

Ecological restoration and deforestation control: Implications for Colombia's agriculture and climate goals

FABLE Policy Brief
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Headlines

- Between 2000 and 2020, around **4.9 Mha of natural forest were turned into grassland in Colombia**.
- We review **five policies passed after 2010 that target halting deforestation and enhancing restoration**. We analyse their impacts on land use, agricultural production, and greenhouse gas (GHG) emissions by 2030 and 2040 using GLOBIOM-Colombia.
- Our results suggest that without forest protection measures and restoration policies ('Inaction' pathway), a further **1.3 Mha of forests will be converted to agricultural land between 2020 and 2040**.
- By stabilizing the area where agricultural activities are allowed and restoring areas that were deforested after 2010 ('Closing the Agricultural Frontier' pathway), **emissions from land could turn negative** and store 134 Mt CO₂ over 2020-2040 in Colombia.
- **The natural restoration of endangered ecosystems inside the Agricultural Frontier** ('Going the Extra Mile' pathway) could complement existing restoration and deforestation policies, with large benefits for biodiversity and no major trade-offs.
- To realize the alternative pathways, complementary innovations are needed to increase productivity and reduce rural poverty, including equitable access to technology and financing and secure land rights.

About FABLE

The Food, Agriculture, Biodiversity, Land-Use, and Energy (FABLE) Consortium is a collaborative initiative to support the development of globally consistent mid-century national food and land-use pathways that could inform policies towards greater sustainability. FABLE is convened as part of the Food and Land Use Coalition (FOLU). The Consortium brings together teams of researchers from 22 countries and international partners from the Sustainable Development Solutions Network (SDSN), the International Institute for Applied Systems Analysis (IIASA), the Alliance of Bioversity International and CIAT, and the Potsdam Institute for Climate Impact Research (PIK). The global report published in 2020 further describes the FABLE approach to developing pathways to sustainable food and land-use systems.

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1. Introduction

Colombia is one of the world's "megadiverse" countries.¹ In 2020, natural forests covered 59.7 million hectares (Mha), equivalent to 52% of Colombia's territory. Up to 66% of the country's natural forest is located in the Amazon macrobasin (Fig. 1).² **Yet, between 2000 and 2020, around 4.9 Mha of natural forest were lost** (Fig. 1), with an average of 0.22 Mha deforested per year.³ In 2021–2022 the most affected macrobasin is the Amazon, which accounted for two-thirds of the deforestation (0.11 Mha), followed by the Andean region with 17%.⁴ In Colombia, deforestation accounted for 1.24 Gt CO₂ between 2013 and 2020,³ and major biodiversity loss.

In 2020, **agricultural lands covered 43.5 Mha,⁶ equivalent to 37.9% of Colombia's land surface**, the second largest area after natural forests. Most agricultural lands (33.7 Mha) were used as pasture for cattle raising, while a smaller share (9.8 Mha)⁶ was used for permanent crops including coffee, palm oil, sugar cane, and annual crops (e.g., rice, potatoes, cassava, corn).^{7,8} In 2020, the area devoted to cattle production was almost five times the area deemed suitable for it.¹¹

Between 2005 and 2015, **50% of deforested areas were transformed into pastures with low-productivity cattle ranching.**⁵ The cultivation of illegal crops remains a problem but in the last 34 years, cattle ranching has overtaken coca farming as the main driver of forest loss outside of the area where agricultural activities are allowed ('Agricultural Frontier').⁹ Unregulated cattle ranching has been driven by speculation on land prices and unclear land rights, rather than by market opportunities for beef.^{9,10}

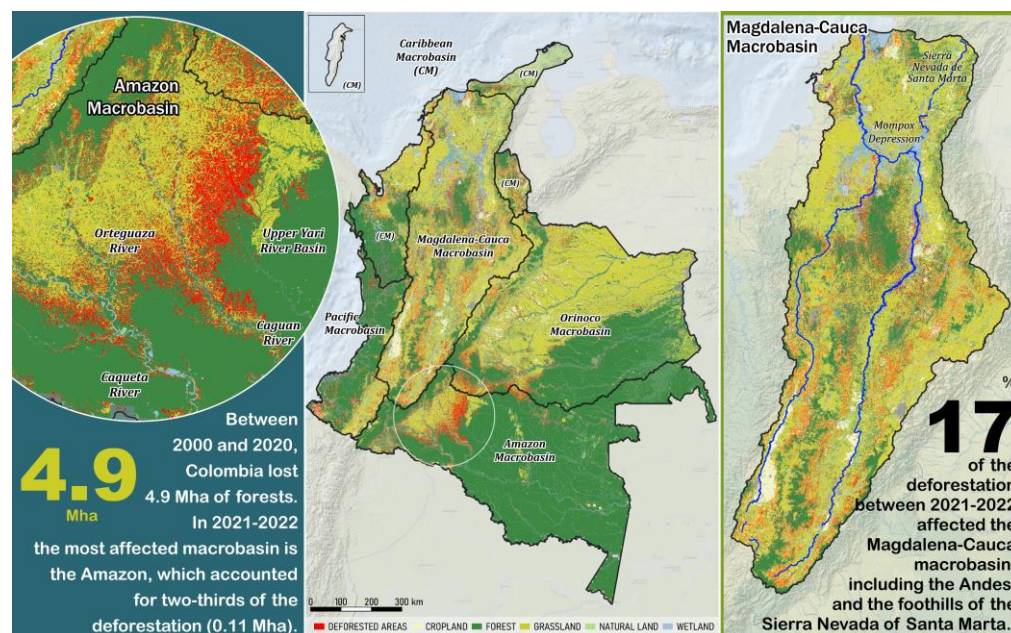
Colombian policy aims to limit agricultural expansion into natural ecosystems through **deforestation control and forest restoration**. These actions support climate change mitigation and contribute to biodiversity conservation by reducing extinction risk and expanding critical ecosystem areas. They create a buffer between agricultural activities and the remaining primary forest areas.

However, reconciling forest conservation and restoration goals with growing agricultural production and improving rural livelihoods **remains a challenge**. In 2017, agriculture accounted for 6.3% of Colombia's GDP;¹² and in 2019, agriculture employed 16% of the labour force.¹³ In 2020, the **rural poverty rate was 42%, and almost half of the landholdings lacked duly registered titles.**¹⁴

This brief assesses the impact of Colombia's Agricultural Frontier policy and restoration targets on future land use, greenhouse gas (GHG) emissions and agricultural production using **GLOBIOM-Colombia**, a regional version of the global partial equilibrium model GLOBIOM.¹⁵ This tool can support decision-making to ensure agriculture contributes to the achievement of the Sustainable Development Goals and the Paris climate agreement.

Between 2005 and 2015, 50% of deforested areas were transformed into pastures with low productivity cattle ranching in Colombia.

Figure 1. Historical deforestation and other land use in Colombia



Source: Authors' calculations based on forest cover data published by IDEAM-SMByC (SIAC).¹⁶

Deforestation figures correspond to gross forest loss between 2000 and 2017, without accounting for forest regrowth. Other land use was estimated using IDEAM data (2018). Note: This map shows the five macrobasins of Colombia: Amazon, Magdalena-Cauca, Orinoco, Caribe, and Pacifico. Macrobasins are hydrographic areas grouping basins and rivers flowing into the same sea. These areas are the spatial reference for long-term environmental planning in Colombia.¹⁷

2. Restoration and deforestation policies

In 2018, Colombia approved Resolution 261 which established the Agricultural Frontier to guide the reorganization of existing agricultural lands, increase land-use efficiency, and deter further land conversion. The Agricultural Frontier defines areas where agricultural production should take place, and excludes areas of ecological importance such as primary forests from agricultural use.¹⁸ Importantly, the resolution states that areas deforested after 2010 should be used for sustainable agricultural practices or restoration. Based on IDEAM Forest Cover Change data for 2010-2018, this area covers 0.97 Mha.

Colombia has included restoration and deforestation control in several national policies and planning instruments. This analysis focuses on five policies that were passed after

2010, include national-level restoration actions, have a long-term horizon (i.e., 2030+ as reference year), set significant area-based targets (>0.5 Mha), and propose deforestation control (Table 1):

- 1) Colombia's National Restoration Plan (NRP)**
- 2) Integrated Strategy for Deforestation Control and Forest Management (ENREDD+)**
- 3) National Resolution 261 of 2018, which defines the Agricultural Frontier**
- 4) 2020 Nationally Determined Contribution (NDC)**
- 5) Law on Climate Action 2167 of 2021**

This analysis focuses on five policies passed after 2010, that target halting deforestation and enhancing restoration.

Table 1. Selected Colombian policies targeting restoration and deforestation

| | | National Restoration Plan (NRP) ^a | Integrated Strategy for Deforestation Control and Forest Management ^b | National Resolution 261 (Agricultural Frontier) ^c | Nationally Determined Contribution (NDC) ^b | Law on Climate Action 2167 |
|--|-----------------------------------|---|--|--|---|----------------------------|
| Year of approval | | 2015 | 2017 | 2018 | 2020 | 2021 |
| Aim of restoration and deforestation control | Conservation | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Mitigation | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Adaptation | ✓ | | | | |
| | Closing the Agricultural Frontier | | ✓ | ✓ | | ✓ |
| Target (Mha) | | 1 | 0.8 | 1 (estimated) ^d | 1 (rounded) ^d | Not indicated |
| Target year for full implementation | | 2035 | 2030 | Not indicated | 2030 | |
| Priority areas | | Degraded areas nationwide | Areas of recent deforestation (Amazonas - Andes - Orinoco macrobasins) | | | |
| Proposed restoration type | | Passive and Active (restoration, rehabilitation, reclamation) | Not indicated | | Passive | Not indicated |
| Land cover targeted for restoration | | Not indicated | Pastures (implicit) | | | |

Source: Authors' elaboration based on policies that were passed after 2010, include national-level restoration and a long-term horizon, set significant area-based targets, and propose deforestation control.

^a National Policy on the Integral Management of Biodiversity (PNGIBSE). ^b National Policy on Climate Change (PNCC). ^c National Policy on the Social and Productive Organization of Rural Properties (PNOSPPR).

Note: The restoration area for the Agricultural Frontier and the NDC (0.96 Mha) has been approximated to 1 Mha. The target area for restoration under the Agricultural Frontier corresponds to the deforested area between 2010 and 2018 using official datasets from IDEAM. The National Resolution 261 of 2018 states that deforested areas after 2010 should be restored and/or converted into sustainable activities.

Restoration policies are not consistent on the total area, the targeted land cover type for restoration and on whether the proposed restoration is passive or active.

There are three main uncertainties in the proposed restoration actions:

1) How much? These policies propose different area-based targets ranging from 0.8 Mha to 1 Mha by 2030–35 and there is no consensus on whether the targeted areas for restoration in each of these five policies are spatially overlapping, or complementary. For this analysis, we assume some of the areas for restoration proposed by these policies will overlap.

2) Where? Except for the NRP which includes a map of areas with potential for restoration (over 8 Mha), these policies do not specify the targeted

areas for restoration. Most pastures have great potential for restoration, especially those close to the remaining forests. In areas of recent deforestation, most pastures harbour low-productivity cattle grazing, and they are often used to claim land property rights.

3) How? Most restoration policies do not specify whether the measures involve active or passive restoration. Ecosystems can be restored either through actively planting vegetation (active) or depending on natural regeneration (passive).^{19–21} Only NDC's mitigation measure 26 explicitly indicates that restoration should be mostly passive.²²

3. Restoration options

To achieve the attributes of fully functioning natural forests, passive or natural ecological restoration is most feasible in lightly degraded areas close to remaining natural forests. Active restoration activities are needed in other locations to kick-start the forest regeneration process.²³

Natural restoration on endangered ecosystems inside the Agricultural Frontier could complement existing restoration policies.

Natural forest regrowth (also known as passive restoration) is recognized as the most cost-effective option for large scales.²⁴

With the passive restoration approach, the remaining forests in the nearby areas can contribute as a source for species of flora and fauna facilitating forest regrowth (i.e., ecological succession).²⁵⁻²⁷ The recovery of all tropical forest attributes can take up to 120 years after moderate-intensity land use.²⁸

Active restoration can face complex challenges linked to unclear property ownership in remote areas, which are subject to recent deforestation²⁹⁻³¹ and the presence of armed groups conducting illegal activities.^{32,33} Planting seedlings of native species, *in situ* maintenance, and follow-up in these remote areas can be quite costly²⁴ and difficult to monitor. For these reasons, most active restoration

interventions have taken place at small scales (i.e., less than 100 ha).³⁴

Restoration can also focus on endangered ecosystems, as proposed by Etter et al. 2020.¹⁹ This approach prioritizes areas where ecosystems are most at risk (i.e., ecosystems classified as Critically Endangered, and Endangered using the IUCN Red List of Ecosystems approach³⁵), agricultural productivity is low (i.e., mostly pasture lands for cattle grazing with limited accessibility and low profit), and natural regeneration for passive ecological restoration is possible (i.e., nearby forest remnants act as a source for seeds).

Under this latter approach, restoration could occur inside the Agricultural Frontier on lands designated for agricultural production. Specifically, it would tackle areas that were deforested several decades ago (i.e., areas in the Caribbean and Andean regions). These high-priority areas – mostly corresponding to forest ecosystems – account for 0.8 Mha, which is relatively close to national targets. This approach could complement existing national policies, helping to raise the ambition beyond 2030.

4. Methods

We use the GLOBIOM-Colombia model to analyze the outcomes of forest restoration pathways. GLOBIOM is a global partial equilibrium economic and land-use change model representing the evolution of agriculture, forestry, and bioenergy.³⁶ In this version of the model, Colombia is singled out as a separate region with the highest

spatial resolution possible in GLOBIOM (between 10x10 and 50x50 km grid cells) and is run in 5-year time steps between 2000 and 2040 (see Annex for details). The model has been improved and recalibrated with the best available Colombian official data. We compare the evolution of land cover, agricultural production,

and related GHG emissions over 2020–2040 for three pathways:

1) Inaction: This pathway assumes agricultural lands (i.e., pastures and croplands) expand freely, except inside protected areas where deforestation is prevented, and no forest restoration takes place.

2) Closing the Agricultural Frontier:

It assumes that (1) agricultural expansion beyond the boundaries of the Agricultural Frontier stops, halting deforestation after 2020 in all locations, and (2) natural forest regrowth (i.e., restoration) takes place on pastures that were deforested between 2010–2018, mostly in the Amazon (Fig. 2). Of the 0.97 Mha^a deforested between 2010–2018, 89% was used as pasture (0.86 Mha by

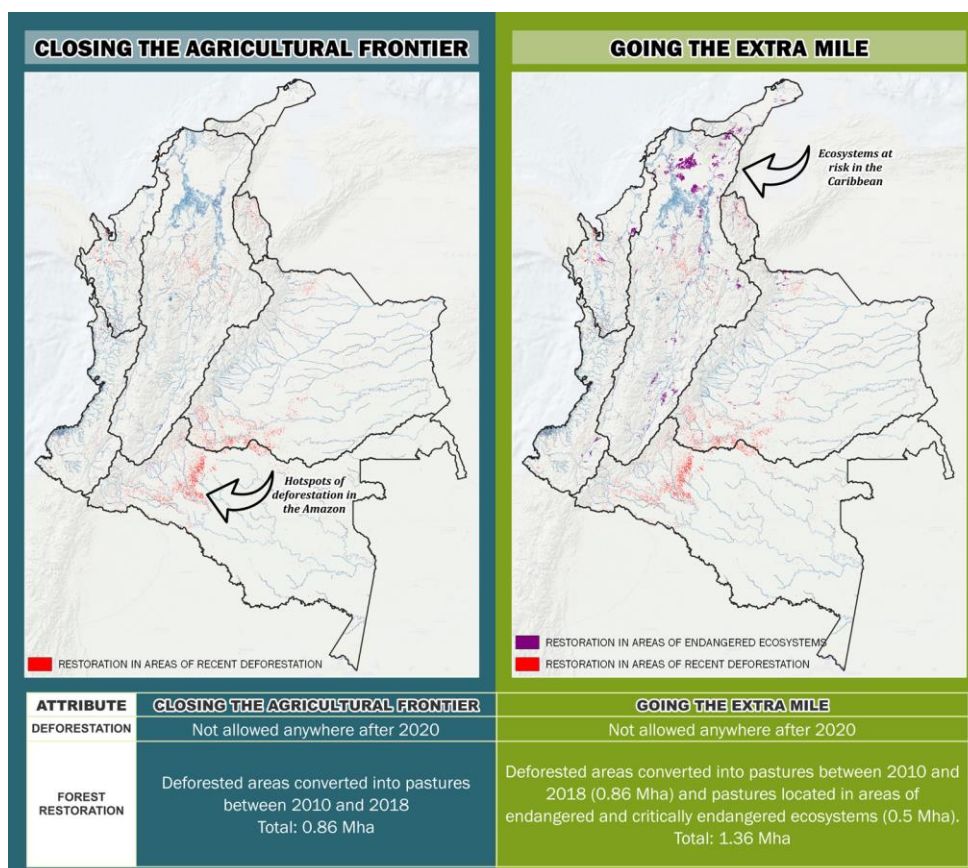
2020). This area forms the final restoration target which we assume will be achieved linearly through forest regrowth between 2020–2035.^b

3) Going the extra mile: In addition to the assumptions in “Closing the Agricultural Frontier”, in this pathway, natural forest restoration would take place in priority areas where there are endangered forest ecosystems,¹⁹ including areas in the Agricultural Frontier. This adds a further 0.5 Mha to the final restoration target, adding up to a total of 1.36 Mha, also achieved linearly from 2020 to 2035.

In all pathways, we assumed that restoration would be natural and not active and take place in deforested areas converted into pastures.

We assumed that restoration would be natural and not active and take place in deforested areas converted into pastures.

Figure 2. Description of the scenarios and targeted restoration areas



Source: Authors' calculations.

^a IDEAM Forest Cover Change data.

^b For this pathway, GLOBIOM assumes that cropland will remain unchanged. Forest regrowth would take place on 25% of the area, at the start of each time step (2020, 2025, 2030, 2035).

5. Results

Evolution of agricultural land and forests

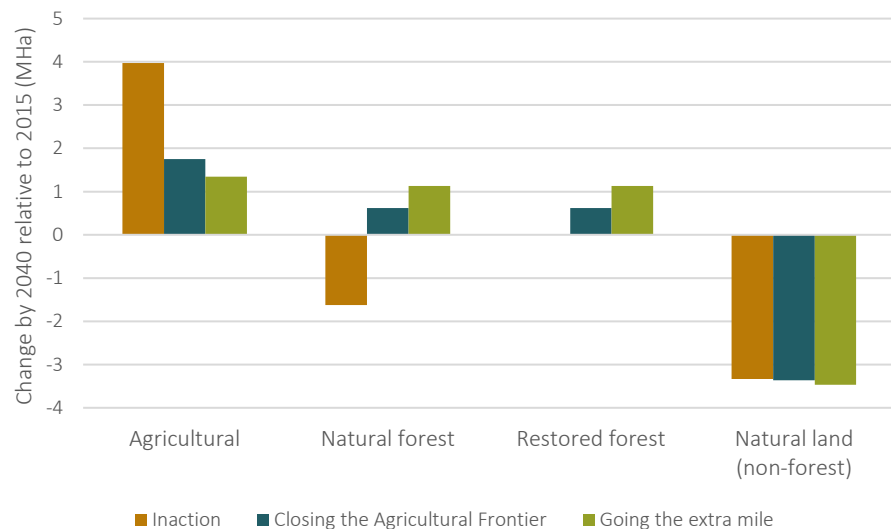
In 2015, agricultural land covers 21.5 Mha (of which pasture covers 18.9 Mha), forests 64.1 Mha, and non-forested natural land 18.5 Mha.

For the Inaction pathway, we compare our results in 2020 and 2040 with 2015 values. In the **Inaction pathway**, total agricultural land increases to 22.3 Mha by 2020 and 25.4 Mha by 2040, i.e., a gain of 4 Mha compared to 2015 (Fig. 3; Annex Table 2). Grassland used for pasture drives 70% of this expansion^c. Over the same period, the forest area falls to 62.4 Mha in 2040 (a loss of 1.6 Mha), and other natural lands decline by 3.3 Mha. By looking at these changes spatially, we find that **the largest**

increase in agricultural land is projected in the Magdalena-Cauca macrobasin with 1.1 Mha. About 37% of this increase leads to deforestation, and 63% leads to a decline in open shrubland. The Orinoco is the second macrobasin with the largest projected increase in agricultural land with 0.32 Mha of deforestation bordering the Amazon, and 0.34 Mha loss of other natural vegetation. **As agricultural areas expand, agricultural production increases** from a baseline of 76.9 Mt in 2015, to 85.5 Mt in 2020, and 114.4 Mt by 2040. **Crop production drives 91% of this increase** (34.3 Mt), and livestock production, 9% (3.3 Mt).

In the Inaction pathway, projected deforestation due to agricultural land expansion is the largest in the Magdalena-Cauca and Orinoco macro-basins.

Figure 3. Land cover changes by 2040 relative to 2015



Source: Authors' calculations

^c Most conversion of forest into pastures for extensive cattle grazing has occurred informally in remote areas where property rights are unclear. In some areas, this has served as an incentive to occupy land and claim land ownership³⁷.

For the Closing the Agricultural Frontier pathway and the Going the extra mile pathway, we compare our results for 2040 with the results from the Inaction pathway.

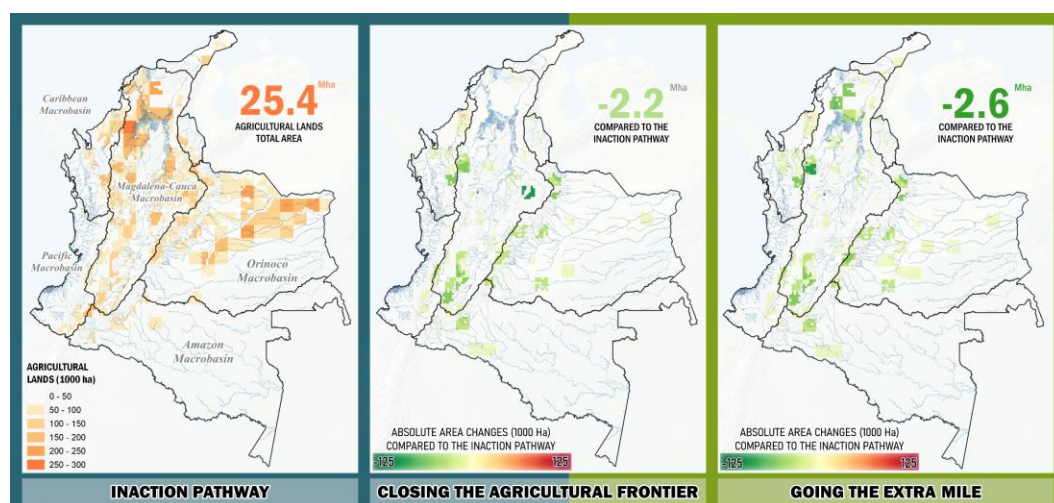
tonnes and milk production reduces by 87 thousand tonnes. However, this represents a relatively small impact on agricultural production (1% maximum) compared to the Inaction pathway.

In the Closing the Agricultural Frontier pathway, expansion of agricultural area is halved and forest increases by 2.25 Mha by 2040 compared to the Inaction pathway.

In the **Closing the Agricultural Frontier pathway**, due to constraints on deforestation and the replacement of pasture with restored forest, the expansion of the total agricultural land is halved by 2040 (Fig. 3) but the cropland area is unaffected. There is only a small displacement of the agricultural area expansion to other non-forest natural land (0.02 Mha). The forest area is increased by 2.25 Mha relative to the Inaction pathway, including 0.62 Mha of forest restoration by 2040. **This leads to a reduction in agricultural production which is compensated by higher imports.** By 2040, cattle meat production reduces by 10 thousand

The Going the extra mile pathway accentuates trends observed in the Closing the Agricultural Frontier pathway. **The total forest area (i.e., pre-existing forest and restored forests) increases by 2.76 Mha relative to the Inaction pathway.** Agricultural production declines further but limited, e.g., by 2040, cattle meat production declines by 12 thousand tonnes which is equivalent to 1.1% of the production in the Inaction pathway. This is due to the reduction in pasture area and the fact that we assume no change in cattle productivity across the three pathways.

Figure 4. Absolute changes in agricultural land by 2040



Source: Results of the GLOBIOM-Colombia model output for agricultural lands.
Note: agricultural land includes both pastures and cropland.

Deforestation emissions and carbon removal

Forest regrowth can capture up to 313 and 524 Mt CO₂ in the Closing the Agricultural Frontier and Going the extra mile pathways respectively, between 2020 and 2040.

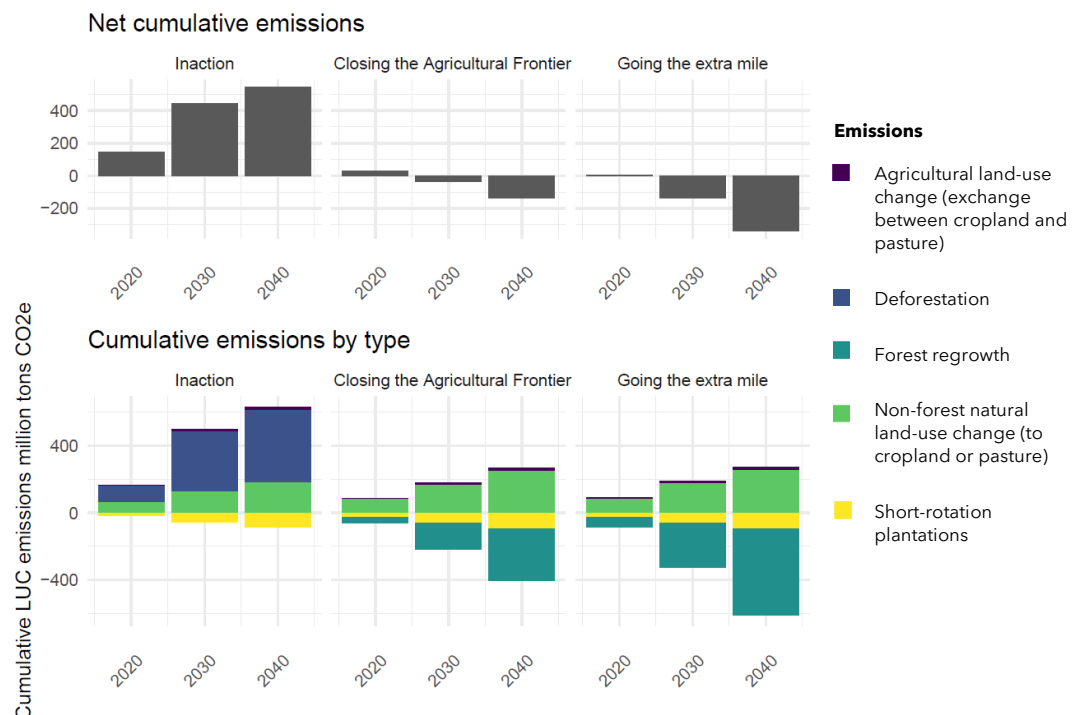
In the Inaction pathway, cumulative CO₂ emissions from deforestation between 2020 and 2040 total 463 Mt CO₂ (Fig. 5). In the Closing the Agricultural Frontier and Going the extra mile pathways, we assumed that no deforestation would take place resulting in no CO₂ emissions from forest conversion. Meanwhile, emissions from the conversion of other non-forest natural lands to agriculture increase by 64 Mt CO₂ by 2040 in the Inaction pathway, and by 69 Mt CO₂ in the Closing the Agricultural Frontier and Going the extra mile pathways. This indicates that **when deforestation is forbidden, agriculture tends to expand to other natural land and may still result in new emissions.**

If we use optimistic assumptions of carbon accumulation through successful forest recovery in all

restored areas (a linear increase of carbon accumulation over time),³⁸ **forest regrowth can capture up to 313 and 524 Mt CO₂ in the Closing the Agricultural Frontier and Going the extra mile pathways, respectively, between 2020 and 2040** (Fig. 5). The cumulative net GHG emissions from land-use change are 546 Mt CO₂ in the Inaction pathway by 2040. In contrast, they are net negative in the Closing the Agricultural Frontier (-134 Mt CO₂) and the Going the extra mile pathways (-338 Mt CO₂) (Fig. 5).

In both pathways, avoided deforestation is critical to reaching negative land-use change emissions. In addition, successful long-term forest regrowth is needed to offset additional emissions from the conversion of other natural lands to agriculture. Deforestation control and forest restoration result in a leakage of agricultural expansion onto non-forest natural lands, which can be important for carbon and biodiversity.

Figure 5. Cumulative land-use change emissions between 2020–2040



Source: Authors' calculations.

6. Discussion and recommendations

In this brief we assess interactions between food production, forest conservation, and climate change target policies in an integrated manner, using the GLOBIOM-Colombia model. Our findings highlight the need for integrated policymaking to ensure consistent and congruent policy targets across sectors and spatial scales, and the opportunities and challenges for success that may exist.

The analysis shows that deforestation control combined with **restoration in recently deforested areas turned into pastures and highly endangered ecosystems** offers a unique opportunity to bring Colombia significantly closer to achieving climate and biodiversity goals, complementing its progress towards meeting the Sustainable Development Goals. We recommend that the revised National Restoration Plan especially targets these areas, including areas inside the Agricultural Frontier with low productivity cattle raising.

Reaping the benefits from passive restoration requires long-term commitments and investments.

Unlike halting deforestation, for which the GHG reductions are immediate, the carbon sequestration from forest regrowth is slower and uncertain. Studies estimate that it could take up to 60 years for a tropical forest to recover 70% of the above-ground biomass existing before deforestation.²⁸

There are limitations to this study. These pathways are based on assumptions such as the complete halt of deforestation in primary forests. To achieve this, **Colombia would need to implement a set of**

complementary interventions that go beyond the scope of this study (i.e., incentives, support to formalize land ownership, and community roundtables). Importantly, stopping, displacing, or restricting the expansion of agricultural activity in certain areas requires the buy-in from rural communities and farmers. This will require policies that support job creation for the rural working population whose livelihood depends on deforestation-related activities.

Our results show that a reduction of pasture in areas used for low-productivity cattle raising, after deforestation control and restoration policies could lead to a slight decrease in cattle meat and milk production, and a consequent increase in imports for these products. However, these scenarios did not envision any major increase in agricultural productivity through technology innovation and investments. Thus, this potential trade-off can be reduced with adequate policies.

Currently, the livestock productivity in Colombia is still relatively low, and has much potential to increase.

By increasing agricultural productivity, especially livestock, Colombia can avoid the offshoring of deforestation-linked products and potentially reduce land use for pastures. We recommend promoting investments and policies that incentivize and facilitate agricultural productivity gains to help farmers compensate for any potential trade-off from decreasing agricultural land. Colombia has recently launched Productive Management Plans (POPs) for the agricultural sector. We recommend the swift implementation

of the POP for meat and milk to support farmers in increasing productivity and land-use efficiency inside the Agricultural Frontier, mainly on pastures. This is only likely to be successful if agricultural productivity increases are directly linked to land-sparing, through management agreements, to avoid unintended consequences from increased agricultural profitability.³⁹

To better realize the alternative pathways, we recommend **complementary innovations** to increase productivity and reduce rural poverty, potentially including areas such as equitable access to technology and financing and secure land rights. The latest agricultural census (2014) shows that only 9.6% of farms had received any kind of rural extension service.⁸ Most landowners (67%) are small and medium farmers, who own less than 5 ha (equivalent to 4.2% of agricultural land), and almost half of the landholdings lacked duly registered titles.¹⁴ To improve agricultural productivity, we recommend addressing these large gaps which have been exacerbated by decades of armed conflict and forced displacement of rural communities.⁴⁰ Colombia's National Agricultural Innovation System (Law 1876 of 2017) is a step forward, but it needs to involve smallholder farmers in its operationalization. This can

contribute to reducing inequalities in rural areas, and build an inclusive and just transition.⁴¹

An important challenge is the low spatial resolution (1:100.000) used to demarcate the Agricultural Frontier, which is not high enough to implement precise policy actions at the land property level. We recommend prioritizing **the use of local scale and/or high spatial resolution instruments** (i.e., multipurpose cadastral system, river basin management plans, land-use planning instruments). These can help provide legal certainty on land ownership, identify priorities on technical assistance for smallholder farmers, and reduce incentives to deforest. These types of instruments can also help support the successful implementation of the Climate Action Law's *Natural Conservation Contracts*, which aim to involve local communities in the restoration of areas to close the frontier.

The Agricultural Frontier is a cornerstone of Colombia's peace agreements, and it should be consistent with its national climate and deforestation strategies. The definition and consistency of targets, supported by effective local community participation will be crucial for meeting climate and restoration goals, as well as for continued peacekeeping.

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Annex

Table 2. Overview of land cover changes estimated for 2020 - 2040 (Mha)

| | Inaction | | Closing the Agricultural Frontier | | Going the extra mile | |
|---|----------|------|-----------------------------------|------|----------------------|------|
| | 2020 | 2040 | 2020 | 2040 | 2020 | 2040 |
| Agricultural land, incl. cropland and pasture | 22.3 | 25.4 | 21.8 | 23.2 | 21.7 | 22.8 |
| - Cropland | 2.7 | 3.7 | 2.7 | 3.7 | 2.7 | 3.7 |
| - Grassland (Pasture) | 19.6 | 21.8 | 19.1 | 19.6 | 18.9 | 19.2 |
| Forest | 63.7 | 62.4 | 64.1 | 64.1 | 64.1 | 64.1 |
| Non-forested natural land | 17.8 | 15.1 | 17.7 | 15.1 | 17.7 | 15.0 |
| Planted forests | 2.0 | 2.8 | 2.0 | 2.8 | 2.0 | 2.8 |
| Forest restoration | - | - | 0.1 | 0.6 | 0.3 | 1.1 |
| Total forests | 63.7 | 62.4 | 64.2 | 64.7 | 64.4 | 65.2 |

Table 3. Overview of agricultural production and trade estimated for 2020 - 2040 (Mt)

| | Inaction | | Closing the Agricultural Frontier | | Going the extra mile | |
|-------------------------|----------|-------|-----------------------------------|-------|----------------------|-------|
| | 2020 | 2040 | 2020 | 2040 | 2020 | 2040 |
| Agricultural production | 85.5 | 114.5 | 85.5 | 114.4 | 85.5 | 114.4 |
| - Exports | 13.9 | 16.5 | 13.9 | 16.5 | 13.9 | 16.5 |
| - Imports | 9.2 | 13.6 | 9.2 | 13.7 | 9.2 | 13.7 |
| Crop | | | | | | |
| - Production | 74.1 | 100.8 | 74.0 | 100.8 | 74.0 | 100.8 |
| - Exports | 13.6 | 16.1 | 13.6 | 16.1 | 13.6 | 16.0 |
| - Imports | 8.6 | 11.3 | 8.6 | 11.3 | 8.6 | 11.2 |
| Livestock | | | | | | |
| - Production | 11.4 | 13.7 | 11.4 | 13.6 | 11.4 | 13.6 |
| - Exports | 0.3 | 0.4 | 0.3 | 0.4 | 0.3 | 0.4 |
| - Imports | 0.6 | 2.3 | 0.6 | 2.4 | 0.6 | 2.4 |

Overview of the Model

For this brief, we used the IIASA's Global Biosphere Management Model (GLOBIOM) to assess the potential effect of selected AFOLU mitigation measures on agricultural production and the environment. GLOBIOM is a partial equilibrium and land-use change model representing the main land-based activities including agriculture, forestry, and bioenergy.³⁶

The model has been subject to a series of improvements contributing to its calibration and validation to better reflect the particularities of the Colombian context. Default input data has been replaced with country-specific information on land cover from IDEAM,⁴² and spatial data crop and livestock production has been included from Agronet (MinAgricultura).⁴³ A new land class has been added to the model (forest regrowth) to represent passive ecological restoration. We assume a continued linear carbon uptake over time from the moment the restoration is applied based on annual carbon accumulation data for forests provided at 30 meter resolution, published by Cook-Patton *et al.* (2020)³⁸. Carbon emissions from deforestation are based on 30 meter resolution data from Harris *et al.* (2021)⁴⁴.