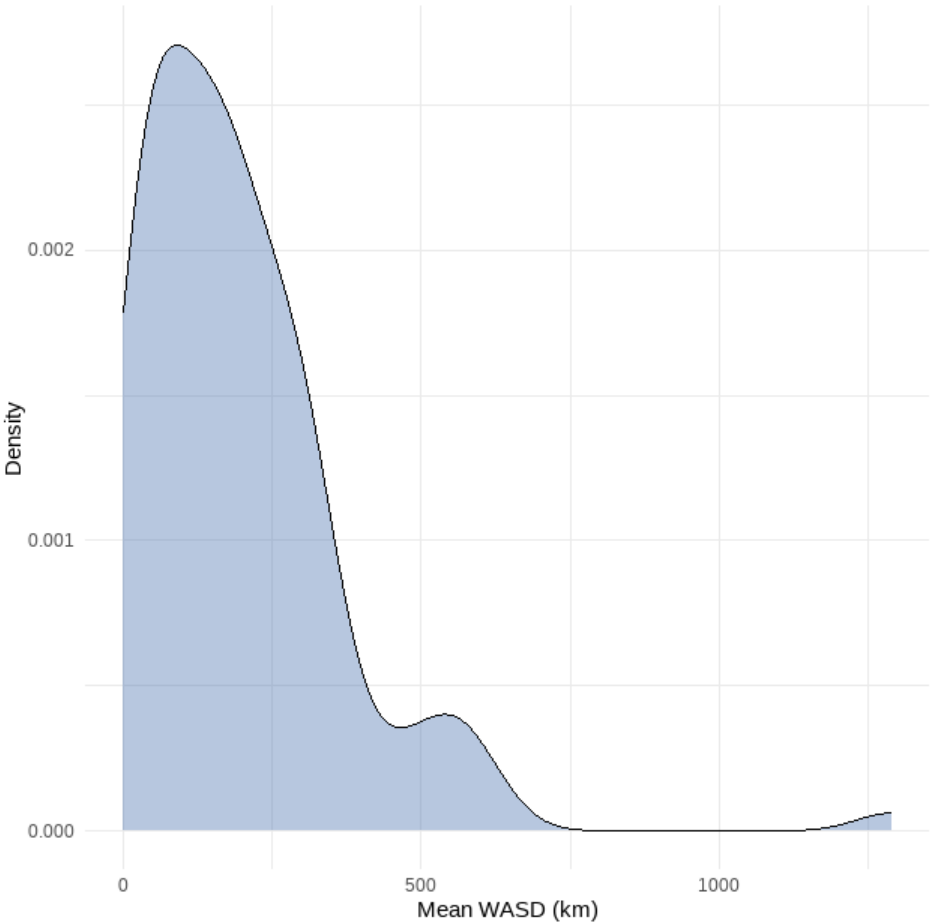


Figure 15. *Weighted Average Shortest Distance of municipalities supplying Cauca in 2024.*
Note: No data was reported for Putumayo in 2024.

Disaggregating the WASD by food item for distances below 60 km (Figure 16) provides additional insights into the composition of short food supply chains. In both Cauca and Putumayo, the food groups of fruit, vegetables, and meat are primarily supplied through short-distance supply chains, indicating that everyday food consumption relies largely on local and nearby producers.

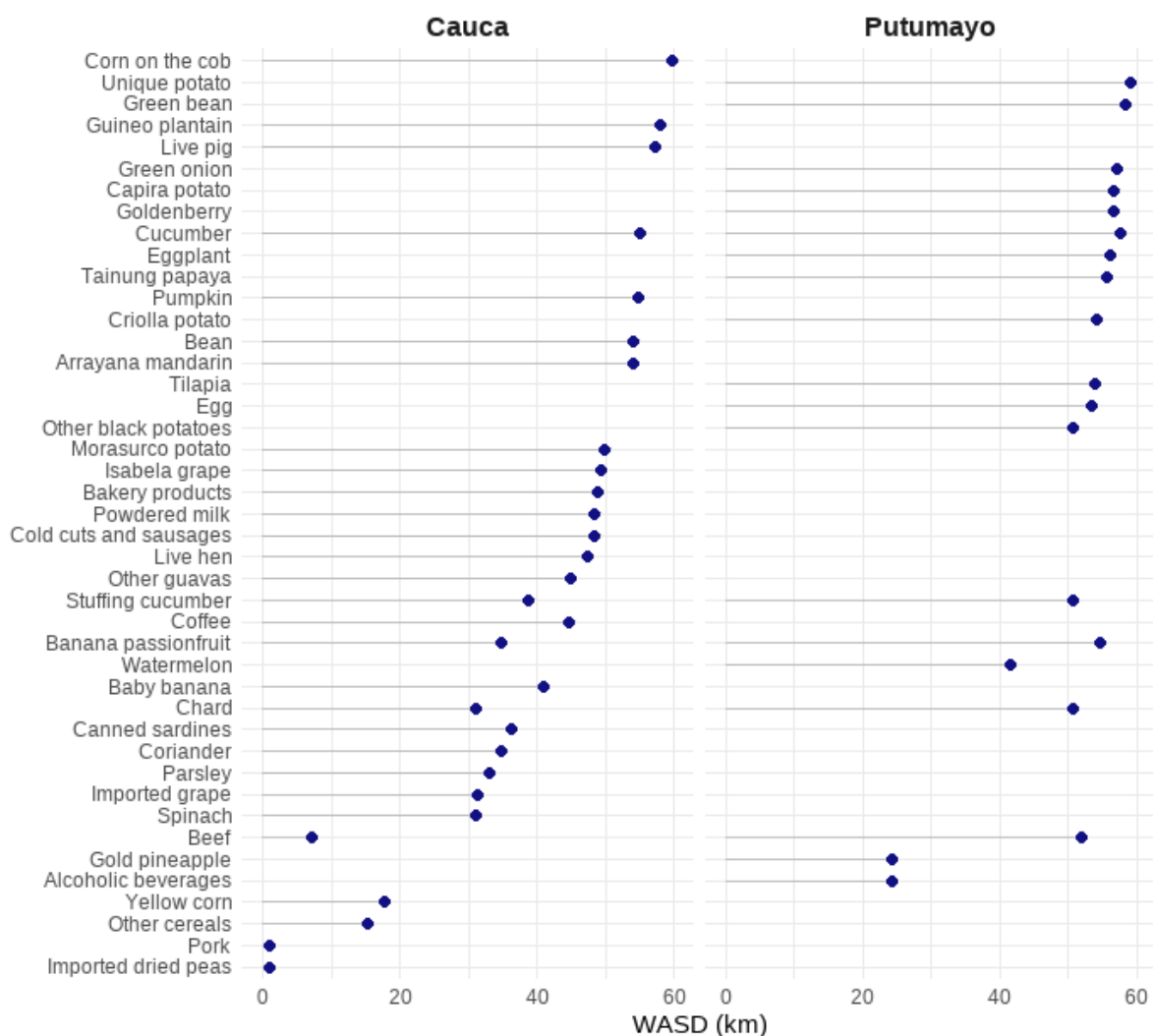


Figure 16. Weighted Average Shortest Distance by food item for short food circuits (< 60 km) in Cauca and Putumayo during 2024.

Source: Authors' own elaboration, based on (DANE, 2024).

Taken together, the WASD analysis complements the flow-based evidence presented earlier by clarifying the spatial structure of food supply networks in Cauca and Putumayo. The results indicate that short supply circuits dominate food distribution in both departments, particularly for perishable products, while long-distance flows occur more selectively in response to market demand, product differentiation, and territorial conditions.

3.3.3 Food mobilization-related emissions

Food mobilization to and from each department generates GHGEs, predominantly due to the strong reliance on land-based transport in Colombia. These emissions are determined by both the distances traveled and the intensity of food flows from Cauca and Putumayo to final market destinations nationwide. Transport-related emissions are estimated using route distances, vehicle categories, fuel types, and corresponding biophysical emission factors (Castillo et al., 2024).

Cauca generates higher transport-related emissions than Putumayo, which is associated with its larger scale of food production and distribution (Figure 17). In 2023, food transport from Cauca produced approximately 3,000 metric tons of CO₂-equivalent emissions, compared to about 585 metric tons for Putumayo. This gap persisted in 2024 and is consistent with previous results indicating Cauca’s stronger market integration and higher volumes of food mobilization.

When emissions are disaggregated by food group, the tubers, roots, and plantains group accounts for the largest share of transport-related GHGEs in both departments (Figure 17). Fruit and vegetables follow as the second- and third-largest contributors, respectively. These patterns reflect the combination of high transport volumes and moderate travel distances, rather than the prevalence of long-distance movements.

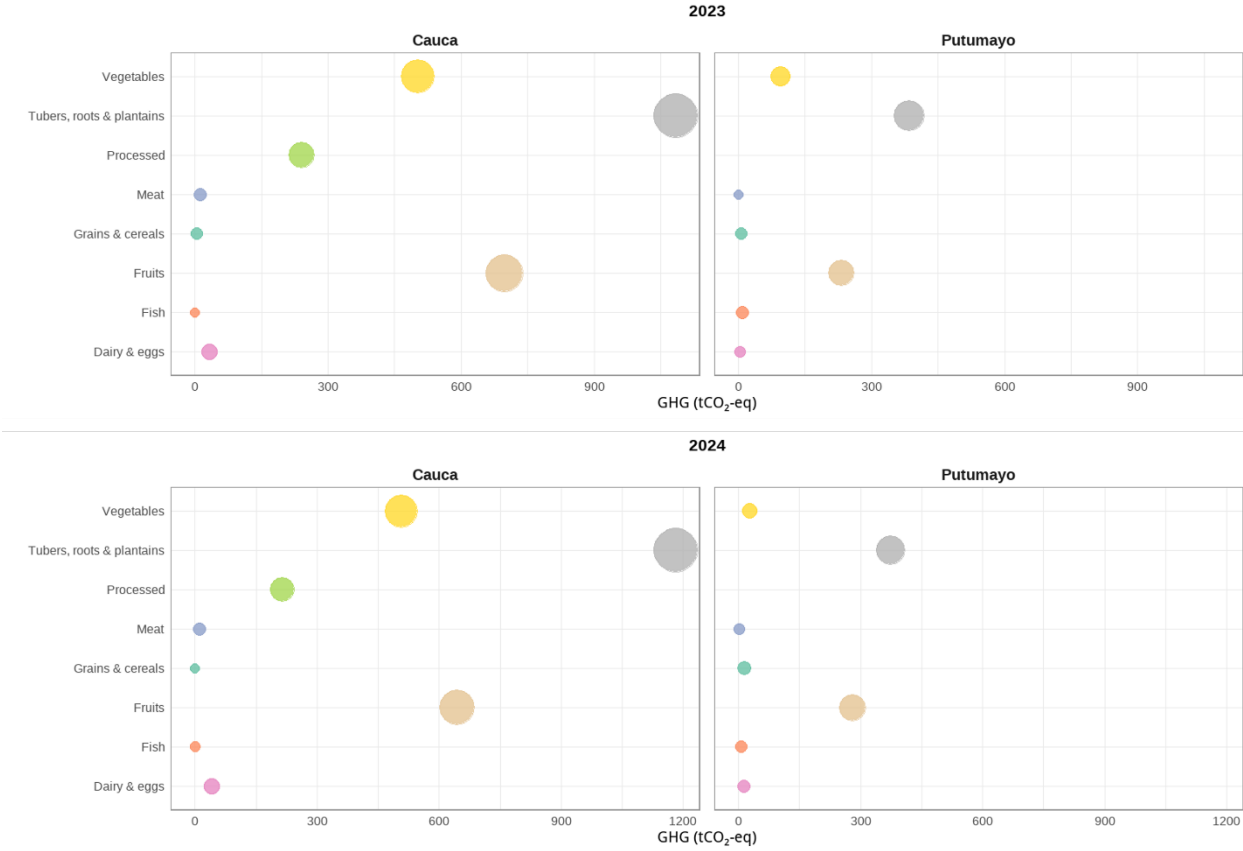


Figure 17. Greenhouse gas emissions generated by food mobilization, presented by food group, in Cauca and Putumayo during 2023 (top) and 2024 (bottom).

Source: Authors’ own elaboration based on (DANE, 2024; Ministerio de Transporte, 2023).

Transport-related emissions are closely linked to the spatial structure of the food supply networks, described in Section 3.3.2. Results for WASD show that products generating higher emissions do so through differentiated spatial mechanisms. In the case of meat, transport emissions originate primarily from frequent movements within short supply circuits, resulting in relatively low transport-related emissions. In contrast, fruit supply chains incorporate long-distance flows toward national markets, leading to higher levels of GHGEs. Transport emissions are therefore determined not only by the distance traveled, but also by the scale, frequency, and spatial configuration of food mobilization across different product groups.

Emissions derived from food transport represent a relatively small fraction of total food system emissions when compared to those originating from agricultural production and land-use change, particularly for animal-based products. In these systems, production processes and land-use transformations account for most of the climate footprint, while transport contributes a smaller share of total emissions (Weber & Matthews, 2008). Nevertheless, transport-related emissions remain territorially relevant, as they depend directly on the spatial organization of supply networks and the efficiency of logistical systems.

In this context, road infrastructure quality also plays a central role in shaping transport-related emissions. Poorly connected or deteriorated road networks increase travel times and fuel consumption, thereby raising emissions per unit transported. These inefficiencies not only have environmental implications but also increase distribution costs and can constrain access to affordable food, particularly in rural and remote areas (Schwartz et al., 2009; Sharif & Tauqir, 2021).

4. Financing and Security Insights

This section examines agricultural financing and conflict, given their significant influence on the departments' food environments through their roles in shaping agricultural production and altering local market dynamics.

4.1 Financing insights

In Colombia, agricultural finance is structured around a second-tier development banking model, where the Fund for the Financing of the Agricultural Sector (FINAGRO) acts as the central institutional mechanism for channeling credit into the rural economy. However, rather than lending directly to producers, FINAGRO provides discounted financial instruments to commercial banks and other financial intermediaries, which in turn allocate credit to agricultural producers and rural enterprises. While this architecture intends to expand the availability of agricultural credit, its reliance on intermediary risk assessment⁵ means that access remains uneven across producer types and territories, with important implications for production systems and local food environments. For example, given the perception of lower returns and higher risks in sustainable investments, investment in lower-emission food production systems is discouraged (Agri3 Fund, 2025).

Indeed, empirical evidence from Colombia's agricultural credit system suggests that small producers face persistent barriers to formal credit access (Guzmán-Finol et al., 2025). However, recent national studies show that, whilst small-scale producers receive less than 30% of the total amount disbursed, they account for more than 90% of beneficiaries (Granger-Castaño et al., 2025). At the Cauca and Putumayo departmental level, these same credit allocation patterns are

⁵ Financial intermediaries or lenders such as banks, not FINAGRO, maintain decisive power over who benefit from credit, based upon lenders' means of risk assessment and likelihood of return, amongst other contributing factors.

evident, reflecting the structural dynamics embedded within Colombia's agricultural finance system. In assessing the latest data provided by FINAGRO (2025), it was found that 95% of all loans were granted to small-scale producers in the form of rural microcredit working capital in these two departments. This corresponds to most of the total loans allocated, alluding to both accessible and impactful assistance from each department to small producers. However, given the nature of the rural microcredit working capital, its ability to enable lasting impact may be overrated. In rural Colombia, loan recipients of rural microcredit indicate that it has high interest rates and provides insufficient credit, and is often used by small producers to stay afloat (Mirza & Pringle, 2025). In this sense, rural microcredit does not necessarily reflect transformative finance, and structural power in the credit system remains unchanged. Therefore, while a significant amount of capital may have been dispersed through this mechanism, its impact is limited compared to other forms of capital-intensive, though structurally transformative, loans (Gutierrez & Reddy, 2015).

The following data is drawn from a deeper analysis of FINAGRO (2025). In 2024, approximately COP 146,156 million in FINAGRO-backed loans were disbursed across both departments, corresponding to an estimated 11,442 credit placements. Cauca received approximately COP 105,604 million (72%) through 8,483 loan placements (74%), while Putumayo recorded COP 40,552 million (28%) distributed amongst 2,959 loans (26%). Compared to previous years, these figures reflect a sharp increase in total credit volumes alongside a limited number of loans, indicating a shift toward larger average loan sizes and more selective credit allocation.

Credit distribution in both departments was strongly commodity-specific, reinforcing existing production specializations. In Cauca, coffee production dominated credit allocation, receiving approximately COP 62,935 million for investments in this sector. This corresponds to almost 60% of total departmental credit; sugarcane for panela followed with COP 17,132 million, while plantains received COP 6,238 million. This configuration reflects a credit environment oriented toward established value chains, particularly export-oriented or agro-industrial crops, rather than diversified food production.

Putumayo follows a similar trend, leaning towards commodity-driven financing. Plantain production accounted for approximately COP 24,475 million, which corresponds to 60% of the total credit allocated, while cocoa received COP 5,148 million. The emphasis on a narrow set of commercially viable crops reflects both territorial risk considerations and intermediary preferences for activities with predictable returns and established market outlets.

From a food systems perspective, the 2024 credit profile presents limited alignment between agricultural finance and improvements in local food environments. Financing is oriented towards a narrow range of cash and staple crops, many of which are integrated into regional, national, or export value chains. This concentration of financing in capital-intensive segments can contribute to increasingly specialized production (Jin & Liu, 2025), thus reinforcing existing production structures rather than facilitating a transformation toward diversified or nutrition-sensitive agriculture. While such investments may increase aggregate production and

stabilize producer incomes, they do not automatically improve local food availability, affordability, or dietary diversity.

Agricultural financing, therefore, does not appear to contribute to more resilient and inclusive local food environments in Cauca and Putumayo. These are high-risk departments with weaker collateral environments, lower institutional presence, and highly conflict-affected. Given this context, banks and intermediaries might avoid long-term lending and fall back on standardized, low-risk microcredit lending. As such, it highlights a risk-averse system, which applies the least transformative instruments available.

4.2 Social conflict and security

Colombia has endured a prolonged internal armed conflict that has profoundly shaped rural realities and the broader political economy of land, livelihoods, and food systems (Iglesias et al., 2024; Vanegas-Cubillos et al., 2022). In departments such as Cauca and Putumayo, historical and ongoing violence interplay with territorial control over illicit economies, weak state presence, and persistent insecurity, creating conditions that limit agricultural production, livelihoods, and household food environments. Furthermore, the means and consequences of conflict are multifaceted, encompassing armed engagements, forced displacement, and territorial disputes, which threaten civilian security. Collectively, the ability to use land, access to productive assets, and rural investment patterns are persistently affected (FAO et al., 2017).

In this subsection on social conflict and security, we examine three indicators that aim to capture different dimensions of conflict intensity and its implications for rural life: (a) spatial distribution of antipersonnel mines; (b) homicide rates; and (c) hectares under illicit coca cultivation. Each of these factors cuts across local economic processes, either directly by restricting access to land and markets or indirectly by shaping risk perceptions that affect investment, labor allocation, and livelihood choices.

4.2.1 Antipersonnel mines

The use of antipersonnel mines (APMs) in conflict, often to protect the production of illicit crops as well as to guard threatened territory, has obvious implications for nearby communities. Given that these devices remain active for years after installation, their territorial impact persists even after armed conflict has ended, serving as a stark and persistent reminder of historical disputes (Ruiz Romero & Castaño Zapata, 2021). Beyond their immediate toll on human life, mines constitute a structural barrier to economic activity by creating enduring areas of de facto exclusion, thus restricting mobility and potentially limiting access to productive land. Furthermore, lands containing mines are high-risk, thus deterring rural investment (Prem et al., 2025) and potentially reinforcing reliance on low-risk, microcredit loans.

Since 1990, Cauca has reported 727 devices, of which 108 remain unidentified, with 243 associated with the former Revolutionary Armed Forces of Colombia – People's Army (FARC-EP). Municipal hotspots include Argelia, El Tambo, Santa Rosa, and Toribío, each with more

than 40 confirmed devices. Putumayo registered 463 mines over the same period, of which almost 200 lack information on responsible actors, while approximately 200 are attributed to FARC-EP dissidents. Puerto Asís, Puerto Caicedo, and Puerto Guzmán are among the most critically affected municipalities, having identified over 40 devices each. Furthermore, each department clearly exhibits hotspots for landmine placement, often in easily accessible places, near roads (in Cauca, on Highway 25, and in Putumayo, on Highway 45) and towns. Landmines in Cauca have rarely been placed on the western side of the *Cordillera* (mountain range) and on the eastern side of Putumayo, where there is little infrastructure, and where there appears to be little landmine activity. One noticeable feature in Putumayo, however, is the concentration of mines placed along the Ecuadorean border. Maps reveal the extent of contamination over the last decade, in Cauca and Putumayo (Figure 18).

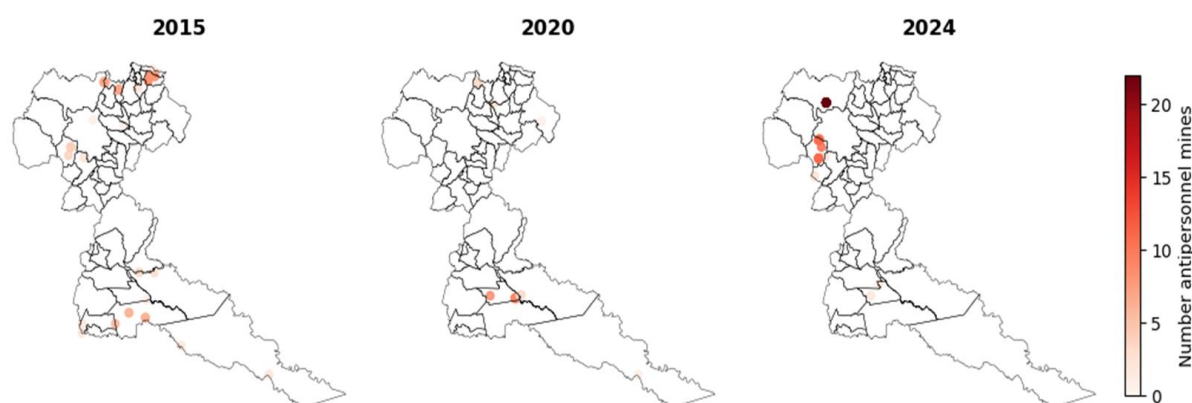


Figure 18. Overview of antipersonnel mines in Cauca and Putumayo in the last decade.

Source: Authors' own elaboration based on (Acción Integral Contra Minas Antipersonal [AICMA], 2025).

These findings indicate that large swaths of rural territory in each department, often agricultural, are subject to the dangers of APM activity. Mines placed on rural roads, fields, and mountainous terrain effectively reduce the availability of arable land and thus constrain production, forcing farmers to shift agricultural activity to lower-risk areas. In this context, there is an increased pressure on forested areas from agricultural expansion, thereby increasing land-use change-related emissions, in line with empirical studies documenting a positive relationship between conflict and deforestation (Bautista-Céspedes et al., 2021; Negret et al., 2019). However, numerous studies have also suggested an inverse relationship between armed conflict and deforestation (Clerici et al., 2020; Murillo-Sandoval et al., 2020; Prem et al., 2020). Given that it is difficult to know exactly when an APM was deployed, it is challenging to provide an explicit link between mine deployment and land-use changes.

Empirical studies linking landmine presence to diminished food security outcomes in the Colombian context are also scarce, though a recent study in Lebanon (Garbino, 2019) highlights this effect. In this study, APM activity negatively affects food production and security, primarily through a decrease in access to arable land. Additionally, recent studies point to the positive effects of 'demining' on improved economic performance in Mozambique (Chiovelli et al., 2025), though with no attempt to assess the effect on food security.

In practice, the presence of APMs in Cauca and Putumayo reinforces broader conflict dynamics that shape rural livelihoods. Mines do not merely signify episodic violence; they create persistent spatial fractures that reconfigure land use, influencing where and how people produce food. Furthermore, as Prem et al. (2025) demonstrate, APM activity can intersect with other conflict variables (in that case, coca leaf production) to shape a multi-dimensional insecurity regime. Addressing these constraints is therefore integral to understanding how conflict continues to influence agricultural production systems and the local food environments of these departments.

4.2.2 Homicides

Homicide represents the most severe and socially disruptive manifestation of violent insecurity across the study territories. While both Cauca and Putumayo exhibit elevated levels of homicide compared to national averages, the scale, spatial concentration, and temporal trajectories differ between departments.

Cauca records markedly higher homicide levels and an overall sustained upward trend over the time period (Figure 19). Annual homicides rose from approximately 512 in 2005 to 843 in 2023, indicating a persistent intensification (48.46%) of lethal violence over two decades, with more than 500 homicides reported in the last three years alone. Victimization is overwhelmingly male, with approximately 91% of reported cases being men. At the municipal level, homicides are concentrated in El Tambo, Corinto, Patía, Popayán, Puerto Tejada, and Santander de Quilichao. Notably, these municipalities also correspond to the most densely populated and economically active areas of Cauca Department, suggesting that absolute homicide counts may, at least in part, reflect population size and urban concentration rather than uniformly higher per-capita risk across all territories.

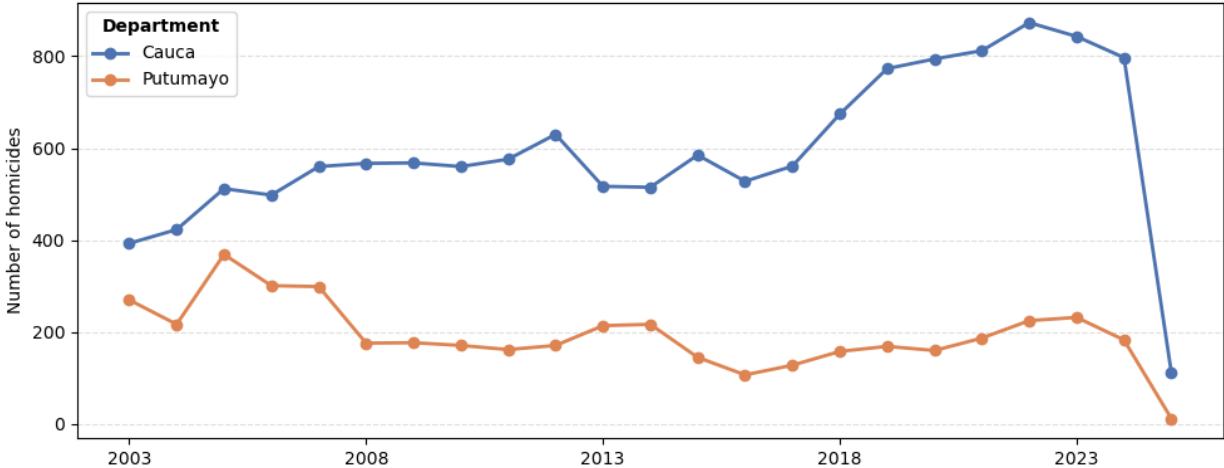


Figure 19. Temporal evolution of homicides in Cauca and Putumayo.
Source: Authors’ own elaboration, based on (Ministerio de Defensa Nacional, 2025).

Putumayo exhibits lower absolute homicide levels but follows a distinct temporal pattern. Over the past decade, annual homicides have averaged around 170, with a pronounced low in 2016 at 107 during the signing of the Peace Agreement. Since then, homicide levels have increased

steadily, reaching 232 in 2023. As in Cauca, approximately 90% of victims are men. The municipalities with the highest reported homicide counts (Puerto Asís, Valle del Guamuez, and Orito) are also the most populous urban and commercial centers in the department (DANE, 2019). This spatial pattern again raises the possibility that observed concentrations of homicide are driven by demographic and settlement patterns, rather than by uniformly elevated violence intensity across rural areas.

Across both departments, the clustering of homicides in population centers complicates a straightforward interpretation of violence intensity. Higher absolute homicide rates in urban municipalities may reflect greater population density, increased economic activity, and improved reporting capacity, rather than inherently higher per-capita risk. Without standardized homicide rates adjusted for population size, it is not possible to determine conclusively whether violence intensity is greater in these municipalities or whether observed patterns are primarily a function of scale. Nonetheless, the sustained upward trend in Cauca and the post-2016 rebound in Putumayo suggest that homicide remains a structurally embedded feature of the territorial security landscape, with implications for social stability, mobility, and economic activity.

From a food systems perspective, these homicide dynamics matter less as isolated indicators of criminality and more as proxies for broader insecurity. Even where violence is spatially concentrated in urban centers, its presence can influence rural–urban linkages, market access, labor mobility, and perceptions of risk across surrounding production zones. And, whilst relevant literature is scarce, studies have linked political violence with decreased farm household efficiency, specifically in Colombia (González & Lopez, 2007). As such, homicide trends provide important contextual information for understanding the operating environment in which agricultural production, commercialization, and food distribution take place, even when direct causal pathways remain difficult to isolate.

4.2.3 Coca cultivation

Nationally and at the departmental level, coca production is linked to the illicit drug economy in Colombia and remains a defining feature of its rural landscapes. There is substantial literature linking coca cultivation, armed conflict, and broader land-use change, illustrating how illicit crop dynamics intersect with structural insecurity and environmental pressures (Ganzenmüller et al., 2022; Murillo-Sandoval et al., 2020; Peña, 2017). Spatial analyses show that coca cultivation and armed conflict intensity are both associated with enhanced deforestation risk in biodiverse regions, particularly where governance vacuums and illegal crop proliferation coincide (Negret et al., 2019). Furthermore, earlier studies have concluded that the expansion of illegal crop growing is a consequence of expanding conflict (Díaz & Sánchez, 2004), exacerbating deforestation.

In 2016, Putumayo and Cauca accounted for 17% (25,162 ha) and 9% (12,595 ha) of the national coca-cultivated areas, respectively, ranking fourth and second nationwide in terms of production (United Nations Office on Drugs and Crime [UNODC] & Government of Colombia, 2017). By 2023, this had increased to approximately 31,845 ha in Cauca and 50,440 ha in

Putumayo, respectively (Figure 20). This growth reflects a sustained upward trend in coca cultivation over the past two decades, during which both departments have consistently remained among Colombia’s principal coca-producing regions.

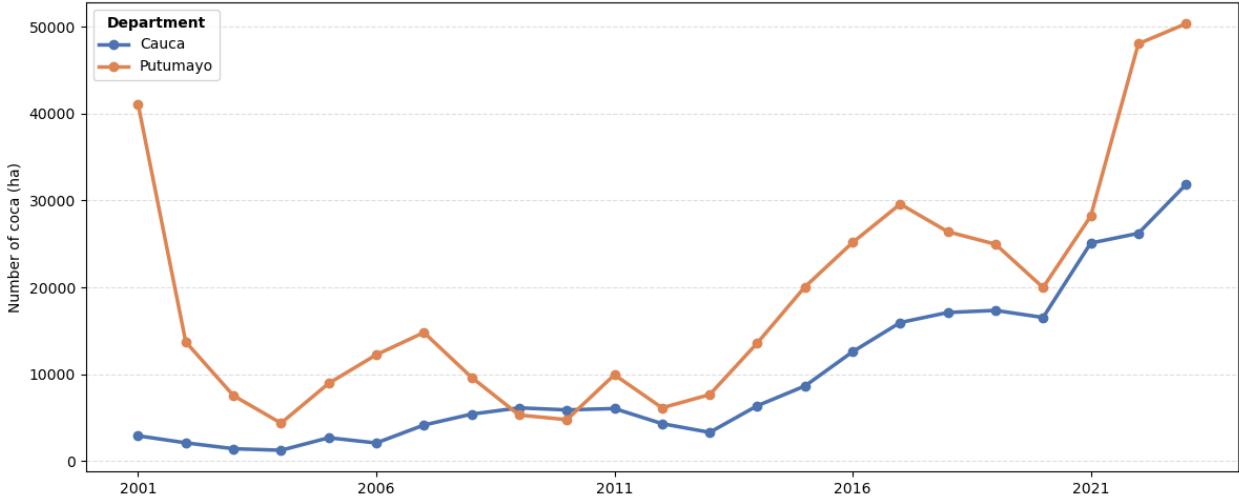


Figure 20. Temporal evolution of coca crops in Cauca and Putumayo between 2001 and 2021. Source: Authors’ own elaboration, based on (Ministerio de Justicia y del Derecho, 2024).

The spatial patterns of coca cultivation in these departments highlight not only rural expansion but also the importance of territorial connectivity and economic nodes in shaping its distribution. In Putumayo, for example, coca is heavily concentrated in and around Puerto Asís, the most populous and commercially connected municipality. This indicates that coca expansion is not confined to remote or marginal frontiers but is also embedded in territories with population, transport access, and market linkages. As such, one cannot maintain a simplistic frontier narrative and must instead note that coca dynamics are influenced by a conjunction of demographic, infrastructural, and illicit value-chain considerations.

As mentioned, coca cultivation in Putumayo is concentrated in Puerto Asís, Valle del Guamuez, Orito, and San Miguel, while in Cauca it is particularly prominent in El Tambo and adjacent rural municipalities. These patterns reflect coca cultivation’s complex geography, where proximity to labor pools, accessibility to transport routes, and functional ties to commercial centers can be as important as isolation or weak state presence in determining where coca is grown. Although conflict dynamics remain intertwined with these geographies, the clustering of coca near populated and connected municipalities suggests that illicit crop economies exploit a spectrum of territorial configurations, from isolated forest edges to peri-urban fringes and transport corridors.

These spatial dynamics have direct and indirect implications for agricultural displacement and local food availability. Coca competes with food crops for land (UNODC, 2025), particularly in areas where rural households rely on smallholder agriculture for subsistence. If coca remains a more profitable and secure source of cash income compared to staple food production, households may reallocate labor and land away from diversified food cropping systems, thereby reducing the area and labor devoted to foods consumed locally (Gutiérrez-Sanín, 2021). As a

result, local food production may contract while coca-linked income and labor expand, increasing household dependence on external food markets and potentially raising local food prices.

Moreover, coca cultivation can contribute to the displacement of agricultural activity through indirect social and economic channels. Areas with high coca concentration often experience a stronger presence of armed actors (Nuñez Ciceros, 2016), risk-averse credit allocation, and reduced public investment in rural services and infrastructure. These conditions discourage long-term investments in food systems such as irrigation, storage, or crop diversification, and can lead to land abandonment or consolidation into more extensive systems (Marín Llanes et al., 2024) that are less supportive of diversified and labor-intensive food production. In areas that remain agriculturally productive, coca's dominance can also skew labor markets toward illicit crop labor (Gutiérrez-Sanín, 2021), potentially crowding out seasonal and family labor that would otherwise support staple crop cultivation.

Importantly, a comparison across the insecurity indicators assessed reveals that coca cultivation does not scale directly with the most visible forms of violence. Despite Cauca exhibiting higher homicide rates and a far greater incidence of antipersonnel mines, total coca cultivation remains considerably lower than in Putumayo. This divergence suggests that coca production is not driven solely by generalized violence or weak state presence. Rather, coca expansion is shaped by a combination of territorial connectivity, proximity to logistical and trafficking corridors, and the capacity of armed actors to embed illicit economies within both rural and peri-urban landscapes. In municipalities such as Puerto Asís, coca cultivation coexists with high population density and commercial activity, underscoring that illicit crop economies can thrive not only in zones where state presence is absent, but also in territorially connected areas where enforcement is partial, selective, or contested.

5. Perspectives on Food and Nutrition Security in Cauca and Putumayo

According to FIES, between 2023 and 2024, the prevalence of moderate or severe household food insecurity increased markedly in Putumayo, rising from 18% to 28%, while it declined slightly in Cauca, from 29% to 27.8% (DANE, 2025a). In both departments, these levels remain above the national average of 25.5%. Severe household food insecurity followed a similar pattern: it increased by 1.2 percentage points in Putumayo, reaching 2.4%, and decreased by 1.7 percentage points in Cauca, standing at 3.8% in 2024. Although both departments remain below the national severe food insecurity rate of 5%, the observed trends point to growing vulnerabilities, particularly in Putumayo.

At the national level, moderate or severe food insecurity disproportionately affects rural households, larger households, single-parent and women-headed households, and ethnic or racial minority populations (DANE, 2025a). This pattern is also evident in Cauca and Putumayo, where rural households consistently experience higher levels of food insecurity than

those located in municipal capitals. Figure 21 illustrates the average likelihood of households in both departments experiencing either moderate–severe or severe food insecurity, highlighting persistent spatial and socioeconomic disparities.

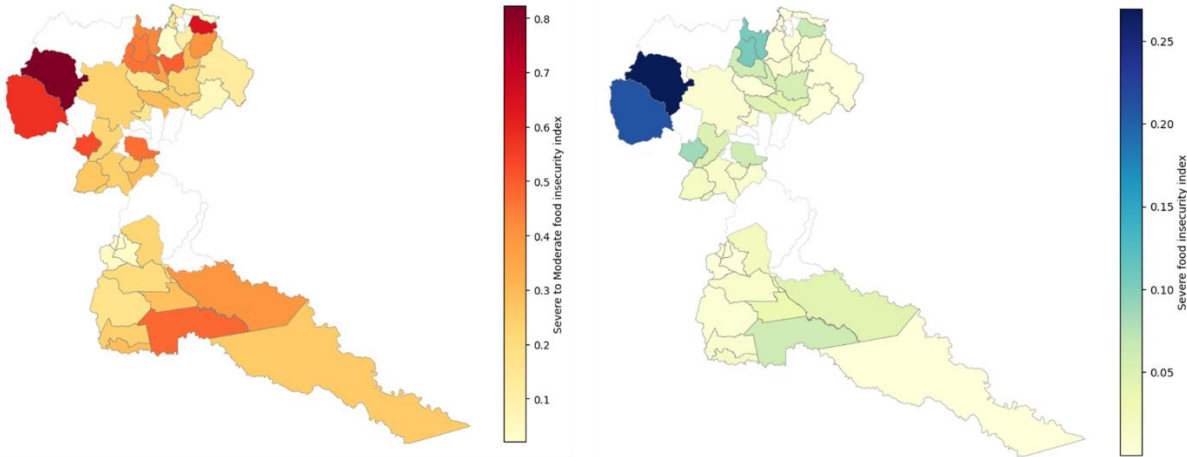


Figure 21. Probability of moderate–severe (left) and severe (right) food insecurity in Cauca and Putumayo during 2024.

Source: Authors’ own elaboration, based on (DANE, 2025b).

The prevalence of moderate–severe or severe food insecurity provides insight into households’ ability to access food, capturing lived experiences related to food quality, dietary diversity, and quantity, whether food is obtained through income, self-production, or other coping strategies (FAO, 2020). Households classified in this category typically lack sufficient resources to sustain a healthy diet, face uncertainty regarding future food access, and often resort to strategies such as reducing portion sizes or skipping meals altogether.

Nationally, approximately 40% of households reported concerns about not having enough food, and nearly one-third consumed diets of low diversity and insufficient nutritional quality (DANE, 2025a). These conditions are particularly pronounced in Cauca and Putumayo. In Cauca, 48% of households worried about food availability, 42% reported low dietary diversity, and 40% lacked access to nutritious and healthy foods. In Putumayo, these figures rose to 46%, 51%, and 44%, respectively. Disparities are even sharper in rural areas, where the gap relative to municipal capitals averages 16.6 percentage points at the national level, 11% in Cauca, and 9% in Putumayo across these indicators. Together, these patterns underscore the structural challenges many households face in achieving adequate and balanced nutrition, driven by persistent economic constraints, spatial inequalities, and unequal access to food and livelihood resources (HLPE, 2020).

5.1 Health and nutrition indicators

In 2022, according to Colombia’s Ministry of Health and Social Protection indicators, the national infant (< one year) mortality rate in Colombia was 11.7 deaths per 1,000 live births, while mortality among children under five reached 14.6 per 1,000 (Ministerio de Salud y

Protección Social, 2024a). These indicators were slightly lower in Cauca (11.1 and 13.6, respectively) but exceeded the national average in Putumayo (13.3 and 15.7, respectively). Nutritional deficiencies and diet-related diseases are estimated to account for 9–10% of deaths among children aged one to four years nationwide (Ministerio de Salud y Protección Social, 2024a), underscoring the relevance of food environments in shaping early-life health outcomes.

Child mortality associated with undernutrition is influenced by multiple factors, including access to sufficient, adequate, and balanced diets; the availability and quality of public health and sanitation services; and household income levels (Observatorio del Bienestar de la Niñez, 2025a). In Cauca and Putumayo, it is estimated that approximately 18% of the population's basic needs are unmet (Ministerio de Salud y Protección Social, 2024a). In Cauca, poverty rates exceeded 41% in 2022, with 17.6% of the population living in extreme poverty; comparable figures for Putumayo are not available. In Colombia, households with at least one child under five years of age face higher levels of moderate to severe food insecurity than households without young children (DANE, 2025a). Notably, more than 70% of children under five in these departments attend community homes or childcare centers operated by the ICBF, where over 90% receive food free of charge, highlighting the critical role of public food provision in local food security.

At the national level, in 2024, the mortality rate due to undernutrition among children under five reached its lowest level since 2018, at 6.5 deaths per 100,000 children, representing a 38.5% decline over this period (Observatorio del Bienestar de la Niñez, 2025a). However, this decline has occurred alongside a rise in the prevalence of acute undernutrition—both moderate–severe and severe—which has increased steadily since 2021, reaching 0.66 in 2024. These contrasting trends are attributed to the expansion of national prevention, and early detection and treatment programs, many of which incorporate a food sovereignty approach (Observatorio del Bienestar de la Niñez, 2025a). Rural populations and Indigenous communities remain disproportionately affected, with Indigenous children accounting for 53% of cases reported between 2018 and 2024. By department, mortality rates due to undernutrition among children under five in 2024 were 3.2 in Cauca and 3.0 in Putumayo (Observatorio del Bienestar de la Niñez, 2025b). Municipal-level data remains limited; however, available figures (Table 3) reveal notable trends, including a sharp increase in Jambaló (Cauca) between 2019 and 2021 and a marked decline in Puerto Leguízamo (Putumayo) between 2020 and 2021.

Table 3. Mortality rate due to undernutrition among children under five.

Department	Municipality	Number of child (<5 years) deaths per 100,000 children under five		
		2019	2020	2021
Cauca	Popayán		4.9	
Cauca	Guapi			33.1
Cauca	Inzá			32.4
Cauca	Jambaló	50.3		100.4
Cauca	Morales			25.0
Cauca	Páez		33.7	17.0
Cauca	Timbiquí	29.0		
Cauca	Toribío		59.7	
Putumayo	Orito		27.6	
Putumayo	Puerto Asís	35.3	17.6	17.6
Putumayo	Puerto Leguízamo		58.6	29.3
Putumayo	Sibundoy		84.2	
Putumayo	Santiago		139.5	
Putumayo	Valle del Guamuez	36.9		

Source: Data from (Ministerio de Salud y Protección Social, 2024b).

Beyond being a direct cause of death, child malnutrition acts as a critical underlying risk factor that amplifies other causes (Ritchie, 2024). One of the most significant causes is low birth weight (<2,500 g), which is linked to maternal nutrition and health status. In 2019, 10.5% of live births nationwide were classified as low birth weight (Ministerio de Salud y Protección Social, 2024a), compared to 8.4% in Cauca and 5.7% in Putumayo (Ministerio de Salud y Protección Social, 2024b). By 2021, Putumayo experienced a deterioration of 1.7 percentage points in this indicator, while Cauca remained stable. Maternal mortality also reflects broader food and health system conditions: in 2022, the maternal mortality ratio within 42 days postpartum was 48.5 at the national level, 42.8 in Cauca, and 21.8 in Putumayo (Ministerio de Salud y Protección Social, 2024a).

5.2 Future perspectives on food and nutrition security in Cauca and Putumayo

Given an increasingly uncertain and potentially extreme climate future, understanding the adaptive capacity of agricultural systems in the departments of Cauca and Putumayo is essential for anticipating risks to food and nutrition security. Climate change is expected to alter temperature and precipitation patterns in ways that will differentially affect crop suitability, productivity, and spatial distribution (Alam & Rukhsana, 2023; Leng & Huang, 2017; Prajapati et al., 2024). Assessing these dynamics enables the identification of crops that become more vulnerable under potential future climate conditions, as well as alternative crops that could offer more favorable growing conditions and contribute to more resilient food systems.

This analysis focuses on a high-emissions scenario (SSP5-8.5; Shared Socioeconomic Pathway 5 – Representative Concentration Pathway (RCP) 8.5), projected for the year 2060. This scenario represents a development pathway characterized by rapid economic growth, continued reliance on fossil fuels, and sustained increases in GHG emissions (Intergovernmental Panel on Climate Change [IPCC], 2021). Although SSP5-8.5 reflects an extreme assumption, its inclusion is analytically justified, as it provides a stress-test for agricultural systems and allows for the identification of adaptation needs under particularly adverse climatic conditions (IPCC, 2023).

The relevance of this exercise lies in its ability to link climate information with food and nutrition security by focusing on crops that are produced or consumed in the department and their climatic viability in the future. As discussed in Section 3, agricultural production in these departments has historically focused on crops such as sugarcane, plantains, cassava, potatoes, coffee, and corn, while household purchases and consumption preferences include, apart from those mentioned, fruit, vegetables, rice, and legumes such as beans. The crops included in the assessment were those for which reliable climate-suitability information was available in the departments.

To assess the comparative climate advantage of various staple crops, we draw on an analytical exercise conducted by the Alliance Bioversity International & CIAT (2025). The methodology estimates the proportion of spatial units within defined geographic boundaries where a reference crop is currently cultivated, and where its climatic suitability is projected to change under future climate conditions. By comparing the future suitability of a reference crop with that of alternative crops at the same locations, the analysis identifies potential pathways for crop persistence, substitution, or diversification. While this approach may yield a wide set of candidate crops, it provides a technical basis for anticipating climate-driven shifts in agricultural systems.

In this assessment, two complementary indicators are employed, namely the “Climate Advantage of Alternatives” (CAA) and the “Climate Advantage of Specialization” (CAS). The former measures the proportion of areas where a given crop could be diversified or replaced by alternative crops with higher future climate suitability. High CAA values, therefore, indicate greater potential, and possibly greater need for diversification. Conversely, the CAS reflects the relative future suitability of the reference crop compared with other crops at the same sites; high CAS values suggest a greater likelihood of crop persistence under changing climatic conditions.

The application of these indicators is critical for anticipating changes in climate-induced production, like those observed in other regions facing extreme climate stress (Parker et al., 2019). Furthermore, this framework allows differentiating between areas where traditional crops are likely to remain viable and those where adaptation strategies will be required to maintain productive capacity. Evidence suggests that agricultural diversification reduces vulnerability to climate shocks and enhances system resilience (Lin, 2011), while increased agricultural biodiversity contributes to improved dietary diversity and access to nutritious foods (Fanzo et al., 2013). As such, this analytical approach provides a technical foundation for climate-responsive agricultural planning that simultaneously addresses food availability and nutritional outcomes.

Results of the CAA and CAS assessments for Cauca and Putumayo are presented below, highlighting the crops with greater or lesser adaptability to the extreme SSP5-8.5 emissions scenario for the year 2060.

5.2.1 Cauca

In Cauca, crops with low substitutability ($0.10 < \text{CAA} < 0.27$) and high persistence ($0.80 < \text{CAS} < 0.90$) by 2060 are primarily biofortified bean and rice varieties, along with cacao, cilantro, and dragon fruit (Figure 22). These crops exhibit high adaptive capacity under projected increases in temperature and precipitation variability associated with the SSP5-8.5 scenario. In the case of beans, the persistence of improved and biofortified lines reflects sustained breeding efforts that increase tolerance to heat and water stress, thus reducing the risk of climate-induced yield losses (Duc et al., 2011). Beyond climate resilience, the strategic relevance of biofortified crops lies in their contribution to addressing micronutrient deficiencies, thereby directly linking climate adaptation pathways with nutrition outcomes (Bouis & Saltzman, 2017).

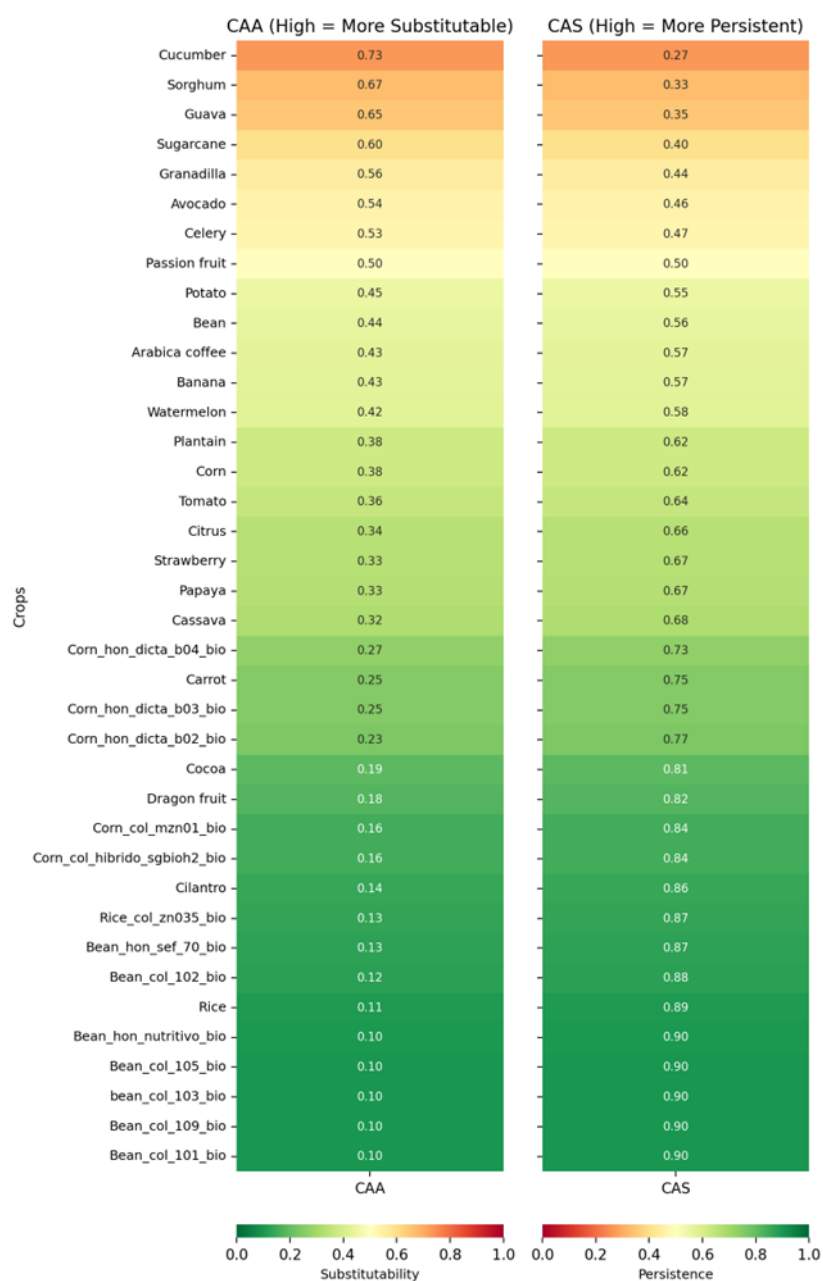


Figure 22. Persistence and specialization of crops based on climatic suitability in Cauca.

Conversely, crops exhibiting high substitutability ($CAA > 0.60$) and low persistence ($CAS < 0.35$), notably cucumber, guava, and sorghum, are projected to lose relative climatic suitability by 2060. Under extreme climate conditions, these crops face production risks, suggesting that continued reliance on them would heighten vulnerability; thus, their high CAA values indicate a need for diversification or replacement with better-suited crops.

When these climate-based results are examined alongside Cauca’s current productive structure (Section 3.2), the department’s dominant crops (sugarcane, cassava, potatoes, plantains, and coffee) mostly fall within a moderate persistence range ($CAS \approx 0.47\text{--}0.62$). This suggests neither imminent collapse nor guaranteed long-term stability. For potatoes, this intermediate position aligns with findings by Raymundo et al. (2018), who project yield declines toward the end of the century under high-emission scenarios.

Cassava emerges as a particularly strategic crop for Cauca's future food security. Its tolerance to heat and irregular rainfall, combined with its capacity for in-ground storage, enhances its role as a climatic and food availability buffer under increasingly uncertain conditions (Amelework et al., 2021). Coffee, conversely, displays clear vulnerability, consistent with evidence that rising temperatures and shifting precipitation regimes will reduce yields, compromise quality, and intensify pest and disease pressures (Ovalle-Rivera et al., 2015). Plantain and potato occupy an intermediate adaptive space; while likely to remain viable, their persistence will depend on adaptive management, including varietal improvement, soil moisture management, and pest control, to cope with heightened climate variability.

Overall, these results point to a future in which Cauca's food system will need to balance the persistence of climatically resilient staples (e.g., cassava, biofortified beans, and rice) with strategic diversification away from crops facing declining suitability. This pattern is consistent with broader evidence that many staple crops are already cultivated near or beyond optimal climate conditions, amplifying vulnerability under high-emission pathways (Gao et al., 2023). From a food and nutrition security perspective, adaptation strategies that simultaneously enhance climatic resilience and dietary diversity will be critical to avoiding future availability and access constraints.

In this regard, the solution implemented in the EPINER project, which includes promoting biofortified bean varieties, perfectly aligns with the needs of the department in a scenario of increasing fossil fuel-led economic development and GHGEs.

5.2.2 Putumayo

In Putumayo, crops with low substitutability ($CAA < 0.23$) and high persistence ($CAS > 0.80$) by 2060 include biofortified rice and bean varieties, cacao, and cassava (Figure 23). These crops exhibit strong adaptive capacity under the SSP5-8.5 scenario, reflecting both physiological tolerance to increased temperature and rainfall variability and their suitability to the department's humid tropical conditions. Among them, biofortified rice (Rice_col_zn035_bio) stands out with the lowest substitutability ($CAA = 0.02$) and highest persistence ($CAS = 0.98$) of all evaluated crops. This outcome is driven by two complementary factors: first, the broad agroclimatic tolerance of improved rice varieties bred for heat stress and intermittent water deficits (Suresh et al., 2024); and second, the limited number of alternative crops capable of simultaneously matching rice's nutritional contribution, climatic adaptability, and cultural centrality in local diets (Fondo Regional de Tecnología Agropecuaria [FONTAGRO], 2016).

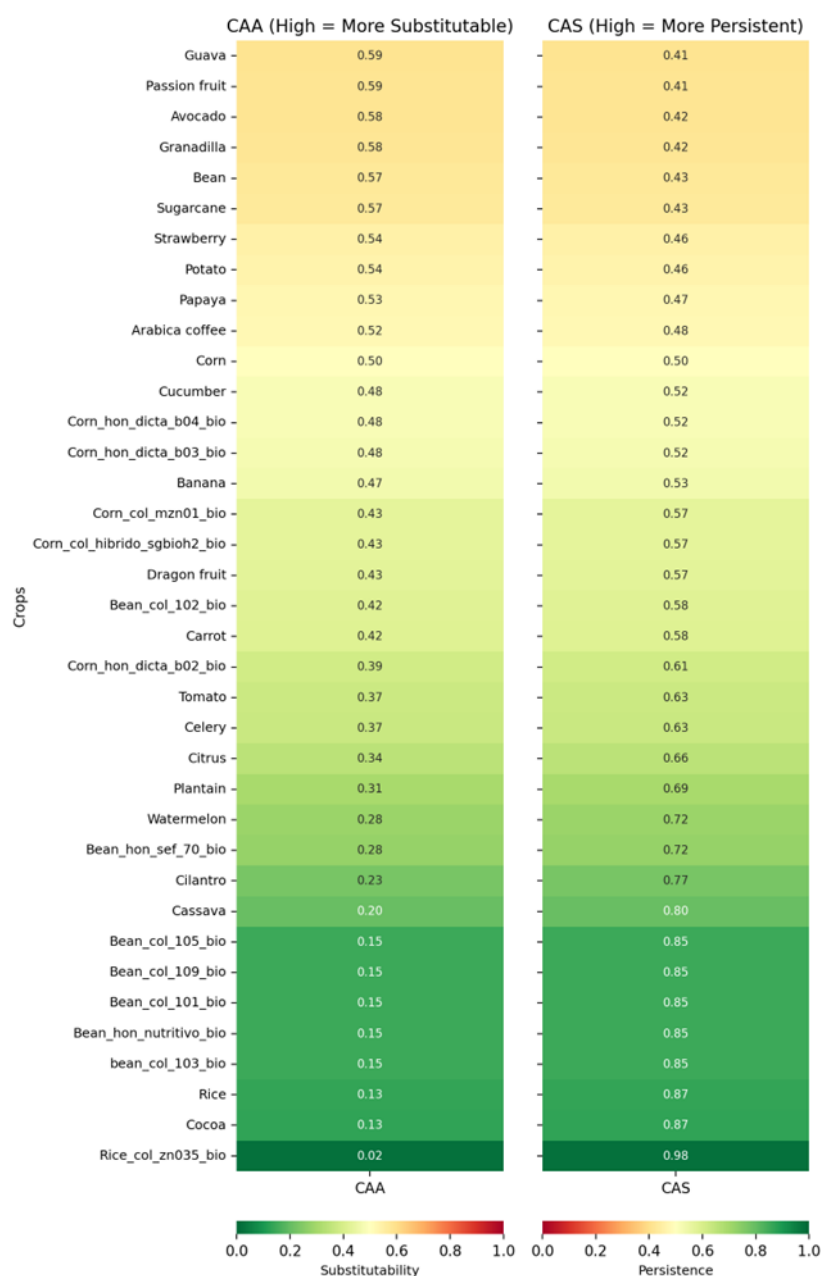


Figure 23. Persistence and specialization of crops based on climatic suitability in Putumayo.

The strategic importance of biofortified rice and beans extends beyond production stability. Enriched with micronutrients such as zinc and iron, these varieties directly address prevalent deficiencies in rural and frontier regions where diets lack diversity. As such, their persistence contributes not only to food availability but also to the nutritional quality of the food systems, strengthening food and nutrition security under increasingly adverse climate conditions (Senguttuvel et al., 2023; Stangoulis & Knez, 2022).

In contrast, fruit crops such as avocado, guava, granadilla, and passion fruit display high substitutability ($CAA > 0.55$) and low persistence ($CAS < 0.42$), indicating a substantial loss of climatic suitability by 2060. These crops are particularly sensitive to water stress and require narrow ranges of humidity, altitude, and temperature, making them vulnerable to intensified rainfall variability and rising temperatures projected under SSP5-8.5 (FAO, 2024). Their

declining suitability suggests that continued reliance on these crops would increase production risk and volatility, particularly for smallholders with limited capacity to absorb losses.

When linked to Putumayo's current production profile (dominated by cassava, maize, peach palm fruit, plantain, and sugarcane), the results reveal a mixed but structurally fragile outlook. Plantain is likely to remain viable across large parts of the department, with moderate persistence ($CAS \approx 0.62$), but its productivity will increasingly depend on adaptive management practices, including varietal diversification and partial shading. Rising temperatures and erratic rainfall are already exacerbating soil-borne fungal diseases, which have begun to devastate entire plantations in tropical regions (Kramer & Ware, 2025).

Cassava stands out in the production profile, promising high persistence due to its water-stress tolerance and its ability to grow in marginal soils and to remain unharvested in the ground for long periods (Banerjee et al., 2021). Moreover, as a key source of carbohydrates for vulnerable populations, cassava's role in food security is twofold: as a resilient staple crop and as a buffer against production crises (Ospina et al., 2016).

On the other hand, crops such as maize and sugarcane are at greater risk. Although both remain viable in certain areas, climate change will progressively reduce the optimal zones for their cultivation. In the case of maize, its vulnerability is concentrated in the reproductive stages, which are extremely sensitive to heat stress and irregular water availability (Jones & Thornton, 2003). Sugarcane, while tolerant to heat, requires abundant and evenly distributed water to sustain its productivity. Furthermore, as Headley et al. (2024) mention, as temperatures continue to rise, a global decline in the sugar industry is expected. Beyond their limited nutritional contribution, these products are deeply intertwined with the culture and economy of the department. As such, their viability in the future is a matter of interest for agricultural planning.

Taken together, these results suggest that Putumayo's future food and nutrition security will depend heavily on maintaining and expanding climatically persistent staple crops, particularly biofortified rice and beans, and cassava, while reducing exposure to crops with declining suitability. Given the department's geographic isolation and limited market access, declining viability of food crops could otherwise intensify shifts toward non-food or illicit land uses. Strengthening the resilience and nutrition contribution of locally adapted food crops is therefore not only a climate adaptation strategy, but a central component of long-term food system stability in Putumayo.

6. Analysis of Cauca's and Putumayo's Food Environments and the Food System Policy Implications

Cauca exhibits a diversified and commercially integrated food environment, with substantial agricultural production and strong linkages to regional and national markets. The department produces large volumes of coffee and sugarcane alongside staple crops such as cassava,

plantain, and potato, although commercial crops occupy a disproportionate share of cultivated land relative to the food crops that are important for local diets. Small-scale family farming remains central to the local food supply, but producers face structural constraints including limited access to infrastructure, markets, finance, and extension services, compounded by land tenure inequities and security challenges. Despite significant production potential, a disconnect persists between local production and household consumption, particularly for nutrient-dense foods such as dairy and fruit, suggesting barriers related to affordability and access. Cauca is also a key contributor to national food flows, with long-distance distribution networks that increase transport-related emissions, although short supply circuits remain dominant for perishable foods.

Putumayo's food environment is more subsistence-oriented and less integrated into national markets, with production directed toward household consumption and local markets. Cassava, maize, plantain, and sugarcane for panela dominate agricultural production, complemented by culturally important crops such as peach palm. Agricultural land use is comparatively limited, and production systems are characterized by low productivity and constrained commercialization capacity. Weak infrastructure and geographic remoteness limit market integration and food mobilization, reinforcing a peripheral position in national supply networks. While Putumayo shows strong potential for food self-sufficiency and diversified agroecological systems, gaps in technical assistance, processing infrastructure, and transport hinder value-chain development and economic opportunities. As in Cauca, consumption of nutrient-rich foods is constrained, reflecting both economic and structural barriers rather than mere availability.

6.1 Priority interventions and policy recommendations for sustainable and nutrition-sensitive food systems

The analysis of the Cauca and Putumayo food environments highlights several structural constraints and opportunities for improving food system sustainability, nutrition outcomes, and climate resilience. Priority interventions should be embedded within coherent policy frameworks that integrate territorial development, climate-change mitigation, and peacebuilding objectives.

Strengthening infrastructure and territorial connectivity

Investments in rural road networks, storage facilities, and cold-chain infrastructure are essential for improving physical access to markets, reducing post-harvest losses, and enhancing the availability of diverse and perishable foods. These interventions are particularly critical in Putumayo, where remoteness and poor connectivity constrain market integration and limit opportunities for value addition. Improving infrastructure would also reduce transaction costs and transport-related emissions by enabling more efficient logistics.

Enhancing market access and value chain integration

Policies should support the development of producer organizations, aggregation centers, and market information systems to facilitate farmers' integration into formal markets. Strengthening local and regional markets, including farmers' markets and public procurement schemes such as school feeding programs, can reinforce short food supply chains, increase access to locally produced nutritious foods, and stimulate local economies. In Cauca, such measures can help smallholders to benefit more from existing commercial networks, while in Putumayo, they can support the transition from subsistence-oriented systems to more resilient market-linked systems.

Expanding technical assistance and extension services

Targeted extension programs are needed to improve productivity, diversification, and sustainable land management practices. Prioritizing nutrient-dense crops such as fruit, legumes, vegetables, and small livestock systems can directly contribute to dietary diversity and improved nutrition. Extension services should also promote climate-smart and agroecological practices to enhance resilience to climate variability while reducing deforestation risks associated with extensive cattle ranching.

Aligning financial instruments and subsidies with climate and nutrition goals


Access to credit, risk-sharing mechanisms, and targeted subsidies should be designed to incentivize diversified, low-emission, and nutrition-sensitive production systems. Financial support mechanisms could prioritize family farming, agroecological practices, and legume and horticultural production, while discouraging land-extensive livestock expansion in deforestation-prone areas. Aligning climate finance and zero-deforestation commitments with nutrition objectives can help reconcile environmental and social outcomes.

Strengthening governance, land tenure, and peacebuilding frameworks

Improving land tenure security, institutional presence, and territorial governance remains central to enabling long-term investments in sustainable food systems. Conflict-related insecurity continues to influence production choices, infrastructure development, and market functioning. Integrating food system interventions into peacebuilding and territorial development strategies can help stabilize livelihoods, support equitable land use, and promote sustainable rural development pathways.

Improving data systems and monitoring frameworks

Strengthening data collection on production, consumption, food flows, and intra-departmental market dynamics is critical for evidence-based policymaking. Enhanced monitoring systems would support the evaluation of climate, nutrition, and development policies and enable adaptive management of territorial food systems.



Finally, future research should address the key knowledge gaps identified in this study. First, more granular data on intra-departmental food flows and household-level consumption patterns are needed to better understand the disconnect between production and dietary outcomes. Second, the drivers of limited consumption of nutrient-dense foods, particularly dairy and fruit, should be explored, including the economic, cultural, and logistical barriers. Third, research on the interplay between conflict dynamics, land-use change, and nutrition outcomes would help clarify how peacebuilding interventions can support sustainable and equitable food systems. Finally, integrating climate-change projections with territorial food system planning could inform adaptive strategies that simultaneously address emissions reduction, agrobiodiversity conservation, and nutrition security.

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