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Opportunity costs and agricultural transformation in the Ecuadorian Amazon: Cacao cultivation in traditional Shuar systems

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Abstract

This study analyzes the socioeconomic dynamics and land-use practices of small-scale Shuar farmers in Taisha, Tuutinentsa, and Macuma, in the Ecuadorian Amazon. Based on surveys of 43 cacao producing households, we analyzed perceptions of well-being, land allocation, and livelihood diversification. Households typically include five to six members and rely on diversified portfolios com-

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bining cacao (*Theobroma cacao* L.), peanuts (*Arachis hypogaea* L.), plantain (*Musa* × *paradisiaca* L.), livestock, forest, and off-farm activities. Gendered labor divisions are present: men are more involved in marketed production and commercialization, while women play central roles in chakra-based agroforestry management, food provisioning, and household economies that reduce cash expenditures and strengthen food sovereignty. Average farm sizes range from 31 to 40 hectares, with forest and pasture, with smaller areas allocated to perennial and short-cycle crops. These patterns reflect multifunctional strategies balancing income generation, risk management, cultural continuity, and environmental stewardship rather than single-crop optimization. Agriculture and livestock constitute the main income sources in Taisha and Tuutinentsa, whereas Macuma exhibits greater economic diversification due to proximity to urban markets. High transportation costs and limited infrastructure constrain profitability. Reported cacao yields are lower than provincial and national averages; however, chakra-based systems prioritize multiple outputs beyond yield, including food security, ecosystem services, and cultural values. Opportunity cost analysis suggests higher short-term returns for peanuts, while cacao remains central due to its larger cultivated area. These findings highlight the complexity of Indigenous agriculture and the need for culturally grounded development policies aligned with socio-ecological realities.

Keywords
Indigenous agriculture, land use, rural economy,

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forest conservation, socioeconomic well-being, Ecuador, Amazon

Introduction and Literature Review

Indigenous peoples represent approximately 6% of the world population, totaling 476 million individuals (Organización Internacional del Trabajo, 2019), and occupy approximately 32% of the world's forests (Fa et al., 2020). Indigenous communities' land use, particularly in the Amazon Basin where vast areas remain under Indigenous governance, is central to forest conservation, territorial autonomy, and cultural heritage preservation (Gray & Bilsborrow, 2020).

The Shuar are an Indigenous group of approximately 110,000 people distributed across Peru and Ecuador. In Ecuador, they inhabit six Amazon provinces, with major concentrations in Zamora Chinchipe and Morona Santiago. These communities display varying degrees of market access and integration in the cash economy (De Salvador-Agra & Martínez-Suárez, 2015; Liebert et al., 2013; Urlacher et al., 2016).

Shuar subsistence is based on agriculture, fishing, and hunting in a cultivation model that combines food production, ecological management, and cultural adapted practices. Main crops include corn (*Zea mays* L.), cassava (*Manihot esculenta*), plantain (*Musa AAB Simmonds*), beans (*Vigna unguiculata* L.), sweet potatoes (*Ipomoea batatas* L.), and peanuts (*Arachis hypogaea* L.) (Confederación de Nacionalidades Indígenas del Ecuador, n.d.). However, some communities have reduced staple crops areas in favor of market-oriented crops such as coffee (*Coffea canephora*) and cacao (*Theobroma cacao* L.), alongside expanded livestock grazing (Gray & Bilsborrow, 2020).

Frequent interaction with oil and mining companies has also reshaped livelihoods, with many members employed in extractive industries (Confederación de Nacionalidades Indígenas del Ecuador, 2023). Contact with religious groups, settlers, the state, and corporations has produced adaptations in Shuar life, including the adoption of monetary system and formal education, sometimes resulting in impoverishment and acculturation (Paño et al., 2020).

Ecuador's decentralization process established Decentralized Autonomous Governments (GADs) at provincial and cantonal levels. In the Amazon, several GADs promote agricultural value chains, including cacao, supporting activities from nurseries to post-harvest processing with chakra. These efforts have taken place in the context of Indigenous communities' chakra-based subsistence farming systems practices, which shape local agricultural practices and livelihood strategies in the study area. The chakra is an ancestral production system used by Indigenous peoples. It is based on the use of traditional knowledge and the sustainable management of natural resources. It is practiced on small plots of land with diversified crops intended for food, traditional medicine, and other uses, contributing both to food security and to the generation of family income. (Bredero et al., 2023; Food and Agriculture Organization of the United Nations [FAO], 2023; Vera et al., 2020).

Although Ecuador is a major cacao producer and exporter, it has historically focused on raw cacao beans (Nieto & Caicedo, 2012; Villacís et al., 2022). Public policies now seek to promote social and productive development in the Ecuadorian Amazon Region (EAR), emphasizing sustainable livelihoods, value-chain strengthening, and cultural identity through instruments such as the National Development Plan (Secretaría Nacional de Planificación, 2021), the Organic Law on the Special Territorial Circumscription of the Amazon (Asamblea Nacional del Ecuador, 2018), and local life plans (Gobierno Autónomo Descentralizado Municipal del Cantón Taisha, 2014).

Globally, the top cacao producer countries are Ivory Coast, Ghana, and Ecuador (International Cocoa Organization, 2024). The coastal provinces of Los Ríos, Guayas, Manabí, and Esmeraldas cultivate 90% of Ecuador's cacao, and the most prominent varieties are "Fino de Aroma" and "CCN-51" (Cedeño & Dilas, 2022; Vargas et al., 2016). However, the eastern provinces of Ecuador Sucumbíos, Orellana, Napo, Pastaza, Morona Santiago, and Zamora Chinchipe, referred to as the Ecuadorian Amazon Region (EAR), makes up 45% of the national territory but contribute only approximately 10% of the cacao nacional (*Theobroma cacao* L. "Nacional," a traditional Ecuadorian fine-flavor genotype) output (Caicedo-

Vargas et al., 2022; Instituto Nacional de Estadística y Censos, 2017). Production in the EAR is dominated by small and medium-sized farmers using agroforestry chakras that provide ecosystem services such as climate regulation and biodiversity conservation, though they are primarily oriented toward subsistence and local markets (Filho et al., 2014; Jadán, 2012; Niether et al., 2020).

Incorporating cacao into chakra systems has generated socio-economic and ecological changes, including biodiversity shifts and disruptions of traditional practices (Bentley et al., 2004; Rice & Greenberg, 2000). Increased dependence on intermediaries who channel approximately 67% of production has heightened producer vulnerability (Viteri et al., 2023). The region's low productivity and profitability are additional factors affecting the adoption of cacao cultivation. The remuneration received by local small and medium-scale farmers is comparatively lower (55%–60% per pound) than the price paid in Guayas Province—a region with large-scale cacao production—which may be attributed to higher transportation costs, limited markets access, and the reduced bargaining power of farmers in Amazon territories (Caicedo-Vargas et al., 2022). Agriculture and livestock remain the main household activities of in the EAR (Gray et al., 2008; López et al., 2013; Torres et al., 2018; Vasco et al., 2015).

Although chakras ensure food self-sufficiency they often fail to generate sufficient cash income to meet household needs (Caicedo-Vargas et al., 2022). A significant portion of the rural population has opted for non-agricultural and off-farm employment to increase household income and meet basic family needs (Bilsborrow et al., 2004). Vasco et al. (2013) demonstrated that non-agricultural and off-farm employment (e.g., extractive activities and service-based tourism) together represent 36% of household income in rural areas and provides employment to 33% of the local population. These employment types have adversely affected the agricultural sector, leading to land abandonment and a decline in the independent and productive capacity to meet families' needs (Vasco et al., 2013). According to Sellers et al. (2017), a lack of employment and educational opportunities are the primary drivers of migration to nearby urban centers or major cities in the EAR.

Taisha is a canton located in the province of Morona Santiago (within the EAR). According to the latest census, 64% of its economically active population are engaged in agricultural, livestock, forestry, and fishing activities (Gobierno Autónomo Descentralizado Municipal del Cantón Taisha, 2020). A transition from ancestral to commercial production has led to forest conversion into pastures and monocultures (Gobierno Autónomo Descentralizado Municipal del Cantón Taisha, 2014), with approximately 12,000 ha lost between 2000 and 2018 (Beuchle et al., 2022). Agriculture and livestock account for 22% and 44% of family income, respectively (Gobierno Autónomo Descentralizado Municipal del Cantón Taisha, 2014).

GAD's priorities emphasize the promotion of organic production systems aimed at reducing the use of chemical pesticides, which have been widely associated with environmental degradation and adverse human health effects (Hayes et al., 2006; Zheng et al., 2016), including dermatological, gastrointestinal, carcinogenic, and respiratory conditions (Mnif et al., 2011). Within this framework, the development of the cacao national industry represents a strategic opportunity, as cacao can be cultivated under organic and agroforestry-based systems that promote diversity conservation, sustainable land use, and rural livelihoods while also offering significant commercial potential. Expanding cacao production could generate employment opportunities, attract tourism, and stimulate the local economy, particularly given the high international demand for Ecuadorian cacao dried beans (Vargas et al., 2016).

A majority of farmers use an organic production system (i.e., without the use of chemical inputs such as fertilizers and pesticides), where the methods and techniques employed are ancestral (Altieri & Nicholls, 2005; Pretty, 2002). As a result, farmers may not consistently implement crop management practices commonly promoted by extension services, such as regular pruning, systematic harvesting, or manual weed and disease control, nor consistently apply organic fertilizers such as biol, a liquid organic fertilizer produced through the an-

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aerobic fermentation of organic materials. These practices are shaped by labor constraints, limited access to inputs, and the subsistence-oriented nature of ancestral production systems, rather than by a lack of traditional knowledge (Altieri, 1999; Gliessman, 2014).

The specific objectives of this study were to: (1) identify the socioeconomic conditions of small-scale farmers from different Shuar communities, (2) analyze comparative advantages through an opportunity cost analysis of different commercial agricultural activities, and (3) determine the role of cacao cultivation in the economic dynamics of Shuar communities.

Applied Research Methods

We used household surveys and field data to examine farming practices, livelihood conditions, and the economic contribution of key agricultural activities in the study communities.

Study Area

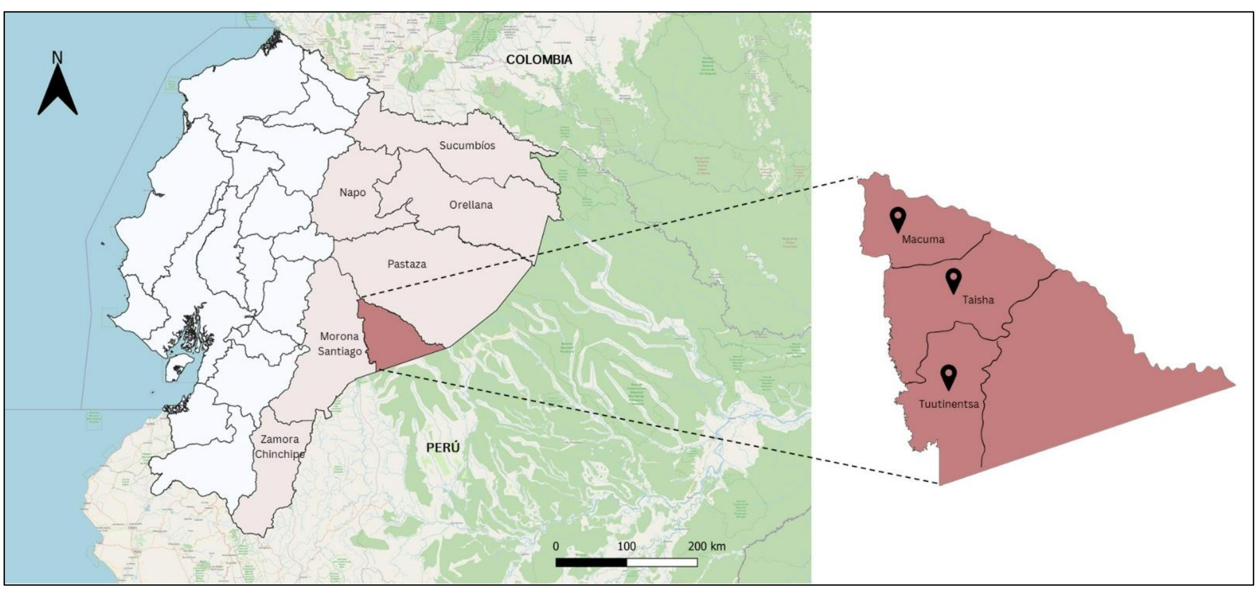
We conducted this study in Taisha Canton, located in the province of Morona Santiago, and collected data in three locations: (1) Taisha (02°30'38.28"S, 77°23'22.26"W), (2) Tuutinentsa (02°30'52.78"S, 77°25'48.91"W), and (3) Macuma (02°9'10.61"S, 77°42'10.53"W) (Figure 1). Taisha Canton covers approximately 6,200 km², accounting for 25.6% of the territory of Morona Santiago province, which is situated in the EAR. The canton has a population of 26,700, of whom 1,864 reside in urban areas. The remaining 24,836 inhabitants live in rural areas (Instituto Nacional de Estadística y Censos, 2022).

Sample Design and Data Collection

We conducted this study over three months (December 2017–February 2018), involving 43 farmers engaged in organic cacao production, representing 10 Indigenous communities (*Amazonas, Jimiaraentza* or *Dos Ríos, Kuamar, Putunza, Shinkiatam, Tintiukentza, Tsentsakentza, Tumpain, Vario Sant,* and *Yaas Nuntsa*). The study was implemented as part of the broader project "Alternatives to Reduce the Use of Pesticides Harmful to Humans and the Environment," which involved 185 farmers participating in training activities related to organic cacao production and the preparation and use of bioles over a 24-month period.

From this project population, we purposively

Figure 1. Location of the Ecuadorian Amazon Region (EAR), Comprising the Provinces of Sucumbíos, Orellana, Napo, Pastaza, Morona Santiago, and Zamora Chinchipe.
The inset highlights the study area in Morona Santiago Province, Ecuador, showing the survey sites in the Indigenous communities of Macuma, Taisha, and Tuutinentsa. Data were collected between December 2017 and February 2018.



selected 43 small-scale farmers for detailed data collection using a geographical cluster sampling approach, grouping communities into three locations (Taisha, Tuutinentsa, and Macuma). We interviewed one member per household to avoid data duplication.

A trained field technician with experience working in rural communities conducted the face-to-face interviews in Spanish; each interview lasted approximately 30 minutes and addressed topics related to the socioeconomic conditions of farming families, agricultural practices, input supply, and crop yields.

Data Analysis

We performed a descriptive analysis of variables using the collected data; the mean was used to measure central tendency, providing the expected or representative value of the population. The standard deviation was used to assess the dispersion of quantitative data.

Finally, we calculated the opportunity cost for producers to assess the comparative advantages of producing cacao, peanuts, plantains, and livestock (Kolinjivadi et al., 2015) using the following formula:

$$VA_{xi} = (I_{xi}/(A_{xi})) - (C_{xi}/(A_{xi}))$$

where the value-added (VA) represent the difference between total income (I) and total cost (C), normalized by the total production area in hectares (A) for each commercial activity (xi). Costs included expenses related to hired labor, transportation for products, commercialization, and the imputed value of family labor. To standardize the valuation of family labor across production systems and ensure comparability between activities, family labor was monetized using the sectoral minimum wage for agricultural workers established by the Ministerio del Trabajo (2019) equivalent to US$395 per month. This approach assumes that the minimum wage represents the baseline opportunity cost of labor in rural areas, reflecting the income that household members could obtain if employed in the local agricultural labor market.

This indicator is used exclusively to compare the cash-income potential of marketed products under the observed production conditions. It does not capture the full opportunity cost of land use within chakra-based or forested systems, where nonmarket values, such as household food provisioning, medicinal resources, cultural continuity, and ecosystem services, are central to livelihood strategies. Therefore, results derived from this metric should be interpreted as partial and contextual rather than prescriptive.

Ethical Considerations, Free, Prior and Informed Consent (FPIC), and Indigenous Data Governance

We conducted this in Shuar Indigenous territories using a participatory approach within an ongoing development project. Prior to data collection, we explained the research objectives, data types, and intended uses (including academic publication) during community workshops and field activities. Participation was voluntary, and we obtained informed consent from all interviewees. We implemented research activities with community knowledge and acceptance through established engagement mechanisms.

In line with principles of Indigenous Data Sovereignty, we anonymized all data and are presenting data only in aggregated form to prevent identification of individuals or households. Although the study predates the formal articulation of the CARE Principles, our data management and dissemination were guided by their core values, emphasizing respect, responsible use of information, and support for locally relevant decision-making. Outputs are available to project partners and participating communities upon request, and no identifiable data are shared beyond the research team.

Additionally, we acknowledge that more recent frameworks, such as the Kichwa–Kara data sovereignty framework and IEEE Standard 2890 on Indigenous data governance, provide important guidance for the stewardship, rematriation, and repatriation of Indigenous data, including legacy datasets. While this study predates the formal adoption of these frameworks, their principles are consistent with the ethical approach followed in this research, and we recognize their relevance for guiding future work in Indigenous contexts (Carroll et al., 2017; IEEE, 2021).

Results

The results provide an overview of the main household and livelihood characteristics observed across the three study communities. They highlight differences in family composition, agricultural activities, income sources, production costs, and opportunity costs that help explain the economic conditions of the surveyed households.

Household Characteristics

Our study findings indicate that the average family size among the surveyed households in Taisha, Tuutinentsa, and Macuma ranges between five and six members, exceeding the national average of 3.8 members per household. The distribution of household sizes shows that families with 1–3 and 4- members represent 23% and 53% of the sample, respectively, while those with 7–9 and more than 10 members account for only 12% and 9%, respectively (Pichon, 2005). All surveyed households were categorized as biparental families with children (i.e., head of household, spouse, and children). The average age of the farmers interviewed was 48 years, with 23.3% being women and 76.7% men (Table 1). Women play central roles in chakra-based agroforestry management, food provisioning, child-rearing, and household economies, contributing substantially to food security and the reduction of cash expenditures (Coq-Huelva et al., 2017). We therefore avoid framing the work of women in the chakra as outside the economy; rather, it constitutes a foundational component of household livelihoods and biocultural continuity.

Land Tenure and Land Use

The land owned by Indigenous farmers is of communal origin, meaning that formal land titles are held collectively by the community rather than by individual households. In practice, however, these communal lands are subdivided into individual managed family plots, where each household is responsible for cultivation and production decisions, while land ownership and governance remain under collective community authority. Farms are often subdivided due to inheritance distribution among offspring, land exchange for livestock, or sales to settlers or mestizo migrants from the mountainous or coastal regions of the country.

The average land area in the three study sites is 31.1, 33.6 and 40.4 ha, respectively (Table 1). These farms are characterized by a larger proportion of forested areas (46%-70%) and pastures (20%-40%), while only a smaller share is allocated to short-cycle and semi-perennial crops such as cacao (4%-7%), subsistence crops (2%-5%), plantains, and peanuts (<1.7%), reflecting diversified land-use strategies that prioritize forest conservation, livelihood resilience, and household provisioning rather than the maximization of single-crop area.

Another notable trend is that Amazonian farmers are focusing increasingly on forest conservation and farm diversification, by integrating annual, short-cycle, perennial crops, and small-scale livestock production. Timber from the forest is mainly used for house construction and not for commercial purposes. Pastures occupy a significant portion of the land but remain underutilized. In at least two of the studied localities, we observed an average stocking density of 0.34 animals per hectare.

Socioeconomic Analysis

The primary source of income in Taisha and Tuutinentsa is derived mainly from agricultural activities, whereas Macuma shows a more diversified income structure linked to off-farm employment, including grocery sales, domestic services, public-sector employment, artisanal crafts, and construction work. This pattern may be partly explained by Macuma's closer proximity to the provincial capital, Macas (approximately 72 km or 45 miles), and its relatively better road access, which likely facilitate greater integration into non-agricultural labor markets.

Income generated from economic activities varies depending on the characteristics of each community. In Macuma, off-farm employment contributes 62%, placing agricultural income in a secondary position (38%). In Taisha, however, 70% of household income is generated from agricultural and livestock activities, and as it serves as the canton's administrative center, off-farm employment contributes 30%, which is higher than in Tuutinentsa, which is the only community where 100% of income is derived from agricultural and livestock activities (Figure 2). The lowest income

Table 1. Descriptive and Summary Statistics Characterizing Social, Farm, and Income at Taisha, Tuutinentsa, and Macuma, Morona Santiago, Ecuador

Data collected from December 2017 to February 2018.

		Statistics											
		Taisha (*n* = 20)				Tuutinentsa (*n* = 8)				Macuma (*n* = 15)			
Variable	**Description**	**Mean**	**(SD)**	**Min**	**Max**	**Mean**	**(SD)**	**Min**	**Max**	**Mean**	**(SD)**	**Min**	**Max**
Social characteristics													
Age	Age of the surveyed (years)	50	(11.4)	23	68	51	(12.5)	30	66	42	(12.4)	22	63
	20–40 [a]	30				25				33			
	41–60 [a]	55				50				60			
	>61 [a]	15				25				7			
Gender	Gender participation [a]												
	Female	20				13				33			
	Male	80				87				67			
Household size	Number of people	5	(1.72)	2	8	5	(3.60)	2	13	6	(3.7)	2	14
	1–3 [a]	25				38				13			
	4–6 [a]	55				38				67			
	7–9 [a]	20				12				0			
	>10 [a]	0				12				20			
Farm characteristics													
Farm	Total land area [b]	31.1	(26.3)	1	100	33.6	(37.9)	1	120	40.4	(23.3)	5	85
Cacao	Land area under production	1.17	(0.74)	0.36	2.50	1.99	(1.50)	0.39	5	1.56	(0.97)	0.30	3.50
Peanut	Land area under production [b]	0.90	(1.93)	0.10	7	0.19	(0.09)	0.06	0.25	0.12	(0.12)	0.01	0.25
Plantain	Land area under production [b]	0.74	(0.60)	0.05	2	0.86	(0.92)	0.01	3	1.27	(1.31)	0.06	5
Livestock	Number of cattle per family	7	(6.39)	2	22	4	(3.06)	1	7	11	(14.4)	2	43
Income characteristics													
Opportunity cost	Cacao production [c]	368	(614)			327	(927)			439	(468)		
	Peanut production [c]	1961	(192)			1984	(484)			2056	(141)		
	Plantain production [c]	714	(676)			318	(68.4)			168	(191)		
	Cattle production [c]	55.9	(38.2)			68.9	(46.1)			485	(575)		
Agricultural	Average net income [e]	2306	(935)	651	4204	1834	(1228)	154	2975	1221	(1028)	224	3256
Livestock [d]	Average net income [e]	1239	(1639)	150	5200	1404	(614)	696	1797	2035	(1336)	755	4460

SD = Standard deviation in parenthesis. [a] Percentage (%); [b] Hectare (ha); [c] Dollar per hectare (US$ ha^{-1}); [d] Cattle, pigs, and poultry; [e] Dollar per family per year

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levels are in Tuutinentsa, as it is the most remote community in the canton, restricting the travel of its residents mainly to crop sales and health emergencies. Furthermore, this isolation hinders interpersonal relationships between Indigenous people and settlers, reducing opportunities to build social networks and access information about employment opportunities in urban areas.

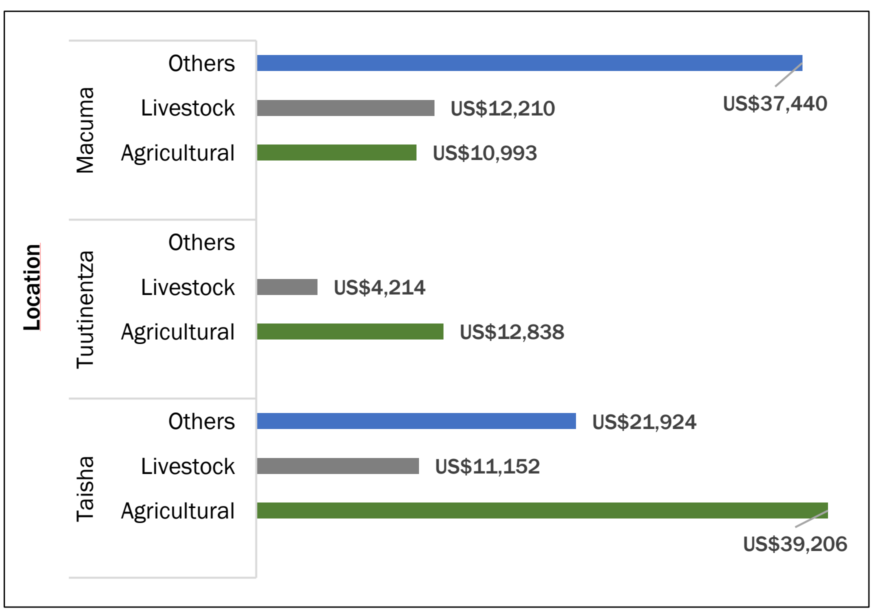
When we asked farmers which crops generated the highest income, they identified three commercial crops (cacao, peanuts, and plantain), along with a fourth income source derived from the sale of cattle. We quantified income from agricultural activities for each community, showing that the agricultural sector contributes, on average per family (household), US$2,306, US$1,834 and US$1,221 per year in Taisha, Tuutinentsa, and Macuma, respectively. We calculated these values based on the yield of commercial crops (e.g., cacao, peanuts, plantain, and pasture), minus the production and marketing costs of each crop. The price for cacao and peanuts is set by Fundación Chankuap (n.d.), while the price of plantains is determined by the local market. Similarly, the livestock sector contributes, on average, US$1,239, US$1,404 and US$2,035 per family per year in Taisha, Tuutinentsa, and Macuma, respectively. Wecalculated these values based on the sale of various animals raised and sold on the farm (e.g., cattle, poultry, and pigs), minus production costs. The relatively high standard deviations reflect substantial heterogeneity in income among households, particularly in livestock-related activities (Table 1).

To facilitate interpretation, we distinguish between three types of economic indicators used throughout this study: (i) household level income (US$ year^{-1}), reflecting overall livelihood outcomes; (ii) per hectare measures (US$ ha^{-1} year^{-1}), capturing production intensity; and (iii) relative cost indicators (percent of income), describing the proportion of resources allocated to production. These metrics capture complementary dimensions of economic performance and are not directly comparable.

On the other hand, costs were divided into two categories: (i) production costs, including expenses related to seeds and labor; and (ii) marketing costs, covering transportation expenses for product sales. At the household level, total costs ranged between 8% and 19% of the total year income across the three study sites. At first glance, this relatively low cost-to-income ratio suggest favorable profitability. However, this interpretation is misleading when absolute income levels are considered. Annual agricultural incomes remain low in all communities and are insufficient to generate meaningful economic benefits for farming households. In this context, similar cost-to-income ratios can occur across systems with very different income levels and should therefore not be interpreted as indicators of economic efficiency.

When expressed in absolute terms, annual monetary expenditures ranged from

Figure 2. Distribution of Economic Activities and Income per Year in Taisha, Tuutinentsa, and Macuma, Morona Santiago, Ecuador
Other income comes from public employee salaries (e.g., teacher, assistant, secretary, driver, etc.). Livestock income comes from the sale of cows, pigs and poultry, and agricultural income comes from cash crops.



US$173 to US$467 ha^{-1} $year^{-1}$, indicating relatively low levels of capital investment. These values are well below those reported for more intensified smallholder systems in the Ecuadorian Coast and Highlands (approximately US$500–US$1,500 ha^{-1} $year^{-1}$), and considerably lower than commercial agricultural systems, where production costs can exceed US$1,500–US$3,000 ha^{-1} $year^{-1}$ depending on the crop (FAO, 2018; Instituto Nacional de Estadística y Censos [INEC], 2017, n.d.). In this context, the low cost-to-income ratio observed in this study reflects limited input use rather than high capital efficiency.

This interpretation is further supported by the reliance on nonmonetized resources, including family labor, recycled planting material, and on-farm preparation of biofertilizers and biofungicides. In practice, planting material for cacao nacional, peanuts, and plantain is commonly reused from a previous harvest or sourced locally from farmers' own fields, while the few inputs applied (biofertilizers and biofungicides) are prepared using artisanal methods. As a result, the low recorded production costs reflect both restricted access to capital and production strategies that prioritize the use of locally available resources, which are characteristic of smallholder systems in the Ecuadorian Amazon.

Within the cost structure, transportation for crop sales emerges as one of the most significant monetary expenses, accounting for approximately 6%–20% (US$113 to US$230 per year) of annual total income, representing 57%–83% of total costs. While these percentages indicate transportation's relative importance, they should not be interpreted as evidence of affordability. In absolute terms, transportation can be a significant financial burden, especially in more remote communities such as Tuutinentsa, where access to markets is limited.

In addition to monetary costs, family labor constitutes a major noncash input across all agricultural activities. Although it does not involve direct financial transactions, it represents a substantial contribution to production and was included in the analysis to better reflect the full cost structure. These noncash costs account for approximately 5% to 20% of total agricultural costs, underscoring their relevance in household decision-making, particularly when family members consider migrating to urban areas or reducing their participation in farm activities.

We observed a similar pattern in livestock (cattle) systems, where monetary costs, such as vaccines and feed supplements, represent about 1%-7% of annual total costs of livestock production. In absolute terms, these expenditures are relatively low (US$12-US$220 per year) when compared to annual livestock income (US$1.416-US$2066 per year). Although these values reflect low levels of financial investment, they also point to limited profitability, as evidence by the low cost to income ratio (0.9%-11%). Rather than indicating efficiency or high returns, these rations primarily reflect minimal reliance on external inputs and services.

Overall, this cost structure is consistent with extensive production systems, in which both crop and livestock activities operate under conditions of limited access to capital, technical services, and formal markets. In this context, livestock often functions less as a profit-maximizing activity and more as a form of savings or asset accumulation, contributing to household resilience rather than short-term income generation.

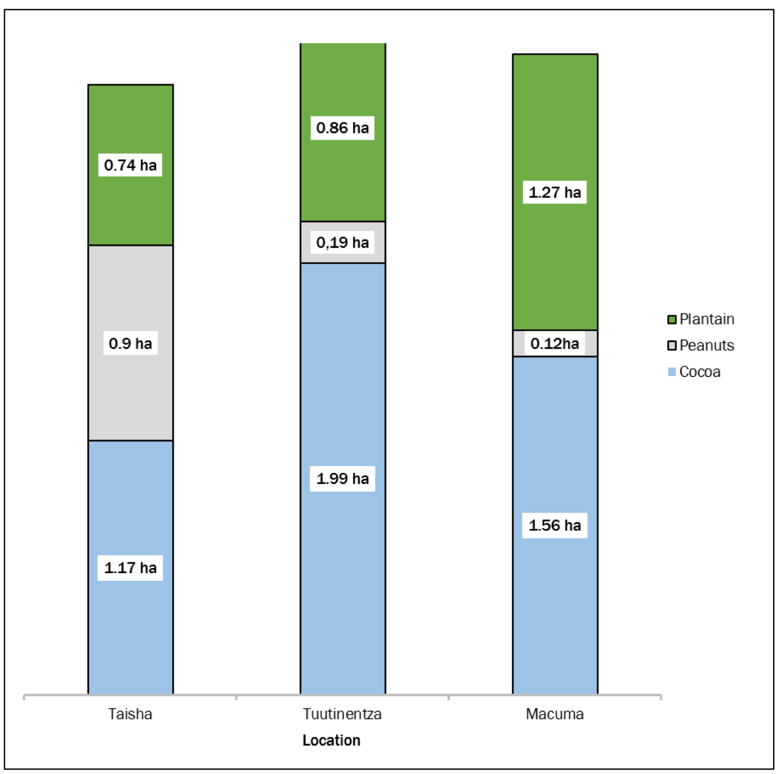
Analysis of Commercial Crops

Cacao is the crop with the largest cultivated area (0.3–5.0 ha) compared to peanuts and plantain (Table 1), generating average income ranging from US$500 to US$700 ha^{-1} $year^{-1}$ from pulp-grain mass (i.e., the amount of wet beans and pulp). Dried cacao in Taisha, Tuutinentsa, and Macuma (0.25, 0.26 and 0.30 t ha^{-1} $year^{-1}$, respectively) are lower than provincial and national reference values. However, these benchmarks should be interpreted cautiously, as chakra-based systems are not designed to optimize single-crop yields but to balance multiple outputs. Reported yield differences are associated with low levels of external inputs and management practices consistent with household labor availability and local agroecological knowledge, rather than with a lack of technical capacity.

In the same context, peanut cultivation shows lower yields (907 kg ha^{-1} $year^{-1}$) than the national average (2.268 – 2.722 ha^{-1} $year^{-1}$). Additionally, we observed that farmers dedicate limited time to the post-harvest process (i.e., removing peanut shells), a key step for improving quality and achieving a better market price. Although peanut cultivation can generate up to US$2,000 ha^{-1} $year^{-1}$ under national average conditions, yields in the study area are substantially lower due to management constraints. As a result, peanut cultivation is generally maintained at a small scale, with approximately 95% of cultivated plots being less than 1 ha (Figure 3), reflecting farmers' risk management strategies rather than expected profitability. The small cultivated areas may be related to the cultural practice of integrating peanuts in chakra.

Plantain is an important crop that is primarily intended for household consumption, with only the surplus sold in local markets. The cultivated area is less than 1.5 ha (Figure 3). The harvested plantain is sold only in local markets, although with lower demand compared to cacao and peanuts. Only 33%–50% of farmers in the three communities sell part of their plantain harvest, while the remaining respondents use the crop for subsistence purposes. The average income from plantain is US$761, US$358 and US$219 ha^{-1} $year^{-1}$ in Taisha, Tuutinentsa, and Macuma, respectively. These income levels correspond to yields of 3.69, 1.73, and 1.06 t ha^{-1} $year^{-1}$, which are approximately 2, 4, and 7 times lower than the national average plantain yield of 7.47 t ha^{-1} $year^{-1}$ reported by the Instituto Nacional de Estadistica y Censos (INEC, n.d.). This comparison highlights the substantial productivity gap between the study area and national production conditions.

Figure 3. The Average Area (ha) is Devoted to the Three Main Crops (Plantain, Peanuts, and Cacao) that Generate Income for the Household Economy of Small Farmers in Taisha, Tuutinentsa, and Macuma, in Morona Santiago, Ecuador



Livestock farming also contributes to household income, although its role varies across communities. The GAD provided significant support to cattle production through technical assistance to farmers, primarily in the form of genetic improvement programs using artificial insemination for dairy cattle. On average, each household sold approximately three head of cattle annually, generating annual income ranging from US$1,200 to US$2,011. These values fall within the national price range for adult cattle (US$376 to US$710 per animal), indicating that livestock prices in the study area are broadly consistent with national market conditions. Other animals, such as pigs, chickens, and ducks, are primarily raised for household consumption (86%), with only 3.5% sold at the farm or local markets, contributing marginally to household income.

To complement these household-level estimates, we conducted an opportunity cost analysis for commercial activities to compare their cash-income potential per hectare under observed production conditions. This indicator reflects short-term monetary returns and does not capture nonmarket values that are central to chakra-based agroforestry and forest systems, such as household food provisioning, cultural continuity, or ecosystem services.

Opportunity cost estimates varied

across activities and communities. Peanuts showed higher short-term cash return per hectare ranging from US$1.961 to US$2.056 ha^{-1} $year^{-1}$, compared to cacao (US$327 and US$439 ha^{-1} $year^{-1}$) and plantain (168–714 ha^{-1} $year^{-1}$), reflecting shorter production cycles and lower establishment costs. Livestock exhibited lowest returns in Taisha and Tuutinentsa (US$55.9 and US$68.9 per year, respectively), while Macuma reported a higher income (US$485 per year), reflecting differences in herd size, commercialization patterns, and market integration values associated with greater herd sizes (Table 1).

It is important to note that these opportunity cost estimates are expressed on a per-hectare basis for specific activities and are not directly comparable to household-level income from livestock sales. In these systems, cattle are typically managed under extensive grazing systems, characterized by low stocking densities and a reliance on relative large grazing areas, including communal or shared land, meaning that income from livestock is more closely linked to herd size and sales dynamics than to individually managed land area.

Cacao occupies a larger cultivated area across communities and provides a more stable source of monetary income over time, complementing other livelihood activities rather than substituting for them. High standard deviations in opportunity cost values across cacao, peanuts, plantain, and livestock indicate substantial heterogeneity among households, driven by differences in production scale, market access, labor activity, and cost structures, which result in wide dispersion of opportunity costs.

Market prices strongly influence opportunity cost estimates; for example, shelled peanuts commanded the highest price (US$1.08 kg^{-1}) among products during the survey period. However, limited cultivated areas, labor-intensive post-harvest processing, and household labor constraints restrict expansion. These results illustrate trade-offs in diversified livelihood portfolios and should not be interpreted as recommendations for land-use conversion or agricultural intensification.

Opportunity cost metrics are useful for understanding income constraints, but they are insufficient to evaluate the overall performance of Indigenous agroforestry systems, which pursue multifunctional objectives beyond monetary returns. These indicators should therefore be interpreted as partial measures of short-term cash-income potential, rather than as indicators of system efficiency or productivity in a broader socioecological sense.

The average opportunity cost of cacao and peanuts is relatively similar across the three communities. In contrast, plantain production shows substantial variation among communities, with the largest difference observed between of Taisha and Macuma (approximately 4:1), and intermediate ratio when comparing Tuutinentsa and Macuma (approximately 2:1).

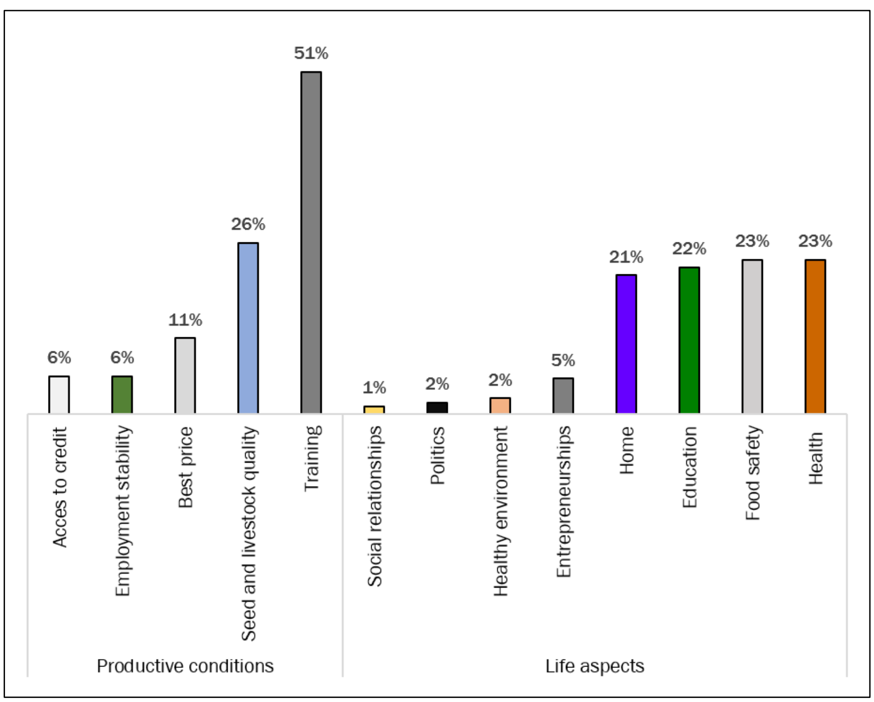
In these two communities, the opportunity cost for plantain differs from that of cacao due to differing economic priorities. For example, in Macuma, a greater reliance on off-farm employment reduces household labor availability for crop management, which influences both cultivated area and crop specific opportunity costs. Despite having a larger planted area than Taisha, its plantain yields are lower (3.69 t ha^{-1} yr^{-1} in Taisha versus 1.06 t ha^{-1} yr^{-1} in Macuma). Lastly, the opportunity cost of livestock production is notably higher in Macuma (US$485), which may be attributed to the number of cattle and stronger market integration, rather than differences in land productivity alone.

Perceptions of Well-being

We assessed the perceptions of farmers of well-being at the household level, encompassing environmental, economic, and social dimensions. From an environmental perspective, respondents consistently identified the forest as a highly valuable resource that supports agricultural activities, food security, and livelihoods. Farmers emphasized the importance of conserving the forest, while also recognizing its role in providing material for household use, particularly timber for home construction. Although we observed small-scale timber extraction , it was described primarily as a supplementary and opportunistic activity rather than a central livelihood strategy.

From a socio-economic standpoint, respondents reported that improving the performance of marketed activities should require better access to technical training, planting materials, livestock quality, markets access, and credit. These responses reflect perceived constraints within current market and service infrastructures. Respondents identified access to credit as a need but did not specify a preference for subsidized or low-interest loans. In this study, well-being is understood as a multidimensional concept encompassing food security, health, education, housing, and livelihood stability, rather than income alone. From this perspective respondents associated quality of life primarily with consistent access to healthy and safe food, free medical care for their families, educational opportunities for children, and homeownership (Figure 4). These well-being priorities are closely linked to livelihood strategies, as 71.4% of the surveyed farmers mentioned that migration to larger cities is considered an alternative to provide their children with better educational opportunities, with the expectation that somemay later return to their communities and contribute to the continuity of family livehoods and traditions. In contrast, 14.3% of respondents attributed children's migration to declining agricultural well-being, including low crop yields, falling prices, and limited local employment opportunities.

Figure 4. Identified Access Needs to Improve Farmers' Productive Conditions and Essential Life Aspects in Taisha, Tuutinentsa, and Macuma, Morona Santiago, Ecuador



Discussion

Our study identified cacao, peanuts, and plantain as the primary commercial crops in the study area, complemented by other crops cultivated at smaller scales, which contribute to household diets and local exchange. These diversified livelihood strategies are consistent with previous research in the Amazon, highlighting their role in reducing dependence on single commodities and buffering households against market volatility (Rudel et al., 2002; Vasco et al., 2018).

The chakra is integral to the cultural identity of Indigenous nationalities. It serves as a means to cultivate food crops that meet the nutritional and medicinal needs of families, thereby ensuring food security (Perreault, 2005; Sirén, 2007; Torres et al., 2014). This small plot of land also serves as a space of informal social interaction, particularly among women, who combine agricultural tasks with childcare while engaging in conversation and mutual support during field activities, as indicated by Palacios (1999) and observed in this study.

A 10-year study conducted in the northern Amazon revealed that 69.4% of the farms sampled at the beginning of the study had been subdivided (Bilsborrow et al., 2004). The authors distinguished between two types of landowners: long-term owners who typically manage larger landholding (>30 ha) with limited subdivision and maintain a higher proportion of the forest or grassland cover, and short-term owners, who manage smaller plots resulting from subdivision through inheritance or land sales. Our findings align more closely with the characteristics of long-term landowners.

Agricultural soils in the Amazon are widely recognized as vulnerable to erosion, nutrient loss, and declining fertility under intensified use (Vasco et al., 2013). In this context, the use of crop rotation, diversified planting, and organic matter management reflects adaptive responses to biophysical constraints rather than a lack of technical knowledge (Altieri, 2004; Corsi et al., 2012; Ellis, 2008). Differences in crop performance, including plantain and cacao yields, are shaped by interactions among soil conditions, climate variability, and disease pressure.

Our findings suggest that productivity outcomes are shaped less by isolated technical interventions than by broader structural and ecological constraints. In the case of cacao, susceptibility to diseases such as frosty pod rot (*Moniliophthora roreri*) and witches' broom (*Moniliophthora perniciosa*) interacts with locally adapted management practices and household labor constraints, influencing yields over time (Ceccarelli et al., 2024). Similar dynamics apply to practices such as grafting or crown replacement using plant material that is high-yielding and disease-resistant..

Monetary incomes from agriculture and livestock in the study communities are low relative to national averages, consistent with broader regional patterns (Córdova et al., 2019; Vasco et al., 2013). However, well-being in Indigenous contexts extends beyond cash income to include food provisioning, forest access, social networks, and cultural continuity (Barbieri et al., 2005). Low monetary returns are largely shaped by structural market constraints such as low farm-gate prices, weak infrastructure, and limited value chain integration (Nieto & Caicedo, 2012).

In this context, cost-to-income ratios must be interpreted with caution. Although these ratios appear relatively low, they primarily reflect the limited use of external inputs rather than high economic efficiency. In absolute terms, household incomes remain modest across the study sites, constraining their capacity to generate meaningful monetary returns.

Annual agricultural incomes of US$2,306, US$1,834, and US$1,221 remain low in absolute terms and limit the capacity of these systems to support improved economic outcomes. While comparisons across regions should be interpreted cautiously due to differences in production systems and market integration, smallholder cacao producers in Ecuador's coastal region have been reported to achieve higher average annual incomes (approximately US$5,000), even under low-input conditions. This contrast suggests that low cost-to-income ratios do not necessarily reflect economic viability, but rather the low-input nature of these systems, where limited investment is associated with constrained income generation.

Transportation costs emerge as a key constraint affecting the economic performance of agricultural systems in the study area. Although these costs represent a relatively small proportion of annual net income (approximately 6-20%), they should not be interpreted as a share of total production costs. Rather, they reflect the structural limitations associated with market access in remote Amazonian communities. Because both total costs and individual cost components are expressed relative to income, these metrics are not directly comparable. In absolute terms, transportation constitutes a significant financial burden, particularly in isolated areas such as Tuutinentsa, where limited infrastructure increases transaction costs and reduces market integration.

In this context, it is helpful to distinguish between household-level income and per-hectare economic measures. While livestock contributes to overall household income through animal sales, opportunity cost estimates are calculated per hectare for specific activities and are therefore not directly comparable. In these extensive systems, livestock income is shaped more by herd size, market access, and sales decisions than by the amount of individually managed land.

This study also highlights how low income and opportunity costs across communities reflect not only crop performance but also factors such as market proximity, herd size, off-farm employment, and culturally embedded land-use priorities (Kolinjivadi et al., 2015). Including family labor costs underscores the limits of monetary indicators in evaluating multifunctional Indigenous agroforestry systems (Mora-Delgado et al., 2007). Although this labor does not involve direct monetary transactions, it represents a substantial contribution to production processes and was valued using standardized wage proxies. This highlights the extent to which household labor substitutes for external inputs in low-input production systems. Rather than signaling inefficiency, these metrics reveal trade-offs within diversified livelihood strategies that prioritize resilience, food sovereignty, and long-term socioecological stability over short-term income maximization.

These findings highlight the importance of recognizing the multifunctional nature of Indigenous agroforestry systems and the limitations of one-size-fits-all frameworks focused solely on yield or income maximization. Consequently, training programs should prioritize soil conservation practices, including minimal tillage, crop rotation, and organic matter application, alongside the diversification of agroecological crops (Altieri, 2004; Corsi et al., 2012; Ellis, 2008).

Moreover, enhancing crop management practices is a key pathway to preventing production issues throughout the crop cycle In the case of plantain, the lack of essential agricultural practices such as fertilization, weed control, and disease management is a primary factor explaining why yields in the study communities are 2 to 4 times lower than the national average plantain yield of 7.47 t ha^{-1} $year^{-1}$, as reported by the National Institute of Statistics and Census (INEC, 2017). For cacao, reliance on seed-derived planting material can limit yield potential due to genetic heterogeneity, a pattern widely reported across cacao producing regions. This is a common characteristic in all cacao-producing countries.

As previously discussed, the economic activities of rural families in the EAR are primarily based on agriculture and livestock farming. However, these activities contribute to high levels of rural poverty, attributed to the low market price of primary products such as plantain, cassava, and others, which are sold at the local market level in the first stage of the supply chain (Nieto & Caicedo, 2012). At the same time, the importance of food security encourages Amazonian farmers to increasingly focus on maintaining forested areas, which provide direct economic and subsistence benefit through sustainable timber use and nontimber forest products such as wild fruits, fibers, and seeds (Barbieri et al., 2005). These forest resources complement diversifying farming systems that combine annual, short-cycle, and perennial crops with small-scale livestock production.

Within these systems, livestock also functions as a form of savings and financial buffer, rather than as an intensively managed production activity. This helps explain why livestock can contribute to household income despite low levels of monetary investment.

Our findings showed that a high percentage of farmers in the communities studied earn an average monthly agricultural income of approximately US$300 (Instituto Nacional de Estadística y Censos, 2021). This income pattern among small-scale farmers is consistent with previous studies conducted in other provinces of the EAR (Córdova et al., 2019; Vasco et al., 2013, 2015). Despite the long-standing policy objective of poverty reduction, investment in the agricultural sector remains limited, and the effectiveness of these investments in improving rural livelihoods remains uneven.

Limited investment in the productive sector continues to constrain agricultural development and highlights the challenges faced by family farming in the Amazon (Inter-American Institute for Cooperation on Agriculture, 2018). The use of recycled seeds, defined here as farmer-saved planting material selected from a previous harvest (e.g., beans and pods) and replanted without genetic or quality certification, together with limited working capital for purchasing organic inputs and the absence of essential equipment for pruning and weed control, contributes to heterogeneous plant stands, reduced vigor, and increased susceptibility to pest and diseases. In addition, institutional barriers to credit—particularly the absence of individual land titles—exclude many farmers from formal financial systems, limiting their capacity to invest in productivity-enhancing practices (Bilsborrow et al., 2004).

These constraints are reinforced by poor infrastructure, limited market access, and restricted opportunities for value addition. Under these conditions, off-farm employment, particularly among adolescents and young adults, is perceived as a strategy to improve household income and finance education (Barbieri et al., 2005; Bilsborrow et al., 2004; Sellers et al., 2017). Agricultural income and activities in the EAR vary based on specific local conditions. Torres et al. (2018) reported an average annual agricultural income of US$2,199 in the northern Amazon, whereas in the present study, the average annual income was US$1,746 . Importantly, the inclusion of family labor costs in the present analysis provides a more accurate representation of net income and opportunity costs across production systems (Mora-Delgado et al., 2007).

Conclusion

As discussed in this study, rural poverty in the Ecuadorian Amazon is shaped by a combination of structural, economic, and institutional factors that condition agricultural and livelihood outcomes. The results indicate that these conditions do not reflect a failure of Indigenous farming systems; instead the socioeconomic conditions documented in this study highlight the constraints faced by Shuar households in accessing markets, public services, infrastructure, and supportive policy frameworks. By examining the contribution of agricultural and livestock activities to household income, our findings align with previous studies showing that rural livelihoods in the Amazon are embedded in diversified, low-capital strategies that balance food security, risk management, and cultural continuity.

Our study also highlights a gap between the design of public policies and their implementation on the ground, particularly the difficulty of aligning top-down development strategies with locally embedded practices and priorities. This is reflected in the limited documented impact of existing programs in the study communities discussed above. The needs identified by Shuar farmers (e.g., strengthening traditional production systems, access to credit adapted to their economic realities, and securing planting materials appropriate to local agroecological conditions) are not always reflected in existing programs. This misalignment underscores the importance of policy frameworks that are responsive to Indigenous socioecological realities.

Consistent with the discussion, the results emphasize the limitations of conventional economic indicators, such as opportunity cost, when the applied in isolation. While these metrics are useful for comparing short-term cash income, they do not capture the broader set of values embedded in Indigenous agroforestry systems, including food provisioning, ecosystem services, and cultural practices.

Based on these findings, our results highlight the importance of development approaches that recognize the multifunctional nature of chakra-based farming systems, support culturally appropriate value chains, and value local knowledge and governance structures through bottom-up strategies. Such approaches are better suited to strengthening livelihoods while maintaining ecological integrity and cultural continuity in Indigenous Amazonian territories.

Finally, we suggest the use of monitoring and evaluation indicators as complementary mechanisms to assess the effectiveness of existing national and regional programs, such as payment for environmental services schemes and territorial development plans in reaching Indigenous communities. While such initiatives (e.g., "Socio Bosque" and "2024–2025 Development Plan") formally aim to enhance agricultural productivity, promote environmental sustainability, and reduce rural poverty, their outcomes at the local level remain insufficiently documented in Amazonian communities.

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