Environmental and social sustainability

The forest, a lever for sustainable development in Colombia

J. Julián Cubero, Nara González, Rafael Ortiz, Diego Pérez, Alejandro Reyes, Juana Téllez[1]

October 2024

Summary and conclusions

Deforestation in Colombia is unsustainable both environmentally and economically. Reversing it requires strengthening the land ownership and use regime, promoting sustainable development in the areas to be protected, enhancing productivity in those designated for economic exploitation, and aligning economic incentives to protect forests through coordinated public policies.

- **Forest deforestation in Colombia is unsustainable both environmentally and economically.** The country loses between 200,000 and 300,000 hectares of tree cover annually to the expansion of agriculture and cattle ranching, illegal mining or illicit crops. There are notable differences in their respective significance across departments, ecosystems and municipalities. This destruction of forests not only affects the environment. It also has a negative impact on the economic and social development of the affected communities. In fact, deforestation slows down the convergence of per capita GDP at the municipal level, with a greater impact for lower income municipalities. In addition, according to indicators such as the unmet basic needs index, there is no correlation between deforestation and poverty reduction.
- **Reversing deforestation requires increasing the possibilities of economic development with policies that act through three levers.** First, by strengthening the system of land ownership and use, without encouraging predatory actions. It is also critical to facilitate responsible productive use of land at risk through strategies consistent with environmental sustainability, while promoting greater productivity in areas designated for economic exploitation through the provision of public goods (security, infrastructure), logistical solutions and financial support based on strategies involving the private sector. Finally, and consistent with the above, progress must be made in the economic integration of the natural value of forests by developing projects that generate carbon credits and reward the protection of biodiversity.
- **The challenge for the authorities: design and implement a strategy that aligns incentives.** Eliminating deforestation requires coordinated action through multiple public policies, with a long-term vision to align the behavior of communities and the private sector. The funding of these policies requires that the different instruments available - which include, among the different environmental tools: carbon tax, tradable emission allowances, and voluntary markets - are fully implemented and aligned with the objective of eliminating deforestation.

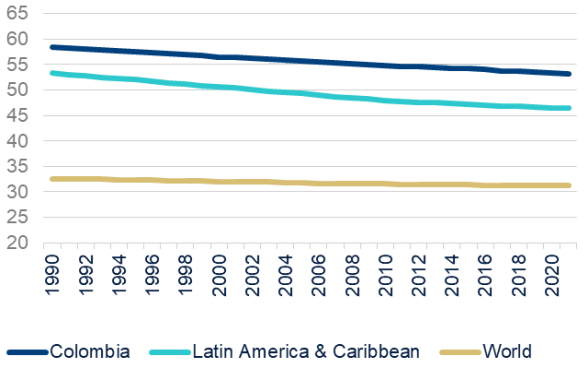
[1] The authors are grateful for the collaboration and comments of Joxe Mari Barrutiabengoa (BBVA) and José Ángel Cañizares (BBVA). In addition, the work draws on conversations with Ingo Ramming (BBVA) and a range of participants in the development of carbon markets in Colombia: Allcot, Asobancaria, Asocarbono, Verra and Conservation International. The conclusions of the paper are the responsibility of the authors.

Deforestation is environmentally unsustainable and slows economic development

Colombia loses between 200 and 300 thousand hectares of tree cover annually due to the expansion of agriculture and livestock and illegal activities. These causes have a widely varied impact across departments and at the municipal level. The destruction of forests is not sustainable from an environmental point of view, nor is it economically or socially sustainable: it slows down the convergence of municipal per capita GDP, with a more intense effect in municipalities with lower relative income.

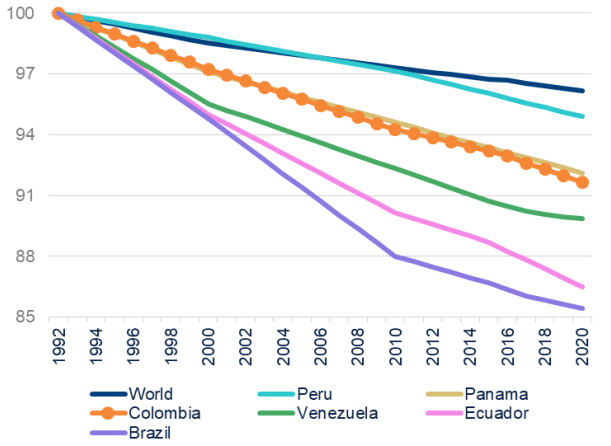
Forests in the world. Forests account for more than one third of the Earth's habitable area [2](**Figure 1**). They are shrinking with the expansion of the agricultural frontier (crops and pasture for livestock).[3] Forest area has fallen by just over 3% since 1990. This percentage rises to 9% in Colombia, close to the midpoint of the trend in neighboring countries, which range from 5% in Peru to almost 15% in Ecuador and Brazil **(Figure 2)**.

Figure 1. **FOREST AREA (% OF THE TERRITORY)**



Source: BBVA Research, based on data from the World Bank.

Figure 2. **FOREST AREA**
(% OF THE TERRITORY, 1992 = 100)



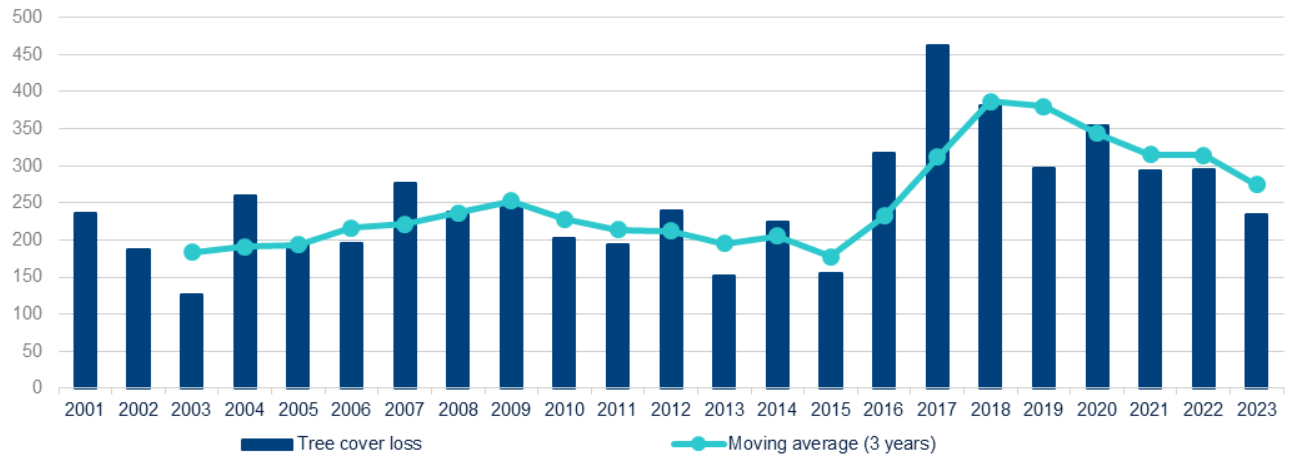
Source: BBVA Research, based on data from the International Monetary Fund.

Colombia: sustained loss of tree cover. Colombia loses between 200,000 and 300,000 hectares of tree cover annually,[4] with a significant increase in the 2016-20 period (**Figure 3**). The upturn observed in that period results mainly from the combination of two factors: The improvement in measurement[5] and the peace agreement between the government and the FARC-EP, which allowed greater access to previously inaccessible areas. With hopes for the end of the conflict, the expected value of land increased, especially in the Orinoco and Amazon regions, where deforestation became a tool for land appropriation. Deforestation can also be associated with the absence of power and control figures, legal or illegal, in the years following the signing of the agreement.

[2] Habitable surface area being defined as that which is not covered by glaciers or sterile land (deserts, rocky surfaces, dunes, etc.).
[3] The Food and Agriculture Organization of the United Nations (FAO) estimates that agriculture occupies about 50% of the habitable area. Source: FAO, 2020. State of the World's Forests 2020.
[4] According to Global Forest Change from satellite images. "Loss" denotes the removal or mortality of tree cover and can be due to a variety of factors, including mechanical harvesting, fire, disease, or storm damage. So "loss" does not equate to deforestation. For more detail on the forest baseline data in this paper, see **Box A. Forest cover loss and deforestation. Data and methodologies**.
[5] The improvement in measurement accuracy from 2012 and in particular since 2015 is due to improvements in satellite data and algorithm adjustments. See: Assessing Trends in Tree Cover Loss Over 20 Years of Data.

Limited improvement in 2023. In 2023 the loss of tree cover fell again, coinciding with new peace talks, but above all with the operation of the Deforestation Containment Plan, and especially with the strengthening of the "Conservar Paga" (Conservation Pays Off) program. This is a scheme of voluntary agreements aimed at peasants, indigenous and black communities to protect and conserve forests in exchange for an economic incentive. This varies according to the socioeconomic and environmental profile of each family and can reach a value of up to 900,000 Colombian pesos per month (75% of the national minimum wage).[6]

Figure 3. **LOSS OF TREE COVER IN COLOMBIA (** THOUSANDS OF HA.)



Source: BBVA Research based on Hansen/UMD/Google/USGS/NASA.

Unequal distribution across departments and ecosystems. The loss of tree cover presents a significantly uneven spatial distribution. During the period 2001-2023, the departments that have registered the greatest loss of tree cover are Caquetá, Meta, Antioquia, Guaviare and Putumayo, more than 50% of the total loss at the national level. The map (**Graph 4)** highlights in blue the areas with the highest deforestation, mainly located in the aforementioned departments. It also illustrates how deforestation spreads across different ecosystems and regions of the country, from the Amazon to the Caribbean region, reflecting the variety of causes that drive it.

[6] In its initial phase, this program covered 14 municipalities that make up the Amazon Deforestation Arc (Putumayo, Guaviare, Caquetá and Sur del Meta), although at the beginning of 2024 it was extended to the Pacific region.

Figure 4. **CUMULATIVE TREE COVER LOSS (** Million Hectares, 2001-2023)

Source: BBVA Research based on Hansen/UMD/Google/USGS/NASA
Note: Annual loss of tree cover, defined as the replacement of vegetation by stands greater than 5 meters in height, with resolution ~30 × 30 meters. The intensity of color refers to the progression over time, from lighter to darker.

Box A. Forest cover loss and deforestation. Data and methodologies

Not all loss of forest cover is deforestation. In Hansen et al. (2013) forest cover is defined as all vegetation over 5 meters in height, whether natural forest or plantations, and within a wide range of vegetation densities. "Loss" denotes the removal or mortality of tree cover and can be due to a variety of factors, including mechanical harvesting, fire, disease, or storm damage. Therefore, it is not possible to equate loss with deforestation, a more specific concept, since it refers only to the abrupt transition from wooded land to treeless land, with no subsequent growth, as pointed out in Curtis et al. (2018),[7] a reference that is followed for the data for this study.

Satellite images. The survey is based on the use of high-resolution satellite images obtained from Google Earth and Landsat. This allows for a detailed and consistent analysis of global forest cover changes since 2001.[8]

Image classification model. The core of the methodology is a decision tree-based classification model that was trained using nearly 5000 sample cells. These cells were visually analyzed to identify the dominant cause of forest disturbance in each.[9] The authors classified disturbances into five main categories:

1. **Commodity-driven deforestation**: It involves the permanent conversion of forest land to other uses, such as agriculture or infrastructure.
2. **Shifting agriculture**: This consists of the temporary conversion of forests for agriculture, followed by forest abandonment and renewal.
3. **Forestry**: Large-scale forestry operations in managed forests, with subsequent forest regeneration.
4. **Wildfire**: Loss of forests due to fires, with no subsequent visible human activity.
5. **Urbanization**: Expansion and intensification of urban centers on previously forested lands.

Regional variability of the causes of forest cover loss. In temperate and boreal regions, forestry and wildfires proved to be the main drivers of disruption, while in tropical regions shifting agriculture and commodity-driven deforestation predominated. Specific patterns of land use and forest management are also identified, such as the expansion of palm plantations in Southeast Asia or the conversion of forests for agriculture in Latin America.

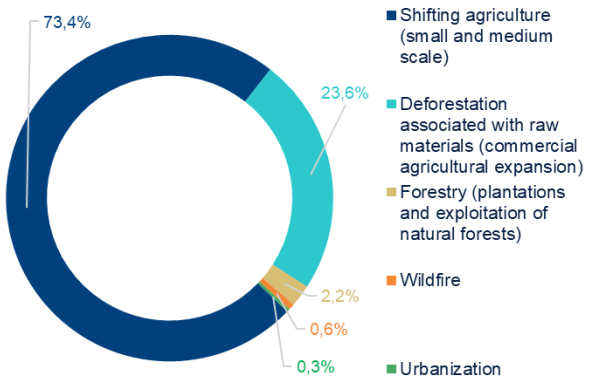
Why has the IDEAM data not been used? Global Forest Watch (GFW) is based on high-resolution satellite data with standardized global reach that are consistently comparable across countries. This methodology, developed by the University of Maryland and supported by studies such as those of Hansen et al. (2013) and Curtis et al. (2018), is widely recognized in the scientific community and commonly used in deforestation studies. The use of satellite data also allows the data to be analyzed with greater detail and granularity. Another key point is the ability to detect and report any loss of tree cover, regardless of its permanence or reversibility, which allows for a more detailed assessment of the real impact of human activity on forests. This contrasts with the methodology of the Forest and Carbon Monitoring System (SMByC), as part of IDEAM, based on its own inventories and methodology that integrates satellite image preprocessing and treatment tools to detect and quantify the loss of forest cover due to deforestation[10]. This approach focuses on permanent land-use changes, resulting in generally lower deforestation figures. P. Rivadeneyra et al. (2023) highlights that GFW, by including temporary losses or minor degradations, tends to report higher levels of deforestation, especially in small and remote areas that IDEAM may not fully capture. Finally, GFW offers updates on a more regular basis. These characteristics make GFW a robust and reliable tool for the analysis of deforestation in Colombia.

[7] "... Deforestation involves the abrupt transition from tree-lined to treeless land; [however] loss of forest cover can also be associated with events such as wildfires, or with directly human-induced land use and management practices, such as clear-cutting or selective logging, plantation forestry, smallholder agroforestry systems, or transitional subsistence farming due to shifting cultivation practices..." Classifying drivers of global forest loss | Science.
[8] Google Earth imagery is particularly relevant, as it provides a high enough resolution to identify different land-use patterns and forest disturbances in 10×10km cells
[9] To assess the accuracy of the model, an independent validation sample of 1565 randomly selected cells was used.
[10] For more information on the SMByC methodology: Cabrera, E., Galindo, G. González J. Update of Forest Area Monitoring Figures 2020. Institute of Hydrology, Meteorology and Environmental Studies – IDEAM-. Ministry of Environment and Sustainable Development. Bogotá, 2022. and Cabrera, E., Galindo, G., González, J., Vergara, L., Forero, C., Cubillos, A., ... Duque, A. (2020). Colombian Forest Monitoring System: Assessing Deforestation in an Environmentally Complex Country. IntechOpen. doi: 10.5772/intechopen.86143.

The causes of deforestation: Expansion of the agricultural and livestock frontier, illicit crops and illegal mining.

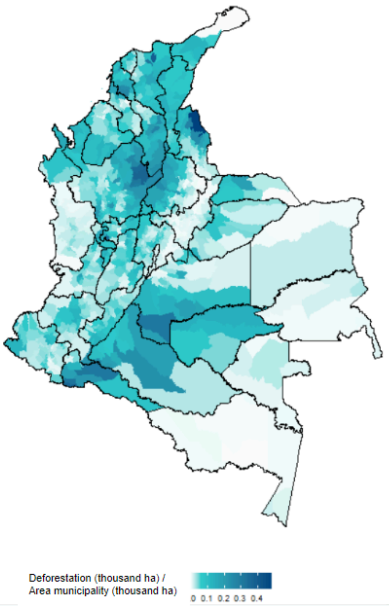
Heterogeneity of causes of deforestation. The loss of tree cover is a heterogeneous phenomenon across geographies and underlying causes. According to Curtis et al. (2018), the main cause of forest cover loss in Colombia is shifting agriculture: small- and medium-scale agricultural and livestock activities, which may well result in a temporary or permanent loss of forest cover. During the 2001-2023 period, shifting agriculture accounts for 73.4% of the total, followed by commodity-related deforestation (23.6% of activities linked to large-scale deforestation - permanent loss - related to the expansion of commercial agriculture). Finally, the loss of tree cover related to forestry, wildfires and urbanization represents 3% of the total (**Figure 5**).[11] **Box B. Quantifying the causes of deforestation shows a statistical analysis whose main conclusion is that the diversity of the relative importance of the causes of deforestation is maintained even at the municipal level.**

Figure 5. **COLOMBIA. LOSS OF TREE COVER, CLASSIFIED BY CAUSE** (% OF THE TERRITORY)



Source: BBVA Research based on Curtis et al. (2018)

Figure 6. **LOSS OF MUNICIPAL CUMULATIVE TREE COVER, 2001-2023** (%)



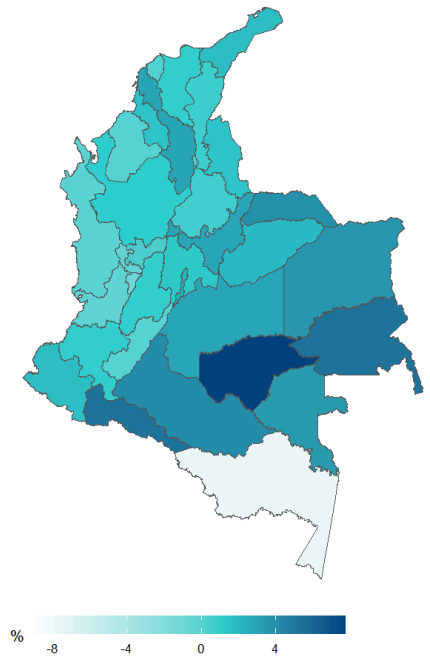
Source: BBVA Research, based on Hansen/UMD/Google/USGS/NASA

[11] These estimates are based on high-resolution Google Earth imagery (10 km × 10 km cells) to map and classify global forest loss since 2001 through a decision tree model that classifies the most likely cause of forest loss. Details: **Box A. Forest cover loss and deforestation. Data and methodologies**.

Importance of livestock farming expansion. In Colombia, according to data from the National Administrative Department of Statistics (DANE), headcount of bovine and buffalo cattle have increased steadily since records began. They peaked in 2023 at around 30 million head. At the departmental level, focusing on the regions with the highest tree cover losses, this trend is also observed in Putumayo and Guaviare: these were the departments with the highest average growth between 2006-2023 of about 5.2% and 7.7% per year, respectively **(Figure 7)**. While, in absolute terms, Antioquia stands out above the rest, with more than 3 million head in 2023.

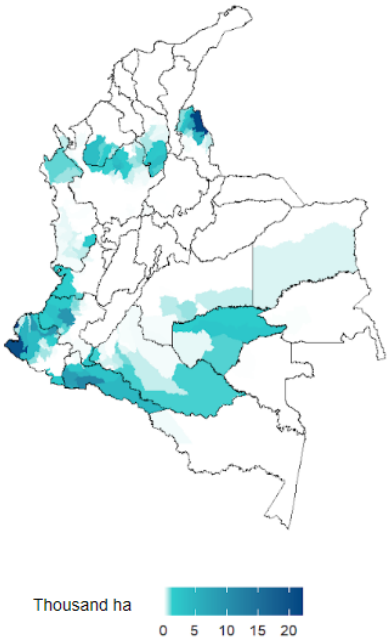
Illicit crops contribute to deforestation, especially in certain border areas. According to the latest records of the Colombian Ministry of the Interior, the greatest detection of illicit crops has occurred in municipalities in the departments of Norte de Santander, Nariño and Putumayo. An examination of the spatial distribution of tree cover loss **(Figure 6)** and coca cultivation detected at the municipal level **(Figure 8)** shows its presence in municipalities with higher levels of deforestation. It should also be noted that its presence is mainly concentrated in regions bordering Venezuela and Ecuador.

Figure 7. **AVERAGE CATTLE HERD GROWTH (** %, 2006-2023)



Source: BBVA Research with FEDEGAN data.

Figure 8. **DETECTED COCA CROPS** (THOUSAND HECTARES, 2022)

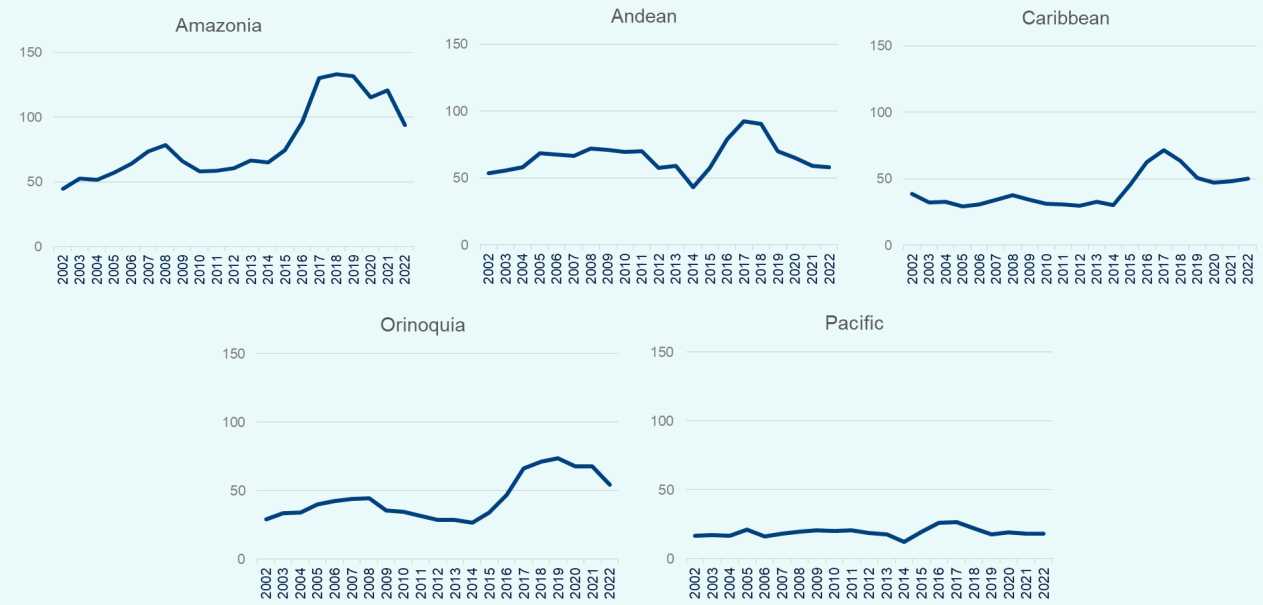


Note: Hectares planted with coca crops identified through interpretation in satellite images.
Source: BBVA Research with data from the Colombian Ministry of Justice and Law.

Box B. Quantifying the causes of deforestation

In order to understand the main drivers of deforestation, we selected tree cover loss as a variable of interest and a proxy for deforestation.[12] In addition, variables representative of the various factors that could be contributing to this phenomenon at the municipal level were identified, covering all of Colombia's 1,121 municipalities (and departmental townships) for the period 2006-2022. In addition, a three-year moving average was used to reduce volatility, allowing for a more stable representation of deforestation trends over time[13]. To adjust for differences in the size of the municipalities, it was decided to use the percentage of tree cover loss as the reference. With regard to the factors that contribute to explaining deforestation, the relevance of agriculture and livestock, the rule of law (forced displacements) and illicit activities (mining and illicit crops) are analyzed.

Figure B.1 **DEFORESTATION (THOUSANDS OF HA) BY REGION**



Note: Moving Average (3 years)
Source: BBVA Research based on Hansen/UMD/Google/USGS/NASA.

Information on agriculture and livestock is obtained from the Evaluaciones Agropecuarias Municipales (EVA), an official and detailed source of data on land use at the municipal level. To quantify the extent of agricultural crops, the hectares dedicated to all types of crops reported (such as coffee, palm oil, among other crops) in each municipality were added, according to EVA records. As for livestock data, the number of cattle and buffalo from the EVA livestock base has been obtained since 2019 due to availability at the municipal level.[14]

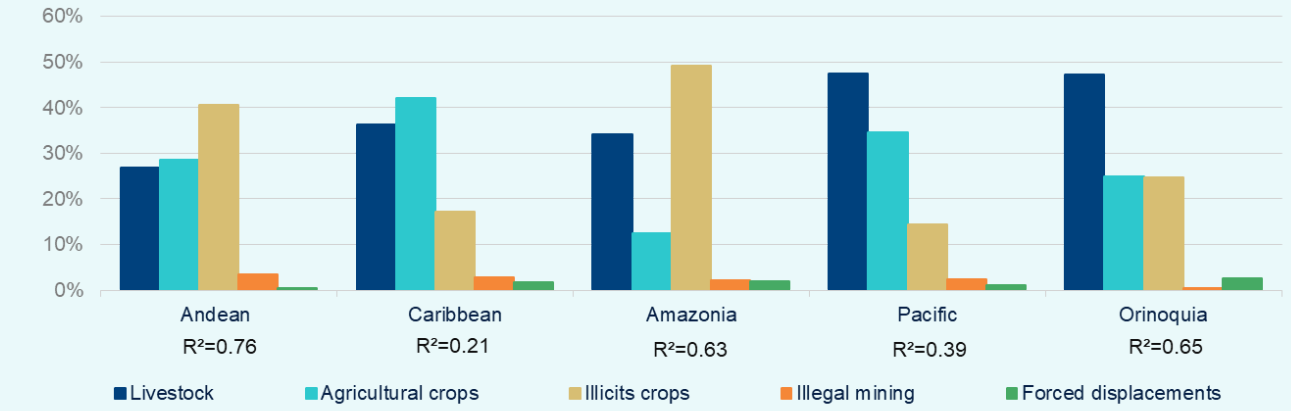
The information on forced displacements, another driver of changes in land cover identified (Ruiz & Tamayo, 2020), was obtained from the Observatory of Memory and Conflict of the National Center for Historical Memory. In addition, for the analysis of the area of illicit crops, defined as the extension in hectares planted with coca

[12] For more details on the data, see **Box A. Forest cover loss and deforestation. Data and methodologies**.
[13] Using a moving average is recommended due to variations in the availability of Landsat satellite imagery, smoothing out potential inconsistencies between years. Assessing Trends in Tree Cover Loss Over 20 Years of Data.
[14] For previous years , the data were estimated by extrapolating the average percentage of participation of each municipality within its department, based on the historical series at the departmental level provided by the Colombian Federation of Cattle Ranchers (FEDEGAN).

crops detected through the interpretation of satellite images, data provided by the Colombian Drug Observatory (ODC), under the Ministry of Justice and Law of Colombia, were used. With regard to illegal mining, which is particularly relevant for the Andean and Pacific regions of the country, the number of people arrested for criminal conduct committed against natural resources and the environment has been chosen as a proxy variable from the Ministry of National Defense of Colombia.

To assess the relative importance of these factors in deforestation, the Extreme Gradient Boosting (XGBoost) technique was used, a machine learning method that is particularly effective in prediction due to its ability to handle large data sets and capture nonlinear relationships between variables.[15]

Figure B.2 **IMPORTANCE OF VARIABLES AT THE REGIONAL LEVEL (%, EXPLAINED VARIANCE)**



Source: BBVA Research based on XGBOOST analysis.

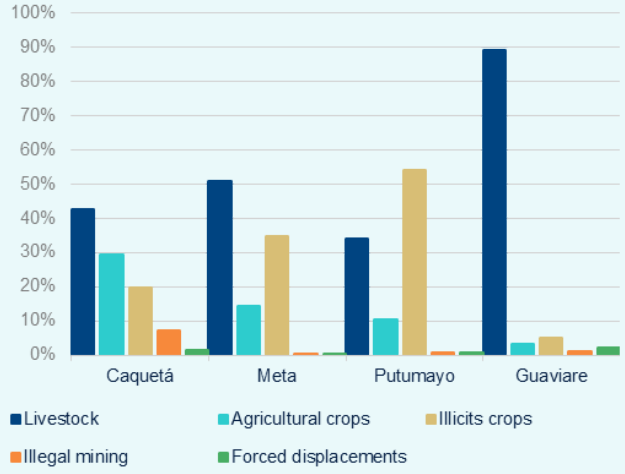
The results shown in Figure B2 indicate a strong explanatory power in deforestation dynamics, ranging from 0.21 in regions with lower deforestation, such as the Caribbean, to 0.76 in the Andean region. This analysis makes it clear that, although the agricultural frontier and illicit crops stand out as the main explanatory factors of deforestation, the relevance of these factors varies significantly between regions. For example, in the Andean region, illicit crops predominate as the main cause of deforestation. This is due to the large presence of illicit crops in border municipalities, as is the case in Norte de Santander, which even extends to protected areas, collective territories, and indigenous reservations (Erasso and Vélez, 2020). The high importance of illegal crops in the Amazon, however, could be caused by the lack of data on other variables in the departments of Vichada and Guainía.

The Amazon Arc, the region with the highest deforestation rate in Colombia, maintains at the municipal level the diversity of dominant causes. This area, composed of the departments of Caquetá, Meta, Putumayo and Guaviare, concentrates 40% of the loss of tree cover in Colombia between 2001-2023. Thus, it seems appropriate to analyze the causes at a more granular level. While recent reports have already pointed to the causes of deforestation in this region[16], our analysis corroborates this quantitatively. The figure on the left (Figure B3) illustrates the significance of the causes in the departments. In the map on the right (Figure B4), the most

[15] XGBoost is a machine learning technique based on the principle of boosting, where multiple decision trees are built sequentially. The goal of each new tree is to improve on the (residual) errors made by previous trees. At the start, a simple tree is trained to make a basic prediction. Then, at each step, trees are added that adjust their predictions depending on the errors made by the previous set of trees. In this way, the model gradually improves. One of the keys to XGBoost is that it optimizes the process using techniques such as parallel processing to speed up the construction of the trees, and regularization to control the complexity of the model, avoiding overfitting. In addition, XGBoost automatically handles missing values and performs pruning (simplifications) to remove unnecessary branches on trees, making it very efficient in terms of both time and accuracy. Reference: Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining: XGBoost: A Scalable Tree Boost. In addition, Ganzenmüller , Sylvester, and Castro-Núñez (2022) show an empirical analysis based on this technique of the relationship between deforestation in Colombia and its Peace Process.
[16] According to the Foundation for Conservation and Sustainable Development (FCDS), the main causes of forest transformation are the opening and expansion of roads, illegal land grabbing, extensive cattle ranching, the agro-industry of Oil Palm and Eucalyptus, and the planting of illicit crops.

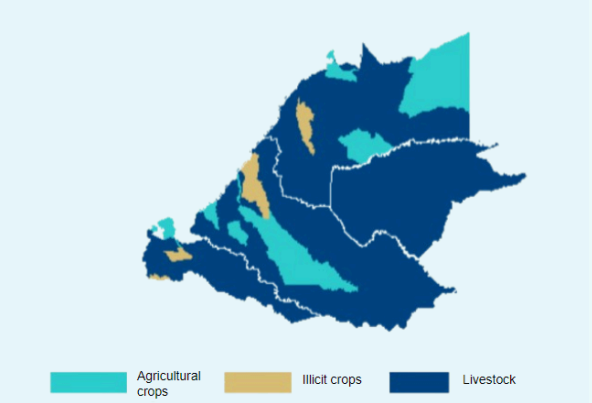
significant variable in each of the municipalities is selected (this does not exclude the role of the other variables). Extensive cattle ranching occupies most of the territory. However, the presence of illegal crops is more prevalent in municipalities with higher levels of relative deforestation - those municipalities located in the northwest - and in neighboring areas. Here, the absence of effective government control facilitates the expansion of these activities.

Figure B3. **IMPORTANCE OF VARIABLES FOR THE DEPARTMENTS OF THE AMAZON ARC**



Source: BBVA Research based on XGBOOST analysis

Graph B4. **IMPORTANCE OF VARIABLES AT THE MUNICIPAL LEVEL IN THE AMAZON ARC**



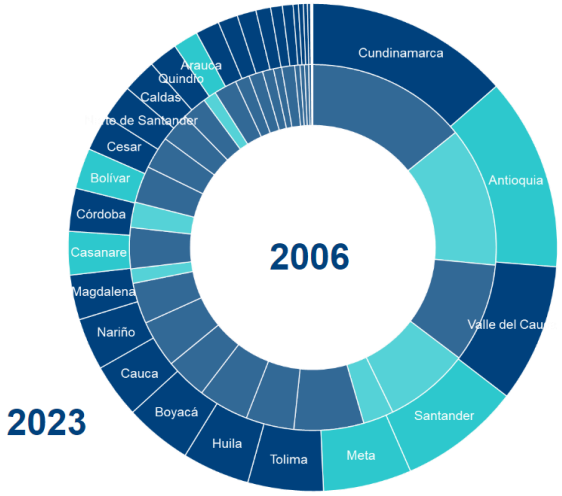
Source: BBVA Research, based on XGBOOST analysis
Note: For each of the municipalities, the cause with the greatest weight has been assigned. This does not rule out that other causes may be significant.

The consequences of deforestation: Convergence of GDP per capita slows down, especially where the relative level of development is lower.

With deforestation, the weight of agricultural and livestock activity increases. Deforestation occurs because there is an economic incentive. The expansion of the agricultural frontier is mainly associated with the advance of small agricultural and livestock farms. These land uses are not always the ones with the most added value, but they are often the ones that can most immediately provide a means of subsistence for the most disadvantaged segments of the Colombian population. **Graph 9** shows the departmental contribution to Colombia's agricultural GDP for 2006 and 2023. Antioquia, Santander, Casanare, Bolívar, Arauca and especially Meta (growing from 2.7% to 5.8% of the national total) stand out with the highest increases in their shares. Antioquia, Meta and Bolívar are in the "top 10" of departments in which the most loss of tree cover has been recorded.

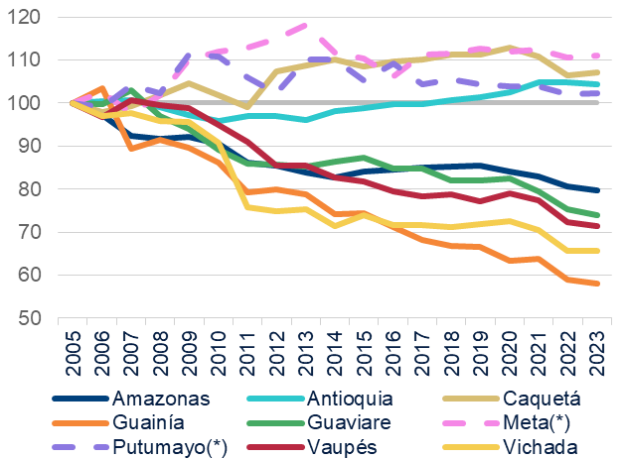
Deforestation does not have a clear correlation with the relative per capita income at the departmental level. An increase in the relative significance of the primary sector is not sufficient to significantly increase GDP or to improve per capita GDP in relative terms (**Figure 10**). Among the departments in which the most deforestation occurs, processes of both real divergence (fall in per capita GDP relative to the national GDP) and convergence (increase) are observed. In particular, the relative position of Meta and Putumayo is affected by the rise in oil revenues. Even correcting for this factor,[17] a convergence process is observed, which is also evident for the most recent years in Antioquia. In the same way, clear processes of relative divergence are observed both in departments with high deforestation (Guaviare) and in others with less incidence (Amazonas, Vichada).

Figure 9. **DEPARTMENTAL CONTRIBUTION TO NATIONAL AGRICULTURAL GDP, 2006 vs. 2023** (%)



Note: The inner circle represents the distribution in 2006 while the outer circle represents the distribution in 2023.
Source: BBVA Research using data from DANE.

Figure 10. **DEPARTMENTAL OVER NATIONAL GDP PER CAPITA RATIO**
(CONSTANT PRICES 2015, 2005=100)



(*) Meta and Putumayo exclude GDP from the Mining and Quarrying sector.
Source: BBVA Research using data from DANE.

Deforestation slows down the convergence of per capita GDP at the municipal level, with a greater impact where relative income is lower. The conclusions of the descriptive analysis at the departmental level are nuanced

[17] For the departments of Meta and Putumayo, GVA from the mining and quarrying sector has been excluded. However, this correction may be incomplete as the taxes collected by the sector and, above all, the indirect demand from other sectors are not subtracted, thus assuming that there is a partial upward bias.

by an empirical analysis with municipal granularity. Although it is concluded that deforestation does not have a statistically significant effect on municipal per capita economic growth, it nevertheless contributes statistically to slowing down its convergence with respect to the national average level, especially in municipalities with lower relative incomes. Thus, a 1% increase in deforestation reduces municipal per capita convergence with respect to the median by 0.007%, contributing to greater economic inequality. On the other hand, the fact that growth in the industrial and service sectors have a positive impact on economic development suggests that a diversified economy is key to sustainable growth (for more details see **Box C. Is deforestation worth it? An analysis at the municipal level**).

Box C. Is deforestation worth it? An analysis at the municipal level

This analysis explores whether the loss of tree cover is positively correlated to municipal per capita GDP, or if, on the contrary, it limits opportunities for economic growth. In addition, since deforestation tends to be more common in areas where the opportunity cost is lower (i.e. in less developed rural areas, where the value of preserving the forest is low), it is essential to examine the relationship between deforestation and the level of economic development of a municipality – measured as the municipality's per capita GDP relative to the national median.[18]

Is it worth deforesting? To answer this question, municipal-level data are used for the period 2011-2022 of per capita GDP and per capita GDP relative to the national[19] median and deforestation (loss of tree[20] cover). This relationship is statistically controlled by the influence of sectoral specialization (with the GVA of the primary, secondary and tertiary sectors, obtained from DANE) and the rule of law[21], these being significant factors for the degree of development of a territory.

The relationship between the variables is established by means of an error correction model (ECM). This is appropriate since the existence of cointegration between the variables is accepted through unit root tests applied to the data panel.[22] The ECM equation we use in our analysis is as follows:

$$\Delta GDPpc_{it} = \alpha_i + \lambda(GDPpc_{it-1} - \sum_{j=1}^{n} \beta_j X_{jit}) + \sum_{j=1}^{n} \gamma_j \Delta X_{jit} + \epsilon_{it}$$

[18] Analysis of the causes of deforestation has shown the significance of geographic granularity, even at the municipal level. This means that in order to study the economic consequences of deforestation, it is relevant to incorporate the same axis.
[19] The choice of the median instead of the average avoids the upward bias introduced by inequality in the distribution of municipal per capita income, with a concentration of high levels in large cities. In this situation, the median provides a more representative measure of the average standard of living of municipalities.
[20] Hansen et al., 2013.
[21] This variable is approximated by the total number of cases of violence at the municipal level, a proxy obtained from the Observatory of Memory and Conflict of the National Center for Historical Memory.
[22] The ECM model is useful for capturing both long-term relationships and short-term adjustments toward equilibrium.

where the dependent variable represents the change in municipal per capita GDP for municipality i at time t (and, in the case of convergence models, the growth of municipal per capita GDP for municipality i at time t with respect to the national median GDP), followed by the constant term specific to each municipality capturing fixed effects, the long-run adjustment coefficient, which indicates the speed at which the dependent variable returns to equilibrium, and the matrix X, which includes the explanatory variables (deforestation, primary GVA, secondary and tertiary GVA, cases of violence). Logarithms are applied for all variables in levels. This model allows us to differentiate between the short- and long-term effects of deforestation and other economic variables on municipal economic growth.[23]

Table C.1 **REGRESSION RESULTS**

	(1) D.l_gdppc	(2) D.l_gdppc_median	(3) D.l_gdppc_median Percentile 75
D.l_deforestation	0.000424	-0.00706***	-0.00955***
	(0.34)	(-4.46)	(-6.07)
D.l_primary_GVA	0.221***	0.196***	0.152***
	(14.30)	(13.93)	(13.03)
D.l_secondary_tertiary_GVA	0.770***	0.362***	0.293***
	(54.62)	(18.38)	(14.42)
D.l_violence_cases	-0.00683***	-0.00722***	-0.00837***
	(-8.96)	(-9.32)	(-10.20)
L.Residuals	-0.175***	-0.168***	-0.320***
	(-11.80)	(-12.36)	(-13.44)
Constant	-0.0124***	-0.0500***	-0.0416***
	(-10.39)	(-30.94)	(-24.14)
Observations	12331	12331	9244
Adjusted R^2	0.731	0.534	0.566

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: BBVA Research.

The results obtained show that deforestation does not have a statistically significant effect on the variation of municipal per capita GDP (Model 1). **On the contrary, deforestation has a significant negative impact on the variation of the convergence of municipal per capita GDP with the national median** (Model 2). A 1% increase in the rate of deforestation reduces the rate of convergence by 0.007%, i.e., doubling the rate of deforestation reduces the annual convergence rate of per capita income by about 0.7%. The magnitude of the impact is similar to that of the increase in cases of violence. In addition, to put these figures in context, the

[23] Additional robustness tests were performed: i) to group the GVA variables of the secondary and tertiary sectors given the strong correlation between the two; ii) Hausman's test on the relevance of using fixed factors in the municipal panel; iii) Variance Inflation Factor (VIF) test to confirm the absence of significant multicollinearity between the independent variables.

average annual growth of the dependent variable (logarithm of municipal GDP per capita compared to the national median) is -2.2%.[24]

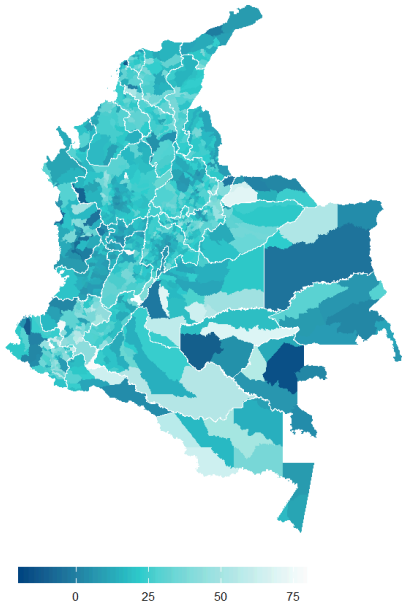
The impact of deforestation remains statistically significant and is more pronounced when municipalities with the highest income levels are excluded from the analysis. The (Model 3) considers municipalities with relative per capita GDP in the 75th percentile or lower of the distribution, excluding the richest 25% of municipalities, which also correspond to the most urban municipalities with the lowest deforestation (and smaller areas susceptible to deforestation). In this case, the variation of municipal per capita GDP with respect to the median of Colombia is reduced by 0.0095% with an increase of 1% in the rate of deforestation (by 1% if the rate of deforestation doubles). The results of the model are consistent with the hypothesis that deforestation slows down economic convergence at the municipal level, and more so in less developed areas. Far from favoring convergence, deforestation seems, with the most favorable reading, not to contribute to closing the economic gaps between municipalities. Also, when excluding the richest municipalities, deforestation aggravates the economic disparity between them even further.[25]

The conclusions on the impact of deforestation hold for the rule of law proxy, with the addition that the number of cases of violence is also statistically significant for the variation in municipal per capita GDP, not only for its relative trend. Finally, the semi-elasticities of the variations in the value added of the primary and combined secondary and tertiary sectors reflect the greater relative importance for municipal economic development of manufacturing and service activities.

Deforestation and social development: Deforestation does not coincide with significant decreases in poverty, approximated by the Unsatisfied Basic Needs Indicator. The Unsatisfied Basic Needs Indicator (UBN) prepared by DANE measures the change in the percentage of the population that does not reach a threshold that classifies the population according to its capacity to cover its needs, i.e., the percentage of the population that is "poor".[26] Between 2005 and 2018 (**Figure 11**), datasets for which UBN information is available, the indicator has shown a significant improvement in welfare and social conditions with a reduction of just over 5 percentage points (pp) in the national total but with average improvements per municipality of 22.7pp (the stark differences stem from the fact that the large capitals containing larger populations also have lower UBN figures). Using this information, a simple synthetic control exercise carried out shows that although the gains are generalized, they have been greater in the municipalities with less deforestation. For this purpose, the 10% of the municipalities with the highest deforestation in 2018 are taken and the simple average of their UBN for 2005 (55.2pp) is calculated. As a synthetic comparative set, it is considered those municipalities that are among the 10% with the lowest deforestation and also have a UBN index for 2005 in the range of one standard deviation of the mean of the other group (53.0 pp). Once the two groups of municipalities are identified, we can see that the reduction of the UBN index in 2018 in the municipalities with higher deforestation is 18.6 pp, while that of the municipalities with lower deforestation was 34.9pp. This is a significant difference. **Figure 12** shows the two sets of municipalities used in the study and their change in the Unsatisfied Basic Needs index in this period. It should be noted that it is a simple exercise, without statistical control for other additional variables, but it shows that, at the very least, deforestation does not coincide with gains in the social conditions and welfare of the communities at municipal level.

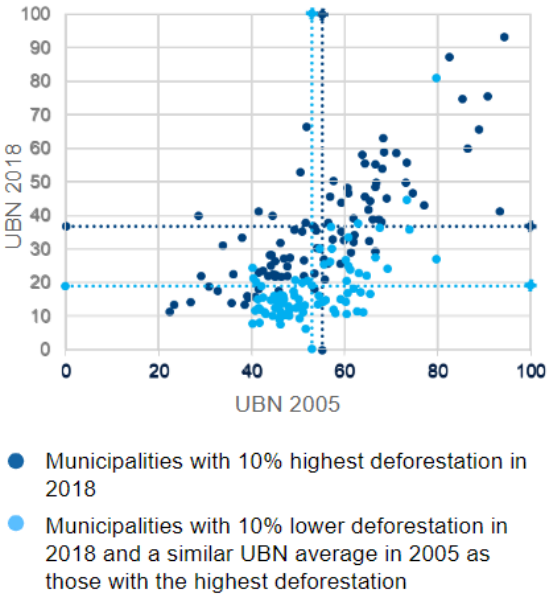
[24] This variation rate of -2.2% suggests that most municipalities tend to lag behind the national median, a phenomenon that may be aggravated by deforestation (although it may also be influenced by the lack of weighting of municipalities in the analysis, which could lead to a downward bias). This impact is even more relevant if we consider that the values of the dependent variable range from a minimum of -2 to a maximum of 4 (with an average of 0.035). In this compressed range, even a small reduction in annual convergence can have a significant cumulative effect, pushing the most vulnerable municipalities away from a potential economic improvement. In this way, the impact of deforestation not only slows relative growth, but also amplifies economic divergence in municipalities that are already lagging behind national development.
[25] Additionally, the non-linearity of deforestation has been verified for different percentiles. Although intuition holds true and the lower the GDP per capita with respect to the median, the greater the adverse impact of deforestation, it is difficult to determine a level of income for which deforestation is particularly harmful.
[26] Unmet basic needs (UBN). This indicator shows whether the basic needs of the population are met (measured as the percentage of the population that does not meet these needs), based on the following variables: Inadequate housing, critically overcrowded housing, inadequately serviced housing, households with high economic dependence, and households with school-age children who do not attend school.

Figure 11. **IMPROVEMENT IN UNMET BASIC NEEDS 2005 AND 2018** (PERCENTAGE POINT GAP)



Source: BBVA Research using data from DANE.

Figure 12. **UBN COMPARED BETWEEN MUNICIPALITIES WITH HIGH AND LOW DEFORESTATION** (PERCENTAGE POINTS)

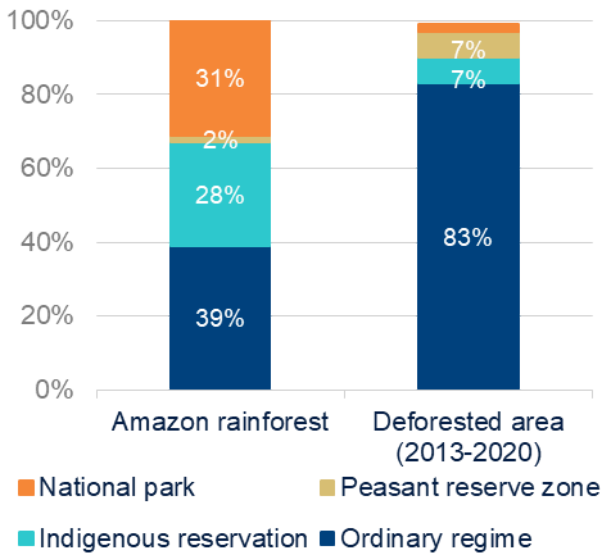


Note: The definition of municipalities with high and low deforestation is made based on deforestation relative to tree cover in each municipality in 2018. UBN corresponds to Unsatisfied Basic Needs.
Source: BBVA Research using data from DANE.

Deforestation with a lower incidence in protected territories. The role of the land ownership regime should be highlighted, especially in some of the least developed areas of Colombia. As noted in Cheston et al (2023)[27] *"[in Caquetá, Guaviare, and Putumayo] The percentages of deforestation occurring in national parks (2%) and indigenous territories (7%) are significantly below the total forest area of those zones (31% in national parks and 28% in indigenous territories) and of the areas near roads in those zones (4% and 19% respectively)... The rate of forest loss is significantly more alarming in areas that do not have well-defined restrictions on land sales and environmentally harmful* activities." (**Figure 13**). This result can also be identified at the **level of satellite images, as shown in Graph 14**. This assessment should be attributed, among other factors, to the land use regime in these areas, especially because land settlement based on tenure is not possible in these areas, as it is in areas under the ordinary regime.

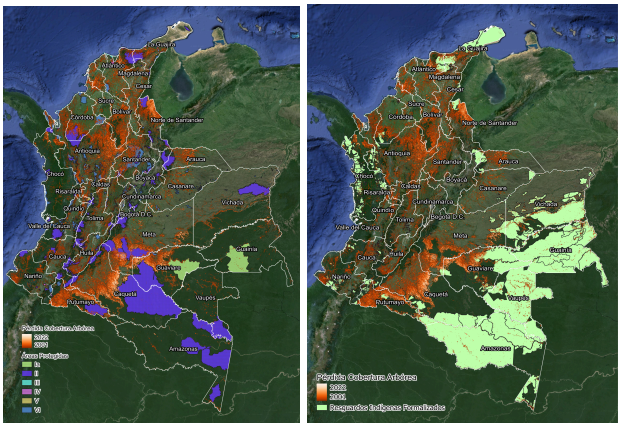
[27] Timothy Cheston, Patricio Goldstein, Timothy Freeman, Alejandro Rueda-Sanz, Ricardo Hausmann, Shreyas Gadgin Matha, Sebastián Bustos, Eduardo Lora, Sarah Bui and Nidhi Rao Mirar el bosque más allá de sus árboles - Una estrategia para frenar la deforestación y avanzar en una prosperidad compartida en la Amazonía colombiana.The Growth Lab at Harvard University, February 2023.

Figure 13. **DEFORESTATION IN CGP(*) AND LAND OWNERSHIP REGIME (** % OF AREA)



(*) CGP: Caquetá, Guaviare and Putumayo.
Source: BBVA Research, based on "Mirar el bosque más allá de sus árboles - una estrategia para frenar la deforestación y avanzar en una prosperidad compartida en la Amazonía" Colombia HKS, 2023.

Figure 14. **PROTECTED AREAS, INDIGENOUS RESERVATIONS AND DEFORESTATION** (2001-2023)



Source: BBVA Research, based on Hansen/UMD/Google/USGS/NASA and the National Land Agency

The levers to reverse deforestation

Deforestation coincides with the expansion of primary and industrial agricultural activities, cattle ranching, illegal mining and illicit crops, which are among the only feasible economic opportunities in rural territories of Colombia. However, there is no evidence to support that this process, complex and with multiple causes, provides economic or social benefits. Policies to reverse deforestation and contribute to the development of Colombia, for which some proposals are made, must be aimed at expanding the availability of development opportunities in rural areas of Colombia.

Policies aimed at expanding development possibilities can be organized around three main facets, with strong connecting threads between them, which makes their coordinated implementation have a substantially more beneficial impact. The three facets proposed for analysis are: i) land tenure rules; ii) productive development of designated areas; and iii) the value of natural assets.

i. Land ownership regime

Reform and strengthen the legal land ownership regime to protect forest areas. The ambiguity of land tenure and its regime of utilization is a problem that several studies in Colombia have linked to the violent conflicts and

underdevelopment in the rural areas of the country.[28] The lack of clarity in land rights favors the appropriation and concentration of land, in addition to forced displacement and rural inequality. In addition, legal uncertainty discourages investment and limits farmers' opportunities to improve their productivity. To some degree, due to the very concentration of land, the mechanisms in place for claiming vacant land can be an escape route for farmers to seek a livelihood at the expense of forest areas. In this framework of analysis, in order to protect forest areas, **a policy is required that reinforces the legal regime of land ownership**. This strategy should include:

- ***An acceleration of the Multipurpose Cadastre*** process developed by DANE to understand the uses and ownership of land, giving priority to forest areas.
- ***A delimitation of the areas to be protected***, beyond the current natural parks and indigenous reservations, while establishing a limited and non-invasive use of the land.
- ***A review of the laws on claiming title to land***. In Colombia, the legal framework encourages land settlement without any environmental, social or economic efficiency considerations. The practical implementation of laws and the lack of adequate resources favor a predatory form of settlement characterized by activities that are often low in productivity and short-lived. In addition to the above, there is a high degree of legal uncertainty in land ownership due to land displacements and restitutions over a long period of time.[29]

Increase the efficient presence of the State in protected areas. To a large extent, the use, colonization and high degree of land predation is due to the low presence of the State in rural areas, especially the most remote ones. This has a particular impact on bordering forest areas threatened by settlement. A policy that achieves a **widespread government presence** could reduce incentives for repetitive and massive settlement, as well as **keep designated protected areas safe**. This strategy may include:

- ***The institutional presence of the State.*** Although ranger schemes and defense units of protected territories help to create control of the areas, a greater presence of government institutions is required, especially including a foothold in the legal system to achieve an expeditious and focused development of the processes of control and stewardship of these areas. The active presence of public policy through the Ministry of Environment is also required, so that there can be greater control, monitoring and adaptability of public policy for these regions. Finally, the communities that inhabit these areas also require public services such as education, health, justice, and security, among others, so that development opportunities can be provided that prevent the depredation of the environment.
- ***The deployment of defense units in protected areas.*** The various causes of deforestation show, to some degree, that there is a struggle for territory with illegal entities or communities utilized for these purposes. The establishment of rapid response units supported by satellite technology to identify pockets of threat to forests helps to discourage incursions into protected areas, but also to combat those that do occur. These units can be police or military forces that have the capacity to deal with criminal groups that seek to establish themselves in protected areas for illegal mining or cultivation of illicit crops. They can also offer a response to violations from the community for the establishment of settlement processes.
- ***The strengthening and expansion of ranger programs.***[30] These programs, a government initiative designed to protect the country's forest ecosystems, especially in areas vulnerable to deforestation, have limited reach in

[28] Among them: LeGrand, Catherine (1986). *"Frontier Expansion and Peasant Protest in Colombia, 1830-1936"*. University of New Mexico Press; Gutierrez Sanín, Francisco (2011) Land and Property Rights in Colombia – Change and Continuity | Nordic Journal of Human Rights.; Ibáñez, Ana María, and Muñoz, Jorge (2010). *"The Persistence of Land Inequality in Colombia: What Happened in the 1990s?"*

[29] With the intention of encouraging the settlement of unproductive vacant land, a relatively lax property entitlement scheme was designed. Law 791 of 2002 set the time of possession of a piece of real estate at 5 years to file an ordinary prescriptive claim and 10 years for an extraordinary one. Moreover, the long armed conflict in Colombia with multiple actors led to large-scale displacements and land seizures by armed actors or their frontmen. In recent years, the State has sought to restore the property rights of displaced people through laws such as 1448 of 2011 on land restitution or Decree 902 of 2017, which encourage the restitution and formalization of land. However, these processes have been complex and there remains widespread uncertainty about land tenure.

[30] Forest Warden Families Program

the national territory, but there are some attractive schemes that can be built upon to achieve greater success in protecting vulnerable areas. The program can be used as a dual-purpose tool: on the one hand, focused on the protection of vulnerable forest areas, but also as an instrument for generating revenues for local populations, thus avoiding the need for deforestation for subsistence.

ii. Productive exploitation of designated areas

This last point highlights one of the main threats to forest areas: the constraining requirement that communities have to meet basic subsistence needs. One of the key policies in the protection of natural capital must come from creating development alternatives for the communities that inhabit these areas that do not threaten forests and protected areas. This should be done by creating endogenous value to areas designated for protection, beyond the establishment and expansion of ranger programs. These strategies, without limitation to others, can be:

- ***The support and development of responsible tourism programs.*** Colombia's tourism potential is widely known and discussed, but the role that the government must play as an enabler of these processes always remains undecided.[31] Among the key issues is the regulation of responsible ecotourism that is suited to the conditions of the areas to be promoted. But it is also necessary to undertake plans to support communities in developing skills, infrastructure and capacity to provide services to tourists. Finally, promotional mechanisms are also required that enjoy the support, not only of government, but also of the various actors in the tourism industry, in order to position as an alternative or complement to traditional tourism models in Colombia[32].
- ***The establishment and promotion of research programs on natural capital and biodiversity.*** These areas have special biodiversity characteristics that are worth studying and that can lead to lessons on environmental conservation, but also to the discovery of new processes and products. These research programs, through government policy, can achieve economies of scale that enable connections with private, academic and foreign entities.
- ***Responsible and limited cultivation***. The communities that inhabit these areas continue to have subsistence needs. Among them, the government should design a process of responsible cultivation, with limitations to processes and spaces, but also, eventually, with space for commercial operation that does not threaten or damage the environment.

Part of the problem associated with deforestation in Colombia lies in the low productivity of the agricultural sector and therefore in the opportunities that it offers. The historical lag in the provision of public goods and investment has led to extremely low levels of productivity that undermine the competitiveness of the countryside and require growth through the addition of new land instead of increasing the productivity of existing land. This makes the expansion of the agricultural and livestock frontier a fundamental piece in the development of deforestation. Therefore, a second approach to stop the cycle of deforestation is **to increase productivity in the areas destined for commercial operation**. This strategy may include:

- ***The development of infrastructure projects in areas intended for commercial operation***. This includes the establishment of irrigation districts, dikes, channels, logistic centers and better means of interconnection, all fundamental factors for the productivity and profitability of agricultural activities. This infrastructure, which is

[31] Colombia | Tourism is a journey to growth | BBVA Research
[32] The policy in favor of promoting ecotourism has a long history in Colombia and in the State. Proof of this is the 2012 Nature Tourism Plan: it highlights the potential of the project and strategies to follow, but lacks implementation.

widely lagging behind in Colombia, has allowed the development and consolidation of agricultural activities in Peru and Ecuador.

- ***Support and development of distribution and marketing channels for production***. A crucial part of the economic risk faced by agricultural activity is concentrated in the placement of its products on the market, since price volatility is extremely high and fluctuations tend to coincide with supply or harvest cycles. Thus, a program to regularize and stabilize production cycles through a scheme that connects the producer with the final buyer could mitigate, to a large extent, part of the volatility to which the sector is exposed. This, in turn, helps activity to have more predictable and stable flows and improves its ability to receive funding, while the counterparty (society) benefits from lower volatility in prices and therefore lower inflation.
- ***An investment in social infrastructure.*** The areas designated for commercial operation lack sufficient and quality social infrastructure to meet the needs of their communities. This creates a negative effect on the quality of human capital and productivity and therefore on the opportunity to successfully pursue rural activities. A program that promotes investment in education, health, justice, security, among other fronts, can improve both the productivity of rural workers and their well-being, both key to achieving a smaller exodus of population in search of the expansion of the agricultural frontier.

This type of initiative requires the accompaniment not only of the State, but also of other relevant agents in society, including banks. Among the strategies to boost these resources are:

- ***The development of risk mitigation programs.*** Through the agricultural guarantee[33] and insurance[34] mechanisms in force, diversified coverage products can be developed, involving non-cyclical or countercyclical agricultural goods that reduce the costs of risk premiums and consequently make it cheaper to ensure the continuity of the activity.
- ***The incentive to grant credits in agricultural development zones.*** Through the role of the State's development banks, programs can be established to expand the resources available to leverage credit in agricultural activities, with appropriate grace periods and accommodated to the cycles of the products to be financed. Financial instruments can also be configured to have some type of subsidy behind them and reduce the costs of capital and human resource investments that can be made within the framework of vulnerable sectors.

Ultimately, the ability to increase productivity in areas designated for commercial operation reduces the threat of expansion of invasive economic activities into vulnerable areas, thus leading to a decrease in deforestation. It is an endogenous rather than an exogenous growth mechanism. Success depends on the ability to create the value chains that sustain the productive clusters.

iii. The value of natural assets

Forests capture carbon, regulate water cycles, preserve soil, support biodiversity, and provide recreation. Forests provide vital ecosystem services, with carbon sequestration being one of the most relevant. Through the process of photosynthesis, trees absorb carbon dioxide from the atmosphere, storing it in their biomass and soil. This helps mitigate climate change by reducing the levels of greenhouse gasses accumulated in the atmosphere. In addition to carbon sequestration, forests offer numerous other ecosystem services, such as regulating water

[33] FAG agricultural guarantee.
[34] FASECOLDA agricultural insurance.

cycles, preserving soil quality, supporting biodiversity, and providing recreational spaces. Protecting and restoring forests is essential to maintaining their multifunctional role in environmental health and human well-being.

Internalize the positive externality of forest services. However, ecosystem services that do not generate monetary flows are not accounted for. The economic benefits produced by ecosystems and the costs of their impairment are not carefully considered. In particular, with regard to carbon emissions, the establishment of carbon markets would make it possible to internalize the positive externality of its capture and accumulation in forests, thus mitigating climate change. This generates economic incentives that contribute to conservation by generating revenues that can also facilitate social development or, at the very least, make transparent the cost of activities that depreciate natural capital and hinder sustainable growth.

Box D. Structure of carbon markets[35]

Carbon markets trade emission allowances or credits for captured, avoided or retained carbon, and may be regulated by public authorities or based on voluntary agreements between stakeholders. These markets fall into two broad categories: Compliance markets and voluntary markets. Both types of markets aim to reduce greenhouse gas emissions, although they operate in different ways and under different regulations and quality standards.

Compliance markets are regulated by public authorities and issue tradable allowances for a specific volume of emissions, which is progressively reduced over time. This mechanism incentivizes companies to decarbonize their operations, as they must stay within the established emission limits or acquire additional permits in the market. This type of market ensures effective emission reductions, ensuring that carbon reduction targets are met over time.

Voluntary carbon markets work by purchasing previously captured carbon credits through various projects, such as reforestation, forest conservation, or renewable energy projects. These markets are not regulated by a central authority, which allows for greater flexibility but also presents challenges, such as variability in quality standards and difficulty in verifying the additionality of projects. The quality of credits is determined by the standards applied to verify emissions reduction or capture, thereby ensuring that projects are additional, permanent and verifiable. These quality standards are essential to earn the trust of buyers and ensure that emission reductions are real and measurable.

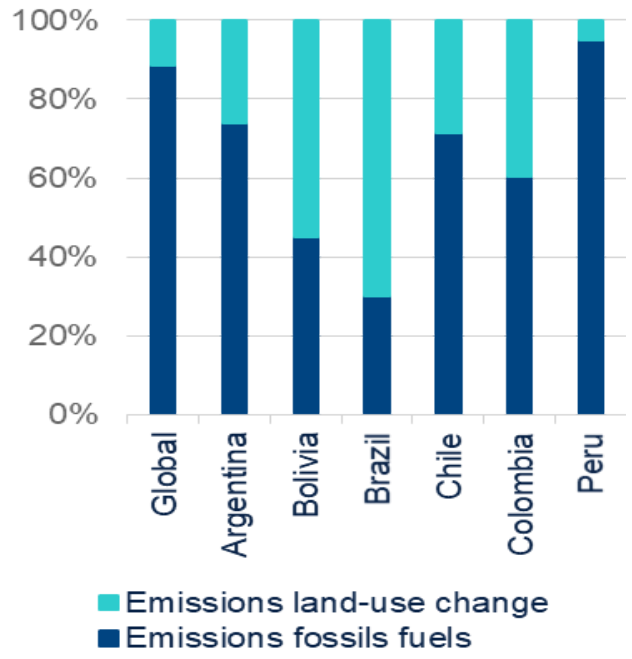
Incentives for demand in voluntary markets also play a key role. A significant incentive is the possibility that credits acquired in voluntary markets can be used to meet obligations in compliance markets. Not only does this increase demand for high-quality credits, but it also provides greater flexibility for companies to meet their emission reduction targets. Integrating voluntary market credits into compliance systems can encourage greater investment in carbon reduction projects and ultimately contribute more effectively to climate change mitigation.

Although the combustion of fossil fuels accounts for 90% of global carbon emissions, deforestation has a significant impact on total emissions in some regions. About 90% of global carbon emissions come from fossil fuel combustion processes, leaving the remaining 10% to emissions from land-use change (**Figure 15**). However, the relative weight of carbon emissions from combustion and those from land-use change[36] is quite different in economies with abundant natural resources, such as forests. Land-use change is responsible, for example, for 60% of Brazil's carbon emissions or 40% of Colombia's.[37] This percentage decreases to almost 50% and 30%,

[35] A description is provided, but the ecosystem of carbon markets is complex and constantly developing. For more details see "Carbon Market Basics" in the Voluntary Carbon Markets Consultation Report, The Board. International Organization of Securities Commission. December 2023.
[36] Emissions from land use are left out, as they have a significant non-anthropogenic component linked to the natural cycle of the carbon cycle.
[37] Net CO2 emissions from land-use change encompass several components: emissions from deforestation, forest growth or logging (forestry), peatland drainage and fires, and other land-use transitions. In general, the highest emissions from land-use change are seen in tropical regions, notably in Brazil, Indonesia or the

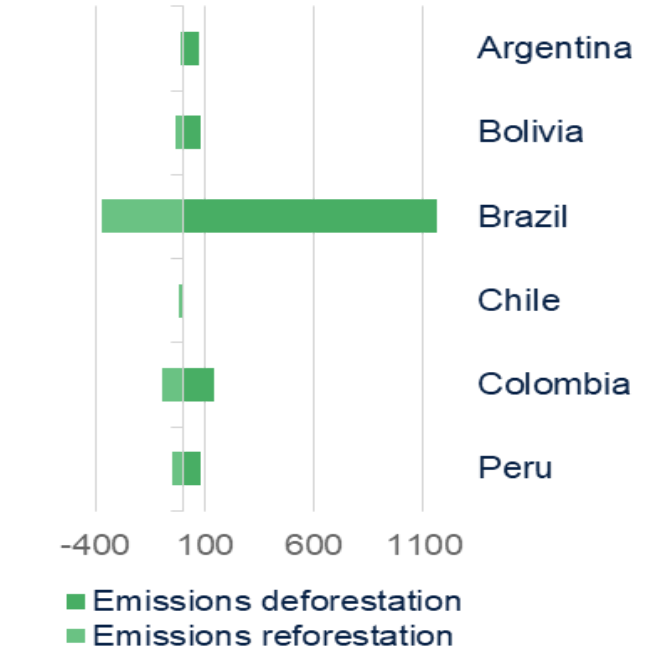
respectively, when considering only net emissions from deforestation, by deducting removals due to reforestation. In both countries, the role of the forest as a carbon sink is key: In the last 10 years, Brazil has captured an average of 374 million tons of CO_2 per year as a result of reforestation, while Colombia has captured around 95 million tons on average annually (**Figure 16**).

Figure 15. **CO2 EMISSIONS FROM FUELS AND LAND USE CHANGE (** %, AVERAGE 2013-2022)



Source: BBVA Research, with data from The Global Carbon Budget 2023 (Friedlingstein et al., 2023b, ESSD).

Figure 16. **CO2 EMISSIONS (DE/RE)FORESTATION (**MILLION TONS, AVERAGE 2013-2022)



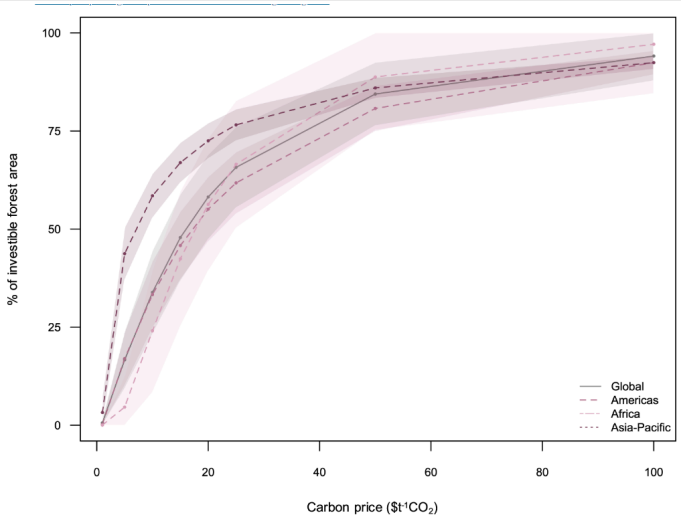
Source: BBVA Research, with data from The Global Carbon Budget 2023 (Friedlingstein et al., 2023b, ESSD).

The price of carbon: the opportunity cost of deforestation, the price of reforestation, with a very uncertain empirical estimate. The price assigned to each ton of carbon sequestered by the forest should at least cover the cost of alternative uses of the land occupied by the forest or intended for reforestation, as well as its maintenance and future conservation.[38] Higher prices for carbon capture increase the percentage of potentially profitable forest areas as carbon sinks (**Figure 17**). According to the reference mentioned above, carbon prices of between US$16 and US$44 per ton of CO2 would be needed worldwide to protect between 50% and 80% of potentially investable areas. Raising the price above $50 per ton would only bring marginal benefits for forest conservation and climate mitigation. However, estimating the carbon price needed to reach break-even is highly uncertain. This uncertainty arises from several factors, including the amount of carbon sequestered by different types of forests, soil and climate regime, the performance of the profitability of alternative crops or long-term maintenance costs. This is especially relevant in economies where the quantity and quality of statistical information available has room for improvement.

Democratic Republic of the Congo, due to large-scale deforestation due to agricultural and livestock expansion. In contrast, regions such as Europe experience carbon sequestration due to net forest growth (including reforestation). Global | The forest, a lever for sustainable development | BBVA Research

[38] The opportunity cost is the return of alternative uses, such as agricultural, livestock and mining activities, and also illicit activities.

Figure 17. **CARBON PRICING AND FINANCIAL VIABILITY OF FOREST CARBON SITES**



Graph indicates the proportion of investible forest carbon that are financially viable for carbon finance. Shadings around the lines represent confidence bands based on standard deviation
Source: Carbon prospecting in tropical forests for climate change mitigation | Nature Communications

The mechanisms for regulating carbon emissions in Colombia. In the case of Colombia, three mechanisms have been defined in the area of markets in carbon, the underlying element whose capture makes it possible to assign value to a forest, which are at different stages of development: i. the carbon tax; ii. the voluntary market and, iii. emission allowances.[39]

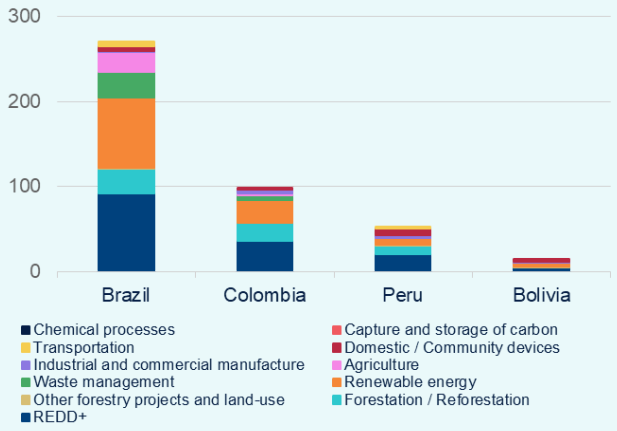
- **The carbon tax in Colombia covers a limited percentage of emissions** (between 12% and 14% according to Asocarbono) and has a relatively low rate, of USD 5 per ton of emission[40]. This tax covers a limited group of industries and generates approximately 575 billion pesos in revenue (in 2023). Its function, however, is fundamental in the scaffolding of public policy by setting a price on carbon emissions.
- **The voluntary carbon market** was developed in Colombia with the incentive of promoting the participation of the private sector in the effort to contain climate change.[41] A carbon credit is a certification that a project has the capacity to prevent the emission of one ton of carbon into the atmosphere. This instrument enables companies to offset emissions, to show their commitment against climate change, either in a reputational way or to offset the payment of carbon taxes.
- **Emission allowances are an instrument that has not yet been fully regulated in Colombia**, but it is widely developed in other geographies. The objective is to set a level of emissions that a country, a region or an industry can sustain. In this mechanism, the government assigns this emission allowance to companies and they must organize their production to comply with it. If they exceed them, they can acquire allowances from other companies that have surpluses. The mechanism also gives the government the possibility of adjusting the level of emissions allowed at any given time.

[39] For an overview of carbon markets, see **Box D. Structure of Carbon Markets**.
[40] The government presented for discussion in Congress a financing law that includes, among other issues, a significant increase in the carbon tax. At the time of writing, discussion has not begun.
[41] For a review of the performance of carbon markets, see **Box E. Voluntary carbon markets in Colombia and international perspective.**

Box E. Voluntary carbon markets in Colombia and international perspective

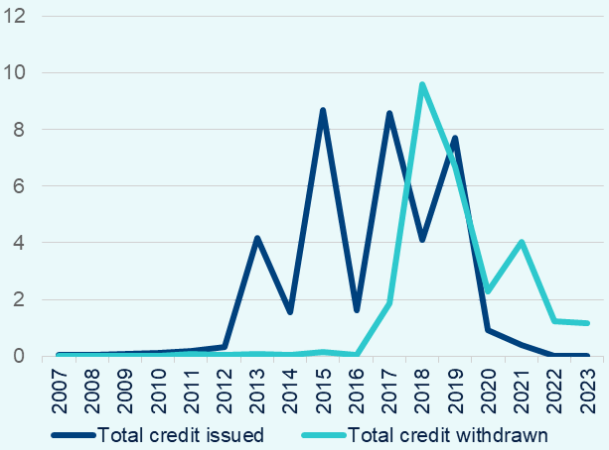
Carbon offset projects, credit issuances, and credit retirements listed globally by four major voluntary registries — the American Carbon Registry (ACR), Climate Action Reserve (CAR), Gold Standard, and Verra (VCS) — according to Berkeley data, are led by forestry and land use projects, followed by renewable energy projects and community and domestic projects. Although the community and domestic projects category has the highest number of registered projects, the credits issued and withdrawn from this category are significantly lower, as they are typically smaller-scale projects and often focus on quality-of-life improvements rather than maximizing carbon emission reductions. In Colombia, 98 offset projects[42] have been registered in the voluntary carbon market, a figure that, although lower than that of Brazil (271), exceeds that of neighboring countries such as Peru (52) and Bolivia (15). In particular, afforestation/reforestation and REDD+ projects are the most numerous both in terms of the number of projects and in credits issued and withdrawn, followed by renewable energy projects (Figure E1).

Graph E1. **NUMBER OF VOLUNTARY REGISTRATION OFFSET PROJECTS, 2002-2023**



Source: BBVA Research based on the Voluntary Registry Offsets Database.

Graph E2. **MARKET PERFORMANCE: CREDITS ISSUED AND WITHDRAWN IN COLOMBIA (MILLIONS PER YEAR)**



Source: BBVA Research based on the Voluntary Registry Offsets Database.

However, despite being the most numerous, these projects have come under significant criticism in recent years, particularly with regard to additionality and governance. This negative perception has generated uncertainty and mistrust in the voluntary carbon market, contributing to a stagnation in its performance (Figure E2). This visible contraction in Colombia is a global trend. In 2023, the voluntary carbon market (VCM) suffered a notable contraction in both volume and valuation, marking the second consecutive year of decline from its peak in 2021. This decline is largely attributed to doubts about the additionality and governance of carbon credit projects (Ecosystem Marketplace, 2024). Within the forestry and land use credit category, REDD+ projects were the most affected, with a 62% loss in value and a 51% decrease in transaction volume and 23% decrease in price. Despite these declines, REDD+ projects remained the most popular, accounting for 78% of the credits traded in this category.

[42] The total of 98 projects include those of the American Carbon Registry (ACR), Climate Action Reserve (CAR), Gold Standard and Verra (VCS), although the figure is higher if other standards are taken into consideration. For example, Cercarbono has recorded 116 projects in Colombia between 2019 and 2024.

In contrast, emission removal projects, such as reforestation projects, have shown greater resilience in the price of their credits compared to emission avoidance projects (World Bank, State of Carbon Pricing 2024). This resilience is largely due to the ease with which additionality can be demonstrated, a significant challenge in conservation projects. However, all nature-based solution projects have faced a global slowdown due to international criticism, which has affected their implementation and perception of quality. Within these projects, Afforestation, Reforestation, and Revegetation (ARR) and Improved Forest Management (IFM) projects have seen price increases of 31% and 11% respectively, although they represent a smaller portion of the market. These projects, especially in regions such as Latin America and the Caribbean, continue to play a crucial role in the global carbon credit market, constituting 36% of transaction volume.

Despite these recent challenges, Colombia has potential capacity to attract investments in carbon projects. In the last year, the country has climbed 13 positions in the VCM Investment Attractiveness Index to position itself in first place (with a score of 81), followed by countries such as Kenya, Cambodia, Mexico and Peru. The index assesses countries based on three key pillars: the preparation of the carbon market, the investment landscape and the environmental and social opportunities offered by the VCM. Colombia's success has been driven by improved carbon market readiness, a stronger regulatory framework, and the boost of the carbon tax, which has generated a significant increase in market activity and incentivized project development. **Although challenges remain, Colombia has the potential to consolidate itself as a leader in the generation of carbon credits, attracting investments that not only seek to mitigate climate change, but also generate positive impacts on local communities**.[43]

Instruments with pending development. Although all three mechanisms exist in Colombia, their development is still limited.[44] In the case of the carbon price, its value and coverage is relatively low. Carbon markets are developing, but the inherent limitation of incentives for their use has led to relatively low levels of transactions and the regulation of emission allowances is still lacking. Therefore, it is necessary that the first strategy in terms of the mechanisms for the assignment of value to natural resources be the implementation and regulation of the institutions and mechanisms created for these purposes.

Complex and therefore ineffective environmental institutions. A second aspect of the policy regarding the value of natural assets should involve timely and quality measurement and reporting of such assets. In the forestry field in particular, these measurements are complex since they usually deal with remote areas that are difficult to control. Although Colombia has the legal structure to do so, there is still a need to make progress in its regulation, in investment in technology and in a sweep to delimit functions and objectives of the network of institutions created. The monitoring, reporting and verification environmental mechanism can be taken as an example. It has at least 5 entities focused on various aspects of the measurement and monitoring of forestry issues:

- National System of Greenhouse Gas Inventories (SINGEI). This entity is not yet legally regulated.
- National Registry for the Reduction of Greenhouse Gas Emissions (RENARE). This entity has made little progress due to technological and legal issues.
- GHG Emission Reduction and Removal Accounting System (SCRR-GHG). This entity is still under construction.
- Forest and Carbon Monitoring System (SMByC). This entity is operational, but lags behind in information.
- Mandatory Emissions Registry (ROE): This entity is in the process of regulation.

[43] Further details VCM Investment Attractiveness Index 2024 • Abatable.
[44]: *"... Currently, there is a lack of vision on the role of carbon markets in meeting environmental objectives in climate change policy and in the planning instruments of our country..."*. Reference: Study Commission for the Promotion and Development of Carbon Markets in Colombia. Final report, July 2023.

A market in which complex intangible assets are traded requires high quality information and verification capacity.[45] In this sense, the following strategies are suggested:

- ***Define mechanisms that guarantee the quality standard of the credits issued.*** This includes minimum quality in certification, carbon capture permanence, additionality guarantee and avoiding double accounting.
- ***To promote internationally recognized standards***. This is because it provides in the first instance a path traveled in the quality assurance of the standard, as well as the recognition of other specialized entities, but also because it allows closing the knowledge gap of local projects with possible external interests, which in the end can translate into an increase in the capacity and possibility of achieving carbon credit negotiations at the international level, which tend to achieve better returns.

To promote international transactions of carbon credits. With the achievement of measurements, records and quality verifications, the inherent tradability capacity of the underlying asset (carbon credit) must be improved. Carbon capture or sequestration capacity is an asset that does not bring value limited to a specific region; on the contrary, it is part of an overarching global goal. Therefore, countries and entities that lack mechanisms to achieve these offsets, or that want to go beyond compliance mechanisms, can increase the intrinsic value of local natural capital through their demand. By leveraging the fact that opportunity cost can vary significantly in different regions of the world, we can increase the resources provided by these mechanisms, thereby enabling their sale and marketing to foreign entities.

A proposal to advance in the protection of the currently less vulnerable forests. It can also be useful to contribute to the global debate on sustainability and nature protection by supporting the value of established forests that may not be at the frontier of economic activity and therefore not directly vulnerable. One of the main principles of carbon markets based on the protection of natural assets is that the action taken to preserve these assets must be because there is an imminent risk of their loss. This reveals the value of these assets and allows us to internalize the externality of carbon emissions in one way or another. However, if the natural asset is not in a risky condition, this mechanism is not applicable and prevents us from using it to give it value and thus promote its protection and care, even though its contribution to the carbon cycle exists and is highly significant.

To focus this discussion, it may be easier to think of an example. The Amazon has fundamental properties in the carbon cycle, climate and biodiversity at a global level.[46] Its extension is still relevant and the threat, although it exists, is mainly located in its borders rather than in its heart. However, events that may appear to be isolated have already caused extensive deforestation that is beginning to generate effects on biodiversity, climate and, obviously, carbon capture. Two examples of this are the flying rivers,[47] this cycle of water that feeds the Andes and that due to its distortion has led to melting ice or lower water inputs in recent years; similarly, there are also studies that have managed to relate the climate cycles in the Himalayas with cycles of deforestation and fires in the Amazon[48].

This threat, not immediate but latent, is not covered by the current principles of carbon markets. Consequently, it cannot be assigned a value or obtain the resources required for the structural protection of these vast but vitally important territories. **One strategy that could be led at the international level is the inclusion of a special clause within the structure of carbon credits for natural assets such as the Amazon, with no imminent risk of deforestation but with a latent risk**.[49] This will not only allow the asset to be valued and help preserve it, but it

[45]: This problem has gained significant importance in recent years. There is disappointment with some projects, which may have been assessed appropriately at the time with the information available, but whose assessed value has changed. This has left some party to the contract unhappy. Some parties have also taken advantage of the lack of knowledge or inability to verify the projects' underlying features.
[46] For more details see for example:
Why Is the Amazon So Important for Climate Change? | Scientific American.
Why the Amazon's Biodiversity is Critical for the Globe: An Interview with Thomas Lovejoy
[47] What are the Amazon's 'flying rivers' – and how does deforestation affect them? | World Economic Forum.
[48] Amazon deforestation may shrink Himalayan snow and Antarctic ice | New Scientist
[49] The fact that there is no immediate vulnerability prevents achieving the additionality yardstick in the reduction or capture of emissions, or showing that without intervention through the generation of carbon credits, GHG emissions are avoided. In any case, there are some initiatives, some recent led by the World Bank

can also achieve second-round impacts that will be of high value, such as protecting ecosystems and millenary biodiverse areas, supporting water cycles, and trying to maintain global climate cycles.

More funding to reverse deforestation. Strategies to reverse deforestation and in general to protect forest areas require ample sources of funding, not only because of their direct cost but also because of the need for supplementary investment to achieve the right incentives in the production and exploitation of the resources available for these purposes. Without wishing to be exhaustive, in any case, the sources of financing can be grouped into three groups according to common characteristics: i. tax resources; ii. resources from cooperation; and iii. resources from carbon markets and emission allowances.

First, it is important to recognize that tax revenues in developing countries are limited and that there are multiple needs that must be met with them, so that the measures that may be suggested should be based on reallocation of resources that create limited distortions or preferably on taxes that do not alter the sources of funding in force for other purposes. Some strategies to increase the sources of funding for these purposes are:

Tax Resources:

- **Carbon Tax:** this tax already exists in Colombia, but its scope and value are low and could be expanded, especially to achieve a better signal of the natural resource's value and enhance voluntary markets. Although there is room on this front, the secondary impact that it could have on central activities in the economy such as food transport, and that can affect inflation, at least at the time of adjustment, must be assessed. The signal of such a low price for emissions is not generating the appropriate incentives to reduce them and does not contribute decisively to the development of nature-based projects. The strategy should not focus only on the price. It should also seek to expand the industries and activities covered, and, as a specific mechanism for the promotion of carbon markets, the expansion of the capacity to offset this tax with carbon credits can be reevaluated. In any case, the regressive impact of this instrument, which is greater at lower income levels, should be offset by the redistribution of part of the proceeds obtained.
- **Multipurpose cadaster**: We have already talked about the importance of the multipurpose cadaster in ascertaining the use and ownership of the land. However, it has another facet that is fundamental. The valuation of properties and land in Colombia has heterogeneous and significant lags in the different areas of the country. The updating of the national cadaster, especially in the areas that are lagging behind, in rural areas and in some urban areas of recent expansion, can lead to a better knowledge of the value of property in Colombia and thus to a better collection of the relevant taxation.
- **Property tax**: Connected to the previous point, the tax charged for property in Colombia has received historical criticism for the outdated value of the underlying assets and for irregularities in the way collections are made. Therefore, the updating of the cadaster will improve these aspects. However, once this is done, there will surely be an increase in the value of the asset and consequently in the payment of tax. The proposal is to take advantage of this situation to allocate part of this increase in revenue in order to protect forest areas. It may be easier to allocate a share of a potential revenue gain than to take already allocated revenue and distribute it, especially given the country's broad social needs.

Resources from cooperation. Sources of cooperation, especially of an international nature, can support the development of the environmental and social strategies suggested above. Including:

(Investors Support Amazon Reforestation Through Record Breaking USD 225 Million World Bank Outcome Bond) or by USAID (USAID Supports New Amazon Rainforest Investments to Advance Sustainable Development | Press Release), which combine incentives for reforestation and conservation, combining carbon market instruments with development aid.

- **Green funds:** There are ample advances in the constitution of green funds that can leverage the development of some of the environmental activities mentioned, such as the financing of planting, the strengthening of ranger programs, among others. It is important to establish structural agreements with these funds and, as far as possible, to promote the formation of specific funds for use in Colombia. This initiative has already been proposed by the government with the idea of a fund for Amazon.[50] Established with the utmost clarity on the institutional framework of the fund and the use of resources, this could leverage more efforts in these areas of the country and the region.
- **Leverage biodiversity**: The second, somewhat underdeveloped layer on the environmental finance front is the discussion on biodiversity. Colombia has a wide biodiversity, home to millions of species – the largest number of species in some amphibians and large numbers of reptiles or insects. At the same time, its geographical location makes it a key player in the route of some mammals such as the jaguar or vital for the migratory processes of birds. With extremely high biodiversity per square kilometer, the development of special funds for biodiversity care can be proposed. These resources can support the protection of the environments of threatened species, but also the promotion of geographical spaces such as forests and jungles.
- **Leverage social impact**: A truly relevant aspect of the analysis carried out is that the problem in Colombia is dual. Not only is there difficulty from the environmental front and the risk of deforestation, but there is also a complex social reality that shows wide gaps in development and opportunities for the most remote communities that inhabit or seek to exploit forest territories. Just as there is a global interest in the development of green and biodiversity funds, the creation of cooperation mechanisms that also have a focus on societies in these territories and on the creation of opportunities for sustainable development and in defense of the areas to be protected must be promoted.

Carbon market resources and emission allowances. At the moment, the resources that can be extracted from this mechanism in Colombia are limited[51], but we believe that there is ample potential if carbon markets and emission allowances can be activated and incentivized. Among the strategies to amplify financing in this way is the possibility of creating greater value from the same carbon credits that are already issued or that have the potential to be issued. This requires a higher carbon value, which in Colombia is anchored to the carbon tax. However, the global market and the value assigned in other geographies to carbon can also be leveraged as an anchor for projects in Colombia through the sale of these credits to international buyers. The differences in value can be incredibly significant. There is also the possibility of achieving value premiums from the additional biodiversity and social impacts that these projects may have.

Given the low value currently assigned to carbon in Colombia and the limited domestic market due to the type of activities and sources of emissions, it may be possible to assess the country's fulfillment of its goals and commitments by raising extensive financing by trading these credits internationally at higher prices. This would be additionally accompanied by a natural expansion of demand, which would improve the scale of carbon markets. Once these resources have been obtained, part of them can be used to achieve the strategies mentioned above and another to finance projects that allow the achievement of goals and commitments on climate change issues.

A second alternative is to construct for new projects that are sold internationally a sort of “royalty” or “tax,” in which part of the carbon credits created by the project are paid or kept in local accounting for the fulfillment of the commitments made. This second alternative most likely implies a reduction in the price paid for these credits and, therefore, for these projects by international investors. It is also especially important that this is done with clarity,

[50] A common front to save the Amazon rainforest was proposed by President Petro at COP 27 in Egypt, Ministry of Foreign Affairs of Colombia.
[51]: For instance, total credits withdrawn from the main registries - American Carbon Registry (ACR), Climate Action Reserve (CAR), Gold Standard and Verra (VCS) - reached an all-time high in 2018 with 9.6 million credits in Colombia, while this figure dropped to 1.15 million credits withdrawn in 2023.

transparency and on new projects, to avoid investors seeing it as a change in the conditions of the signed contracts and generating legal uncertainty in this regard.[52]

Box F. Forest protection projects with credits traded on voluntary carbon markets

Carbon credits traded on voluntary markets are beginning to be one of the options used by governments for environmental protection and the development of local communities. This box highlights some experiences from which lessons can be drawn to identify the strengths and weaknesses of this type of project.

First, two cases in which the protection of forests has been left to local communities, with different results.

- **Yaeda Valley Project:** In Tanzania, the Hadzabe Tribe and a UK social enterprise, called Carbon Tanzania, succeeded in securing ownership of part of their home valley in the form of property to the Tribe. In exchange, the Tribe had to be responsible for protecting the forest against possible threats of deforestation. This protection allowed the tribe to generate carbon credits, which were then sold on the voluntary carbon market, along with Carbon Tanzania. This project has generated US$350,000 for the tribe between 2011 and 2021, through salaries for rangers and other community support. This project has resulted **in deforestation in the territory owned by the tribe being 20 times lower than deforestation in the rest of the valley**.
- **Surui Forest Carbon Project:** In Brazil, in 2013, the Surui-Paiter tribe succeeded in launching a project to encourage activities aimed at the sustainable development of the community. One of the activities was carbon sequestration through the protection and reforestation of the Amazon rainforest. This project had to face the problem that there was no transfer of land ownership. Despite this, under the Brazilian legal framework, the community was considered to have rights to the carbon sequestered by that territory, which allowed the Voluntary Carbon Market (MVC) project to continue. **This project achieved the sale of 250,000 carbon credits, which were sold at a price above the market average**. This shows that the tribe's proximity to the project is a factor that raises the quality standard of the carbon credit issued. The project ceased its activity in 2018 due to diamond and gold mines being found in the territory, resulting in increased deforestation for illegal mining. Members of the tribe themselves participated in this final deforestation, to whom the miners promised a financial reward to buy cattle, which would later graze on the deforested land. This outcome shows the importance of both the transfer of land ownership and the involvement of the local community to achieve significant and long-term results in forest preservation.

Another important issue that voluntary carbon capture projects have to deal with constantly is the potential instability of government policies that regulate the market. An example would be the Zambian government, which stated its intention to change the tax rate for revenues derived from VCM-related projects[53]. The government aims to have the tax rate reach 50% of the revenues derived from the VCM, although its objective is to negotiate revenue sharing on a case-by-case basis. This reflects the opacity of the market that has a negative effect on the price, because the buyers of carbon credits are sensitive to everything that encompasses the production and use of the resources generated with carbon credits. On the other hand, a variable tax rate on a case-by-case basis, with no criteria established to predict the tax rate, makes carbon credit pricing difficult and encourages corruption.[54]

[52]: For details on some representative experiences of carbon credits traded on voluntary markets, see **Box F. Forest protection projects with credits traded on voluntary carbon markets.**
[53]: African Governments Step Up Demands for Share of Carbon Profits
[54]: Another similar case is that of Zimbabwe. In this country, the change in legislation has been even more frequent, which generates great instability for investors. This instability has been compounded by the recent statement by the Zimbabwean information minister on the possibility of declaring void all voluntary carbon credit

Finally, it is also relevant to analyze a project that is being developed in Colombia, which is the **Mangrove Life Program**. Mangroves are coastal ecosystems that have the characteristic that they capture on average more carbon than any other tree, in addition to having a great value for local communities. To prevent deforestation and encourage reforestation, a project based on carbon credits has been carried out. Carbon credits are earned for the reforestation of mangroves, and for the protection of the forest through rangers, work carried out by families from local communities. The effect of this project initially has been positive, since in its first monitoring it has been observed that deforestation has decreased by 69% compared to deforestation prior to the development of the project. Over the next 30 years, the project is expected to sequester 1 million tons of carbon. On the economic side, the project has had a positive impact on local communities, 92% of the profit resulting from the carbon credits sold on the market are shared with them. In addition to these economic benefits, jobs have also been created directly, such as forest rangers, and indirectly, with investments made in improving local infrastructure.

This last case shows that in Colombia there are already projects that have managed to turn a situation of deforestation into an opportunity to achieve greater environmental and financial sustainability through voluntary carbon markets.

Overview and Conclusion. In conclusion, Colombia faces a significant challenge with deforestation, which not only harms the environment but also has profound repercussions on economic and social development, particularly in disadvantaged communities. The loss of tree cover—driven primarily by agriculture, livestock, and illegal activities—slows economic and social progress, especially in vulnerable regions. To reverse deforestation, it is essential to implement a comprehensive strategy that strengthens land ownership and use policies, promotes sustainable productivity, and aligns economic incentives with environmental protection. First, ensuring legal certainty over land is crucial to prevent predatory practices, while simultaneously encouraging responsible economic use that is consistent with environmental sustainability. Second, increasing productivity in areas designated for economic activities is necessary, through the provision of public goods, logistical solutions, and financial support. This must involve the active participation of the private sector to reduce the incentive to expand into protected territories.Finally, the development of carbon markets presents an opportunity to internalize the natural value of forests, creating carbon credits that reward biodiversity protection. The success of these measures will depend on the authorities' ability to align long-term public policies that coordinate the actions of communities and the private sector toward forest conservation. Financing and defining instruments such as carbon taxes, tradable emission allowances, and voluntary markets are key to consolidating an effective strategy for eliminating deforestation in Colombia.

projects whose agreed tax rate differs from the latest tax rate decided by the government. These statements generated a major stir because of what it would mean for all investors if the declaration of nullity of contracts was left to the whim of a government.

References

Barbara K. Haya, Aline Abayo, Xinyun Rong, Ivy S. So., Micah Elias. (2024). Voluntary Registry Offsets Database v2024-08-31, Berkeley Carbon Trading Project, University of California, Berkeley. (Retrieved in 2024 from https://gspp.berkeley.edu).

Bassotti, G. (2012). Diagnóstico Turismo de Naturaleza en el Mundo. Plan de Negocio de Turismo de Naturaleza en Colombia.

BBVA Research (2024). Colombia: El turismo es un viaje al crecimiento.

BBVA Research (2024). Global: El bosque, palanca de desarrollo sostenible.

Bryce, E. (2023). Why is the Amazon so important for climate change? Scientific American.

Cabrera, E., Galindo, G. González J. (2022). Actualización de cifras de monitoreo de la superficie de bosque 2020. Instituto de Hidrología, Meteorología y Estudios Ambientales – IDEAM-. Ministerio de Ambiente y Desarrollo Sostenible.

Cabrera, E., Galindo, G., González, J., Vergara, L., Forero, C., Cubillos, A., … Duque, A. (2020). Colombian Forest Monitoring System: Assessing Deforestation in an Environmental Complex Country.

Cárdenas, M., & Ayala, J. J. G. (2023). Forest-Based Carbon Markets: Pitfalls and Opportunities (No. 313). Center for Global Development.

Centro Nacional de Memoria Histórica. (n.d). Observatorio de Memoria y Conflicto. Sistema de Información de Eventos de Violencia del Conflicto Armado Colombiano. (Retrieved in 2024 from https://micrositios.centrodememoriahistorica.gov.co/observatorio/).

Chen, T., & Guestrin, C. (2016). Xgboost: A scalable tree boosting system. In Proceedings of the 22nd acm sigkdd international conference on knowledge discovery and data mining (pp. 785-794).

Cheston, T., Goldstein, P., Freeman, T., Rueda Sanz, A., Hausmann, R., Gadgin Matha, S., ... & Rao, N. (2023). Seeing the Forest for More than the Trees: A Policy Strategy to Curb Deforestation and Advance Shared Prosperity in the Colombian Amazon. CID Faculty Working Paper Series.

Curtis, P.G., C.M. Slay, N.L. Harris, A. Tyukavina, and M.C. Hansen. (2018). Classifying Drivers of Global Forest Loss. Science.

DANE. (n.d.). Departamento Administrativo Nacional de Estadística DANE. (Retrieved in 2024 from https://www.dane.gov.co/index.php/estadisticas-por-tema).

Erasso, C., & Vélez, M. A. (2020). ¿Los cultivos de coca causan deforestación en Colombia? Bogotá: CESED-Facultad de Economía de la Universidad de Los Andes.

FAO and UNEP. (2020). The State of the World's Forests 2020. Forests, biodiversity and people. Rome.

Federación Nacional de Ganaderos (FEDEGAN). (2023). Registro administrativo del recaudo del Fondo Nacional del Ganado. (Retrieved in 2024 from https://www.fedegan.org.co/).

Friedlingstein, P., O'sullivan, M., Jones, M. W., Andrew, R. M., Gregor, L., Hauck, J., ... & Zheng, B. (2022). Global carbon budget 2022. Earth System Science Data, 14(11), 4811-4900. (Retrieved in 2024 from https://essd.copernicus.org/articles/14/4811/2022/).

Ganzenmüller, R., Sylvester, J. M., & Castro-Nunez, A. (2022). What peace means for deforestation: An analysis of local deforestation dynamics in times of conflict and peace in Colombia. Frontiers in Environmental Science, 10, 803368.

García, P. R., Scaccia, L., & Salvati, L. (2023). An accuracy assessment of three forest cover databases in Colombia. Environmental and Ecological Statistics, 30(3), 443-475.

Global Forest Watch. (2021, Mayo). Assessing trends in tree cover loss over 20 years of data. Global Forest Watch.

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., ... & Townshend, J. R. (2013). High-Resolution Global Maps of 21st-Century Forest Cover Change. Science, 342(6160), 850-853. (Retrieved in 2024).

Ibáñez, A. M., & Muñoz, J. C. (2010). The persistence of land concentration in Colombia: What happened between 2000 and 2009. Distributive justice in transitions, 299.

Koh, L. P., Zeng, Y., Sarira, T. V., & Siman, K. (2021). Carbon prospecting in tropical forests for climate change mitigation. Nature Communications, 12(1), 1271.

LeGrand, C. (1986). Frontier expansion and peasant protest in Colombia, 1850-1936.

Ministerio de Defensa Nacional de Colombia. (n.d.). Número de personas detenidas por las conductas delictivas cometidas contra los recursos naturales (Retrieved in 2024).

Nathanail, D. M. (2023). Public Comment on Voluntary Carbon Markets–Consultation Report.

Observatorio de Drogas de Colombia. (n.d.). Datos sobre cultivos ilícitos en Colombia (Retrieved in 2024 from https://www.minjusticia.gov.co/programas/observatorio-de-drogas-de-colombia).

Ruiz, D. & Tamayo, E. (2020). Efectos del desplazamiento forzado sobre las coberturas del suelo. En: Moreno, L. A. & Andrade, G. I. (Eds.). Biodiversidad 2019. Estado y tendencias de la biodiversidad continental de Colombia. Bogotá, D. C., Colombia: Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. 92p.

Sanín, F. G. (2011). Land and Property Rights in Colombia–Change and Continuity. Nordic Journal of Human Rights, 28(2), 230-261.

Unidad de Planificación Rural Agropecuaria (UPRA). (2023). Evaluaciones Agropecuarias Municipales - EVA. (Retrieved in 2024 from https://upra.gov.co/es-co/Paginas/eva_2023.aspx).

United Nations Development Programme (UNDP). Yaeda Valley Project, United Republic of Tanzania. Equator Initiative Case Study Series. 2021. New York, NY

World Bank (2019, Mayo). Why the Amazon's biodiversity is critical for the globe.

World Economic Forum (2024, Julio). What are the Amazon's 'flying rivers' – and how does deforestation affect them?

Zwick, S. (2019). The Surui forest carbon project: a case study. Washington: Forest Trends.

DISCLAIMER

This document, prepared by the BBVA Research Department, is informative in nature and contains data, opinions or estimates as at the date of its publication. These arise from the department's own research or are based on sources believed to be reliable and have not been independently verified by BBVA. BBVA therefore offers no express or implicit guarantee regarding its accuracy, completeness or correctness.

Any estimates contained in this document have been made in accordance with generally accepted methods and are to be taken as such, i.e. as forecasts or projections. Past trends for economic variables, whether positive or negative, are no guarantee of future trends.

This document and its contents are subject to change without prior notice, depending on variables such as the economic context or market fluctuations. BBVA is not responsible for updating this content or for giving notice of such changes.

BBVA accepts no liability for any direct or indirect loss that may result from the use of this document or its contents.

Neither this document nor its contents constitute an offer, invitation or request to acquire, disinvest or obtain any interest in assets or financial instruments, nor can they form the basis for any kind of contract, undertaking or decision.

The content of this communication or message does not constitute a professional recommendation to make investments under the terms of Article 2.40.1.1.2 of Decree 2555 of 2010 or the regulations that modify, replace or supplement it.

With particular regard to investment in financial assets that could be related to the economic variables referred to in this document, readers should note that under no circumstances should investment decisions be made based on the contents of this document; and that any persons or entities who may potentially offer them investment products are legally obliged to provide all the information they need to make such decisions.

ENQUIRIES TO:
BBVA Research Colombia Carrera 9 No 72-21, 10 floor. Bogotá, (Colombia).
Tel.: 3471600 ext 11448
www.bbvaresearch.com