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Mitigate+: Research for Low-Emission Food Systems

Working paper

Review of Nationally Determined Contributions (NDC) of Colombia from the Perspective of Food Systems

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Abbreviations

AFOLU	Agriculture Forestry and Other Land Use
AWD	Alternative Wet and Dry
BAU	Business As Usual
BUR	Biennial Update Report
CAT	Climate Action Tracker
CIAT	International Center for Tropical Agriculture (CIAT)
CSA	Climate Smart Agriculture
FLW	Food Loss and Waste
GHG	Greenhouse Gases
IPCC	Intergovernental Panel on Climate Change
NDC	Nationally Determined Contributions
NAMA	Nationally Appropriate Mitigation Actions
LUCF	Landuse Change and Forestry
LULUCF	Land Use Land Use Change and Forestry
OCED	Overseas Centre or Economic Cooperation and Development
PIGCCS	Planes Integrales de Gestión de Cambio climático Sectoriales
PIGCCT	Planes Integrales de Gestión de Cambio climático Territoriales
POT	Planes de Ordenamiento Territorial
RCP	Representative Concentration Pathways
SDG	Sustainable Development Goal
TCNCC	Third National Communication on Climate Change
UNFCCC	United Nations Framework Convention on Cliimate Change

Summary

Food is a vital component of Colombia's economy. The impact of climate change on agriculture and food security in the country is severe. The effects have resulted in decreased production and in the productivity of agricultural soil. Desertification processes are accelerating and intensifying. Colombia's government formally submitted its Nationally Determined Contribution (NDC) on December 29, 2020. This paper examines Colombia's NDC from the standpoint of the food system.

Mitigation ambitions and targets: Studies show that methane emissions (mainly from enteric fermentation) need to decline by 10% by 2030 and by 35% by 2050 (from 2010 levels). Nitrous oxide emissions (mainly from fertilizers and manure) need to be reduced by 10% by 2030 and by 20% by 2050 (from 2010 levels).

Colombia's NDC is much more in line with the country's goal of reaching carbon neutrality by 2050. Colombia has increased its mitigation target from 20% of business as usual (BAU) by 2030, with a possible increase to 30% conditional on international support, to a 51% reduction unconditionally. The new target is also stated in absolute terms: emit no more than 169.44 $MtCO_2$ eq by 2030. The updated NDC also includes measures and quantitative targets for key sectors to reduce deforestation by 50,000 ha per year by 2030. Colombia has also committed to reducing black carbon emissions by 40% by 2030 compared to 2014.

Agriculture and LULUCF in general are included in Colombia's NDC. The scenarios for emission and mitigation targets are shown in the table below. The NDC mitigation plan includes measures such as sustainable management, restoration of degraded grazing areas, and waste-to-energy generation, to reduce emissions from cocoa, coffee, and sugar production, as well as from livestock.

Categories	**Emission scenarios in 2030 (Mt CO_2 eq)**	**Targets for emission reduction in 2030 (Mt CO_2 eq)**	**Difference (Mt CO_2 eq)**	**% of gaps**
Overall	345.8	169.44	176.36	49%
Agriculture and LULUCF	174.5	22.145	152.355	86%
Crops	NA	0.08	NA	NA
Livestock	56.56	11.15	45.41	80%
LULUC (forest, cacao, coffee, panela)	NA	10.915	NA	NA

Adaptation ambitions and targets: According to the NDC, eight priority economic sectors (transportation, energy, agriculture, livelihoods, health, commerce, tourism, and industry) have incorporated climate change into their planning instruments and will be implementing adaptation measures. The NDC also establishes 30 adaptation objectives and links them to the Sustainable Development Goals (SDGs) and the Sendai Framework for Disaster Risk Reduction.

Scientific basis and data used in identifying targets: Colombia's Nationally Determined Contribution (NDC) revision and update process was participatory and involved an extensive process of consultation, sensitization, and dialogue, which is described transparently in the NDC. Colombia's sectoral mitigation potential was calculated using assessment models developed through the Low Emissions Analysis Platform, an integrated, scenario-based modeling tool. A technical research team from the Flemish Institute for Technological

Research, the University of the Andes, the International Center for Tropical Agriculture, Wageningen University, the Stockholm Environment Institute, and Energy Super Modelers and International Analysts created the updated mitigation scenario.

In addition, agricultural production and refrigeration were included in the reference and mitigation scenarios, other issues such as food loss and waste and food transport were not included due to a lack of data. Furthermore, the majority of the mitigation actions proposed are also based on some sound scientific basis. For example, the Nationally Appropriate Mitigation Action (NAMA) for livestock was informed by scientific evidence of the development of low-emission livestock in Colombia.

Adequacy of the target from the food system perspective

The overall NDC is rated highly insufficient by the Climate Action Tracker (2022). However, the updated NDC is 6–22% stronger than the first NDC and is heavily reliant on reductions in Land Use, Land Use Change and Forestry (LULUCF). There are insufficient policies in place to address emissions from the energy and transportation sectors, which are heavy users of fossil fuels, or a phase-out of coal, which is critical for the world's fifth-largest coal exporter. According to the NDC review, Colombia has improved the type of target — from a reduction compared to the Business as Usual (BAU) scenario to setting an absolute cap on emissions in 2030. The NDC is rated highly in many categories for the Agriculture Forestry and Other Land Use (AFOLU) sector, indicating that it provides specific indications of actions to reduce emissions as well as information on policies, spatial information, and technology development, and these actions need to be developed and the NDC implemented.

Agriculture contributed 65.2 Mt CO_2 eq of GHG emissions in 2019, accounting for 34.82% of total emissions excluding land-use change and forestry (LUCF) (187 MtCO_2e) and 24.12% including LUCF (271 MtCO2e). The commitment is to reduce GHG emissions in agriculture and LULUCF by 22.145 Mt CO_2 eq, by 2030; this is only 14% of the projected emissions of 174.5 Mt CO_2 eq. In the livestock sector, the government pledges to reduce GHG emissions by 11.15 mt CO_2 eq by 2030, or 20% of the total of 56.56 mt CO_2 eq. On the other hand, no additional information is provided about mitigation efforts in agriculture subsectors or activities. The NDC commits 3.6 million ha to sustainable livestock farming; to an increase in cocoa production surface area through agroforestry (150,000 ha) and restoration (80,000 ha); to the planting of 255,000 ha of irrigated rice and 207,046 ha of dry rice with new technology (AMTEC 2.0); to the planting of 936,477 ha of coffee under the NAMA Café strategy; and to the conversion of 15,000 mills to the latest technologies.

The NDC is rated medium to high in many categories for adaptation, indicating that it provides specific indications of actions to address risk and vulnerability in the AFOLU sector, as well as information on policies, spatial information, and technology development, and it needs to make progress in carrying out these actions and implementing the NDC. At the national and territorial (subnational) levels, detailed strategies, actions, and specific targets are provided for agriculture and LULUCF. This includes providing information on baselines and targets, relevant strategies and/or plans for carrying out the envisioned actions, and the institutions in charge of carrying them out. Comprehensive Sectoral and territorial Climate Change Management Plan i.e. Planes Integrales de Gestión de Cambio climático Sectoriales (PIGCCS) and Planes Integrales de Gestión de Cambio climático Territoriales (PIGCCT), for example, have frequently mentioned AFOLU sector throughout the documents.

Feasibility of achieving the targets

With regard to the feasibility of achieving the specific agriculture-related targets, the NDC has provided descriptive sheets of the sectoral measures with a clear articulation of goal, mitigation target, linkage to SDG, responsible ministry, and details of what is to be done and achieved. The information in the Annex of the NDC on mitigation projects provides some level of confidence in ensuring that the targets can be achieved, as what is intended to be done and how is realistically outlined, along with scientific evidence such as the case of NAMA in livestock. In addition, given the lower ambitions it has set in the food system components such as rice, livestock production, and other production enhancement measures, it may be feasible to achieve the targets as long as the government begins implement the priorities without delay and with adequate financial allocations.

Data gaps in the NDC

Colombia's GHG emissions in the national food systems, particularly the emissions from food loss and waste, are poorly quantified and understood, making it difficult to set intervention priorities, track progress, and report outcomes. Colombia's NDC is supported by scientific analyses and accounting methodologies that considered some food system elements but did not address all the food system components in an integrated manner. Due to a lack of available data, the detailed aspects of GHG emission trends and mitigation potentials in the food production, consumption, storage and transportation, and food loss sub-sectors were excluded from the modeling scenarios. In many cases, food systems have not been considered holistically because the necessary knowledge and data on issues such as food production and consumption, food loss, and food waste have not been included.

Furthermore, the NDC did not fully account for emissions associated with food imports, particularly those associated with deforestation and ecosystem conversion. Although the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement apply the "territorial principle" to GHG emissions — that is, only emissions and removals occurring within national jurisdictions are to be managed and reported internationally by countries — there is room in NDCs to propose measures that consider the full scope of the impacts caused by food systems.

Areas for improvement

Overall, Colombia has enormous potential to raise its agricultural ambitions, particularly in rice cultivation and livestock management. A combination of actions (e.g., implementation of low-emission interventions for improving the efficiency of production systems; promotion of carbon sequestration; reduction in livestock-based protein consumption; and deployment of new-horizon technologies) is necessary to reduce net GHG emissions from food systems aligned with net-zero emission strategies. The transformation of food systems thus offers policymakers a clear way to enhance national climate plans and deliver faster and deeper cuts in emissions.

- **Increase overall ambitions in the agriculture sector**: The agriculture sector, particularly the food system, has the potential to significantly boost Colombia's GHG emission reduction ambitions in the context of 1.5 degrees Celsius. A 1.5°C pathway necessitates dietary changes, more organic farming, and less fertilizer use. Methane emissions (primarily from enteric fermentation) must be reduced by 10% by 2030 and 35% by 2050 (from 2010 levels). Nitrous oxide emissions (primarily from fertilizer and manure) must be cut by 10% by 2030 and 20% by 2050 (from 2010 levels). According

to research, agroforestry systems can function as CO_2 sinks, potentially reducing GHG emissions at the farm level in Colombia. Converting degraded pastures to silvopastoral systems and rice crops to crop rotations can significantly increase GHG mitigation potential at the farm level in different zones of Colombia[i].

- **Increase ambitions to reduce emissions from rice cultivation:** From 2021 to 2030, rice has a mitigation potential of 0.77 Mt CO_2 eq. The GHG emission reduction interventions need to be promoted by encouraging farmers to use low-methane rice and flood-stress-tolerant rice varieties; encouraging early-season drainage with mid-season drainage systems; encouraging improved management practices, such as alternate wetting and drying practice.
- **Increase ambitions in the livestock sector:** Colombia should raise its livestock ambitions to the highest extent possible. As per the estimate of the Institute of Hydrology, Meterology and Environmental Studies The livestock sector produced 26% of Colombia's total GHG emissions (258.8 Mt CO_2 e/yr) in 2012 . This was 42% of the total emissions of the AFOLU sector (158.6 Mt CO_2 e/yr), with cattle producing 95% of the livestock sector's emissions. Cattle, therefore, offer the greatest potential for mitigation in the agricultural sector, estimated at 83% of the proposed national goal of an emission reduction of 13.46 MtCO_2 e/yr by 2030 (Tapasco, J. et al., 2019).
- **Promote Climate-Smart Agriculture Technologies:** The most promising climate-smart agriculture (CSA) technology clusters for the country include intercropping, green manure/cover crops, organic inputs, mulching, improved pastures, stress-tolerant crops, and adequate management of grazing, fertilizer, and water use. Local strategies are also key to tailoring CSA innovations to farmers' needs, including preserving or improving genetic diversity to strengthen resilience, and applying alternate wetting and drying (AWD) for water-use efficiency and reduction of emissions (Swinnen, J. et al. 2022). For example, World Bank's country climate and Development Reports[2] using the International Rice Research Institute's investment model, suggest that investing US $1.4 billion to implement AWD and related techniques could reduce emissions from rice production by 6.8 MtCO_2e relative to BAU by 2030 (World bank CCDR 2021)[ii].
- **Include interventions that promote sustainable intensification of the agricultural sector with the use of agricultural technologies:** GHG emission reductions from the adoption of Low-Emission Climate Resilient Agriculture (LECRA) technologies, which are promising for Colombian agricultural production, will help lessen the need to expand the agricultural land. Co-benefits such as increased physical productivity per unit area, increased nitrogen retention in the soil, and increased water retention capacity in the soil would also be generated.
- **Include interventions to reduce land-use change and conversion of natural habitats:** One possibility is to transition towards a sustainable oil palm expansion in areas with low carbon stock or areas suitable/available for the crop (e.g., cropland, pastureland). This has the potential to reduce 55% agricultural GHG emissions (Ramirez-Contreras et al. 2020). In addition, a pilot project funded by the World Bank in Colombia's Vichada municipality found that land-management techniques paired with the implementation of a tropical grass species increased carbon storage in the soil by more than 15% while also avoiding the need for cyclical burning of the savanna[iii]. Likewise, an improved variety of grass combined with a rotational grazing system could boost levels of soil carbon on tropical savannas by 15 per cent compared to degraded pasture — according to a new study carried out by the Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT), the University of Stuttgart, and the World Bank[iv]. In addition, the adoption of agroforestry systems plays a leading role, as crop rotation and improved pastures can represent a GHG mitigation opportunity for sustainable agricultural production at the farm level in Colombia (Silva-Parra A. et al. 2021). Other mitigation measures include increasing the carbon content in livestock systems, planting trees, and increasing carbon stocks

in soil and biomass in pastures and shrubs. Zomer et al. (2019) reported an average biomass carbon stock of 53 Mg ha−1 in Colombian arable land in 2000, demonstrating that trees in productive systems could significantly increase carbon stocks in Colombia. Also, the sustainable management of silvopastoral systems is a good option that could provide up to 77% of the national goal of the NDC for the agricultural sector. However, intervention would be necessary on 3.82 M ha (Tapasco, J. et al., 2019).. One of the research projects in the Andean zone (Antioquia) intensive silvopastoral systems with five hundred Eucalyptus tereticornis trees ha-1 (SSPi) on pastures is a great neutralizer of GHG emissions, accounting for -26.6 t CO_2 eq ha-1 yr-1.

- **Integrate actions on handling and storage of food:** Interventions should include the following: promoting infrastructure and technology investment to prevent post-harvest losses; aiding agricultural research in the development of technologies to reduce post-harvest food waste; constructing and supplying low-cost storage silos for small-scale farmers to store their harvest; increasing infrastructure investment; promoting urban-rural connections, and connecting farmers to markets; repurposing unused food as animal feed; and reusing organic or agricultural waste to generate energy such as biogas.
- **Include targets to reduce food loss and waste:** The five food products with the highest sum for Food Loss and Waste (FLW)-associated GHG emissions and nutrient losses are bovine meat, milk, rice, and poultry. From the bovine meat chains, 0.13 million tons of FLW represent 4.7 million tons of CO_2-eq emissions. For example, 0.77 million tons rice is either lost or wasted with the GHG footprint of 2 Mt CO_2 eq..(Axmann, H. et al., 2022). Therefore, there is a need for targets to reduce food loss and waste. Interventions could include these: measuring national food loss and waste baselines to understand the scope of the problem and opportunities for cost savings and GHG reductions, as well as identifying hotspots of loss and waste along the value chain; putting in place educational programs to prevent and reduce food waste; promoting the use of food waste as animal feed and organic fertilizer; and composting and energy recovery that can be used to promote the conversion of food waste into biogas.
- **Include targets and interventions to reduce consumption of emission-intensive food:** This includes stricter guidance for government procurement; mandating food labels and sustainable labeling frameworks to increase consumer awareness and transparency; advancing research into alternative proteins (for example, algae); taxing animal proteins to discourage consumption; providing long-term dietary training to all medical professionals to educate patients; food education, including making school gardens; and promoting public procurement of food for schools to promote more sustainable and healthy diets, with a focus on plant-rich diets.
- **Give more emphasis to improving information and access to technology:** Recommendations include ensuring that non-discriminatory trading rules for agriculture and food are aligned with climate-smart policies, while investing in low-emission solutions for safe, efficient storage and transportation along value chains.

Chapter One: Aspects of food included in their NDC target.

1.1. Context

Food is a vital component of Colombia's economy. In 2018, agriculture accounted for 6.3% of Colombia's GDP, 16.4% of employment, and 19% of exports. While much of Colombia's food is consumed locally, the country is also a food importer and exporter. Coffee, flowers, and plantain contributed the most to agricultural exports in 2015, totaling 23,591 billion Colombian pesos (COP) (US$ 6 billion). Colombia imported more than 15,727 billion COP (US$ 4 billion) in food products in the same year, primarily corn, wheat, soy oil, and soybeans. Many of Colombia's 10 million rural residents rely on food production as their primary source of income, with agriculture accounting for 60% of rural employment in rural areas in 2020 (Global Alliance for the Future of Food 2022). Although as few as 1% of landowners own as much as 81% of the land, agriculture is primarily performed by smallholder farmers. Colombia must therefore transform its food system into one capable of ensuring food security, promoting healthy diets, promoting environmental sustainability, and ensuring prosperity for all.

Colombia is a middle-income country, but it is also a developing country with significant social, economic, and environmental challenges ahead of it. Among these challenges, the country is extremely vulnerable to climate change. Colombia proposes an NDC that it claims is ambitious and equitable, considering both the country's capabilities and the development challenges that it faces.

1.2. Climate-Change Scenarios of the country

The climate-change scenarios prepared for Colombia (2011–2100) as part of the Third National Communication to the United Nations Framework Convention on Climate Change UNFCCC show that the average annual temperature towards the middle of the twenty-first century (2040–2070) could gradually increase by up to 1.6°C. These increases are expected to continue until 2100, when continental areas may see a 2.1°C increase. Precipitation, on the other hand, is expected to show non-uniform changes across the country, with increases toward the middle of the century, primarily in some Andean region sectors[1].

Rainfall will decrease by 10% to 40% in geographical regions such as the Caribbean and the Amazon (IDEAM et al., 2015; 2017). In addition to the above, and in search of a more detailed approach for modeling threats that allow us to approximate the prospective risk in Colombia in 2050 due to climate change, the HadGEM2-AO model was run considering the various Representative Concentration Pathways (RCP) scenarios (2.6, 4.5, 6.0, 8.5), to consider multiple future scenarios and their impact on the estimation of risk due to hydrometeorological phenomena.

Climate-change assessments indicate in percentage terms an average precipitation decrease of 11% with values as high as 51% in rainfall reduction and an increase in the average temperature of 5.4 °C in the RCP 8.5 scenario in the long term. The reduction in precipitation occurs to a greater extent towards the northeast of the country, while the increase in temperature is greater towards the southeast for the RCP 8.5 scenario (IDEAM et al. 2017).

In recent years, the country has made progress in conducting analyses of vulnerability and risk due to climate change, not only on a national scale but also by administrative units of departments and municipalitiesfocusing on the services of socioecological systems such as wetlands and in productive sectors such as agriculture. This analysis, introduced in the Third National Communication on Climate Change (TCNCC), is based on 113 indicators distributed

[1] https://unfccc.int/sites/default/files/NDC/2022-06/NDC%20actualizada%20de%20Colombia.pdf

in the components of Threat, Sensitivity, and Adaptive Capacity, subdivided into six dimensions: Food Security, Water Resources, Biodiversity and Ecosystem Services, Health, Human Habitat, and Infrastructure.

Additionally, based on the TCNCC and the AR5 report of the Intergovernmental Panel on Climate Change (IPCC), Colombia has sought to deepen the understanding of its vulnerability and risk to climate change. This has been done through initiatives such as the analysis of vulnerability and risk to climate change of the flood plains of the Magdalena-Cauca macro-basin (IDEAM -TNCCC 1), and the analysis of vulnerability and risk to climate change (IDEAM et al., 2017).

The impact of climate change impact in Colombia is severe and has resulted in reduced production, a decrease in the productivity of agricultural soils, and acceleration and intensification of desertification processes. According to Colombia's Long-Term Strategy (LTS), the average (expected) annual loss value due to drought in the two crops considered (corn and rice) is equivalent to 1.3% of the heading in agriculture and rural development (1.7 billion US$).

The Colombian Low Carbon Development Strategy was launched by the government in 2012. Similarly, in 2013 and 2014, the Sectoral Mitigation Action Plans were developed (PAS). The National Climate Change System (Sistema Nacional de Cambio Climático -. SISCLIMA), established by Decree 298 of 2016 (Art. 1), aims to coordinate, articulate, formulate, monitor, and evaluate policies, regulations, strategies, plans, programs, projects, actions, and measures related to climate-change adaptation and greenhouse-gas mitigation. The government has also established the Intersectoral Commission on Climate Change, which will oversee and coordinate the implementation of the National Climate Change Policy.

Two major policy instruments are specifically focused on the long-term transformation of Colombia's cattle sector. The recently launched Nationally Appropriate Mitigation Action for Sustainable Bovine Production is one example (NAMA-bovine). It lays out the steps that must be taken to reduce GHG emissions and increase carbon storage in cattle production systems to meet Colombia's international commitment to reduce cattle-related GHG emissions by 15% to 33% by 2050. (i.e., equivalent to 5–11 Mt CO_2 eq year-1). Land-based mitigation measures account for 70% of Colombia's updated NDC target, and the NAMA-bovine plays a critical role in achieving it. The other policy is the 2021–2050 National Policy for Sustainable Bovine Production (PNGBS). This document defines the roadmap for modernizing and reconverting Colombian livestock systems between 2021 and 2050 towards low-emission and climate-resilient systems.

1.3. Mitigation Priorities and actions for the agriculture, food, and LULUCF sectors

Colombia has increased its contribution to global emissions from 0.37% to 0.42% in recent years. In 2010, a national inventory of greenhouse gases (GHGs) was completed. In terms of global GHG emissions, the country ranks 40th out of 184 countries monitored by the World Bank's World Resources Institute (WRI). It is also ranked fifth out of the 32 Latin American and Caribbean countries. Over the last two decades, the country's emissions have risen by 15% (36 million tons of CO_2 equivalent) from 245 Mt CO_2 eq in 1990 to 281 Mt CO_2 eq in 2010. Between 1990 and 2012, agricultural emissions increased by 44%. Table 1 provides information on the national Agriculture, Forestry and Other Land Use (AFOLU) emissions covered by Colombia's NDC.

Table 1: Categorization of AFOLU emissions of Columbia.

Categories of emissions reduction	Mt CO_2 eq
Absolute AFOLU emissions (in Mt CO_2 e)	151.73
The relative share of global AFOLU (in percent)	2.01
The relative share of AFOLU in national GHG (in percent)	56.09
The relative share of agriculture in national GHG (in percent)	25.34

Source: FELD (Food, Environment, Land, and Development) Action Tracker, 2022

Colombia submitted a revised NDC in 2020, in which the overall goal is to achieve 169.44 Mt CO_2 eq in 2030 (equivalent to a 51% reduction in emissions compared to projected emissions in 2030 in the reference scenario), kicking off a reduction in emissions between 2027 and 2030 that will lead to carbon neutrality by the mid-century. Other goals include establishing carbon budgets for the years 2020–2030 no later than 2023 and reducing black carbon emissions by 40% from 2014 levels.

Recognizing Colombia's vulnerability to climate change and the importance of incorporating climate-change criteria in economic reactivation in the short, medium, and long term, the GHG mitigation goal for the period 2020–2030 is defined and presented. Colombia's updated goal is based on a long-term vision that was established by the aspiration towards carbon neutrality expressed by the country at the United Nations Climate Action Summit in September 2019, and that will be reflected in the Long-Term Strategy 2050, a medium-term vision as far as 2030 that was established through the Colombian Low Carbon Development Strategy and the Comprehensive Strategy for the Control of Deforestation and Forest Management, and a short-term vision established through the National Plan.

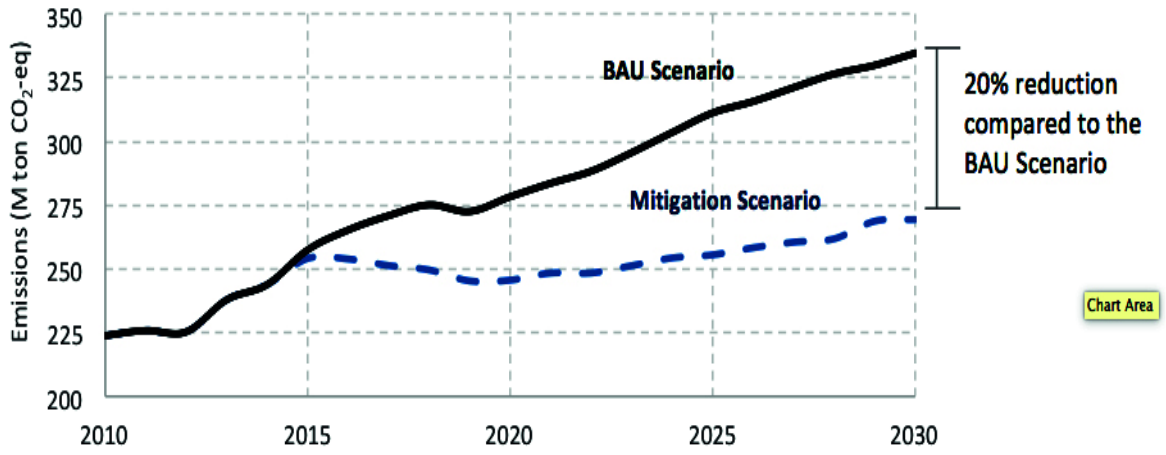


Figure 1: Emissions versus mitigation scenarios

Colombia's mitigation goal is based on the projection and analysis of its reference scenario (growth trend in emissions in the absence of GHG mitigation actions) as well as on the analysis and modeling of policy scenarios and reduction measures. Colombia's NDC includes an annex with specific details on mitigation actions and targets at the sectorial (national) and territorial (subnational) levels, including several targets covering most aspects of the food and land system, the policies and planning associated with them, and the institutions in charge of implementing them. The sections that follow provide a summary of quantifiable mitigation targets.

In the agricultural sector in Colombia there are six major mitigation priorities. The first is to practice sustainable cattle farming. This aims to reduce GHG emissions from livestock production while increasing carbon removals from livestock-specific agroecosystems. The second priority is to increase, restore and rehabilitate the area dedicated to cocoa cultivation under agroforestry systems to increase carbon stock. The third mitigation priority is to reduce GHG emissions from rice production through the widespread adoption of technology (AMTEC 2.0). The fourth priority is to implement farm-level strategies for reducing GHG emissions during the production, harvesting, and post-harvest stages of Colombian coffee. The fifth priority is to create a central strategy for planning, management, and institutional and financial support for low-emission development and contribution to the sustainable development of panela[v] production in the country. To date, the ecological conversion of 1,500 sugar mills with 800 hectares of restoration is planned as compensation for historical deforestation. Table 2 provides detailed mitigation priorities and quantifiable targets.

Table 2: Mitigation targets reflected in the NDC.

GHG emission-reduction quantifiable targets	**The GHG emissions-reduction target in 2030 (tCO_2eq)**
NAMA for sustainable cattle farming: Sustainable intensification of livestock production; Restoration of natural areas within livestock farms; Management of manure and use of methane gas; Logistical improvements in the marketing of raw milk.	11,151,000 t CO_2eq Total intervention areas: 3,628,959 hectares
Strategies to reduce GHG emissions in the life cycle of cocoa production: Renovation and rehabilitation of established hectares; Conversion of grasslands to cocoa crops; Management of Agroforestry Systems (SAF).	165,000 tCO2eq 80,000 ha under renovation and rehabilitation; and 150,000 ha in SAF with timber
Reduction of GHG emissions in rice production through the massive adoption of technology (AMTEC 2.0) in Colombia: Management of volumetric water consumption; Reduction in the use of production system fertilizers; Management of harvest residues.	84,000 tCO_2 eq in N2O reduction due to fertilizer consumption. 255,000 ha implemented in irrigated rice; and 207,046 ha implemented in dry rice
NAMA Coffee from Colombia: Implementation of agroforestry systems in the properties where coffee is grown; Optimization of practices in the coffee post-harvest process and change of fuel in mechanical coffee dryers; Increase in planting densities of crops in free exposure; Efficient use of fertilizers; Promotion of best fertilizer application practices.	The potential in AFOLU is 285,000 t CO2eq. For water treatment, an aggregate potential of 5,00 tCO_2 eq was modeled with the Panela NAMA, and for energy efficiency, an aggregate potential of 80,00 tCO_2 eq was modeled in aggregate with the Panela NAMA. Coffee planted area (ha): 936,477. Traditional production (ton): 625,482 Becolsub Production (Ecological Processing of Coffee and its by-products) (ton): 205,673 Ecomill Production (ton): 10,825

	Reduction of approximately 4,198 t of urea due to volatilization losses.
Integral Strategy of the Panela Subsector for the mitigation of climate change and the sustainable development of the productive chain (NAMA – PANELA): Component 1: Improvement of panela production practices and restoration of affected natural systems at the local and national level; Component 2: Comprehensive technological transformation of Panela production processes in Colombia; Component 3: capacity development of the panela sector for the adoption of the contemplated transformational changes; Component 4: monitoring, reporting and verification (MRV) and knowledge management.	the potential in AFOLU is 21,00 Mt CO2eq. Adjustment to the report is expected to add to the projected potential for energy and water treatment. 1,500 production units: Installation of thermal recirculation and replacement of diesel engines with electric ones; 800 ha restoration processes for compensation for historical deforestation
LULUF: Development and consolidation of the productive chain of forest plantations for commercial purposes: Technical and economic articulation for the production of wood from the forest plantations for commercial purposes with the action plan of the chain.	**10.37 Mt** CO_2 **eq** (Modeled with 300,000 ha 2015-2030) Plantation of 27,282 hectares (300,000 hectares 2015–2030): an increase in ambition is expected for the year 2030 from the annual increase in plantations to 34,165 ha (46,000 ha including reference scenario), which would be equivalent to 368,836 ha in commercial forest plantations for the 2030 mitigation scenario.

In reference to the increased ambitions, Colombia's updated NDC includes specific food-related mitigation measures by crop, such as coffee and panela, while food mitigation measures are broader in its previous NDC. The updated NDC has an increase in ecosystem-related measures, focused on mangroves and coasts, and considers food security (which is not included in the previous NDC). Both the previous and current NDC consider agroforestry and sustainable livestock (WWF, 2022). However, there are challenges ahead in terms of raising ambitions. A study by Rogelj et al., 2018 shows that methane emissions (mainly from enteric fermentation) need to decline by 10% by 2030 and by 35% by 2050 (from 2010 levels). Nitrous oxide emissions (mainly from fertilizers and manure) need to be reduced by 10% by 2030 and by 20% by 2050 (from 2010 levels).

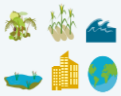
Country	NDC version	Food Systems in Mitigation	Food Systems in Adaptation	Numerical mitigation targets for food systems	Ecosystems mentioned	Role of IP/LC mentioned	Status of integration of food in NDC	Summary assessment findings
COLOMBIA 	Previous NDC	✓	✓	✗		✗		Colombia's updated NDC includes specific food-related mitigation measures by crop, such as coffee and panela, while food mitigation measures are more broad in its previous NDC. The updated NDC has an increase in ecosystem-related measures, focused on mangroves and coasts and considers food security (which are not included in the previous NDC). Both NDCs consider agroforestry and sustainable livestock.
	Updated NDC	✓	✓	✓		✓		

Figure 2: Comparison of NDCs in Colombia from a food perspective Source: WWF, 2020

1.4. Adaptation Targets or ambitions reflected in the NDC

The updated NDC of Colombia shows clear progress in terms of adaptation priorities, sectors, and territorial planning. It has also increased the number of multi-sectoral goals from 10 to 30. The NDC also ties adaptation goals into the SDGs and the Sendai Framework for Disaster Risk Reduction. The adaptation component is based on the country's adaptation progress within the National Adaptation Plan for Climate Change (PNACC in Spanish) that was developed in 2011 and has been implemented through various territorial and sectoral efforts.

The NDC mentions Adaptation Communication elements such as National Circumstances; Risks and Vulnerability; NDC Adaptation Priorities (Targets); and Priority Needs for Support (technology transfer and development, finance, capacity building). Furthermore, the country's NDC states that it has made progress in undertaking a risk and vulnerability analysis, not only at the national but also at departmental and municipal levels, with a focus on agroecological systems and productive sectors such as agriculture and cattle ranching. The eight priority economic sectors (transportation, energy, agriculture, livelihoods, health, commerce, tourism, and industry) have incorporated climate change into their planning instruments and will implement adaptation measures. The NDC also defines thirty adaptation targets and links them to the SDGs and the Sendai Framework for Disaster Risk Reduction. Furthermore, prioritized sectors corresponding to each Ministry are making progress in developing their sectorial adaptation plans. Table 3 provides detailed adaptation interventions, baseline, and quantifiable targets.

Table 3: Adaptation priorities reflected in the NDC.

Interventions	Baseline	Targets
Include climate change considerations in the planning instruments of the agricultural sector (PIGCCS) and implementation of adaptation actions.	Adaptation strategy of the agricultural sector in the face of climatic phenomena in 2014: the portfolio of adaptation and mitigation measures for the productive systems of potatoes, cocoa, corn, rice, beans and bananas prioritized due to their importance for the country's food and socioeconomic security, as	By 2024, at least one action of each of the PIGCCS measures will have been implemented. By 2028, 80% of the measures proposed in the PIGCCS will have been implemented for one or more of the actions.

	well as implementation progress in some selected measures.	
Ten agricultural subsectors (rice, corn, potato, beef cattle, dairy cattle, sugar cane, cocoa, bananas, coffee, and sugar cane) will have improved capacities to adapt to climate variability and/or climate change.	In 2014, 7 subsectors — rice, corn, banana, livestock, sugar cane, potato, and coffee — managed to obtain knowledge on topics such as agroclimatic information, applied research, and advances in the development of plant material with characteristics of tolerance to phenomena of climatic variability.	By 2024, the rice, banana, livestock, corn, cane, and potato subsectors will have strengthened their adaptation capacities. By 2027, the ten subsectors will have strengthened adaptation capacities in the proposed topics according to the available means.
3 natural regions of the country with the greatest agricultural potential (Andean, Caribbean, and Orinoquía) participating in the agroclimatic technical tables articulated with the national table, and 1 million producers receiving agroclimatic information to facilitate decision-making in agricultural activities.	Two regions (Andean and Caribbean) participated in the agroclimatic technical tables articulated with the national table. 9,176 producers received agroclimatic information according to direct reports from the participants of the agroclimatic technical tables.	By 2024, 3 natural regions of the country with the greatest agricultural potential will participate in the agroclimatic technical tables. By 2025, governance will be achieved by local actors for the sustainability of the tables. By 2030, 1 million producers will be receiving agroclimatic information to facilitate decision-making In agricultural activities.

1.5. Policy measures on mitigation and adaptation reflected in Colombia's NDC

The mitigation policy measures for the agricultural sector are detailed extensively throughout Colombia's NDC, including specific targets and measures for adaptation:

- Policy measures that support reducing GHG emissions from livestock production and increasing carbon removals from farming agri-ecosystems through regional guidelines to intensify productivity and maximize efficiency.
- Supportive policy measures for emission reductions in the life cycle of cacao production.
- Mitigation strategies for the production, harvesting, and post-harvesting of coffee, including the implementation of agroforestry systems in coffee farms (specific targets in hectares are mentioned).
- Inclusion of food security as a cross-cutting issue in the NDC.
- The development and transfer of technology, which includes improved methods for estimating and measuring water demand in the agricultural sector.
- Mass adoption of technology for rice production.
- Mainstreaming climate change in the formal instruments for sectoral and territorial planning, through the formulation of Comprehensive Plans for Climate Change.
- Management at the sectoral (PIGCCS) and territorial (PIGCCT) levels: plans to be developed for eight priority sectors, including agriculture; these plans will contain climate-change considerations in their planning processes and adaptation actions.

- 30 adaptation targets are included, 10 of which relate to AFOLU and 3 specifically to agriculture: to include climate-change considerations in agricultural planning instruments and implementation of adaptation activities; to improve the capacities of ten agricultural subsectors (rice, corn, potatoes, beef cattle, dairy cattle, sugar cane, cocoa, bananas, coffee, and sugar cane) to adapt to climate change.
- Interventions designed for the three natural regions with the greatest agricultural potential to receive agroclimatic information to support agricultural decision-making.
- Increasing the area for cocoa cultivation under agroforestry systems to 150,000 ha, as well as rehabilitating another 80,000 ha to improve their carbon stocks.
- Inclusion of various existing and new land-use plans for adaptation to climate change and disaster risk management.

Chapter Two: Scientific basis, data, and analytics behind NDC targets

2.1. The process adopted.

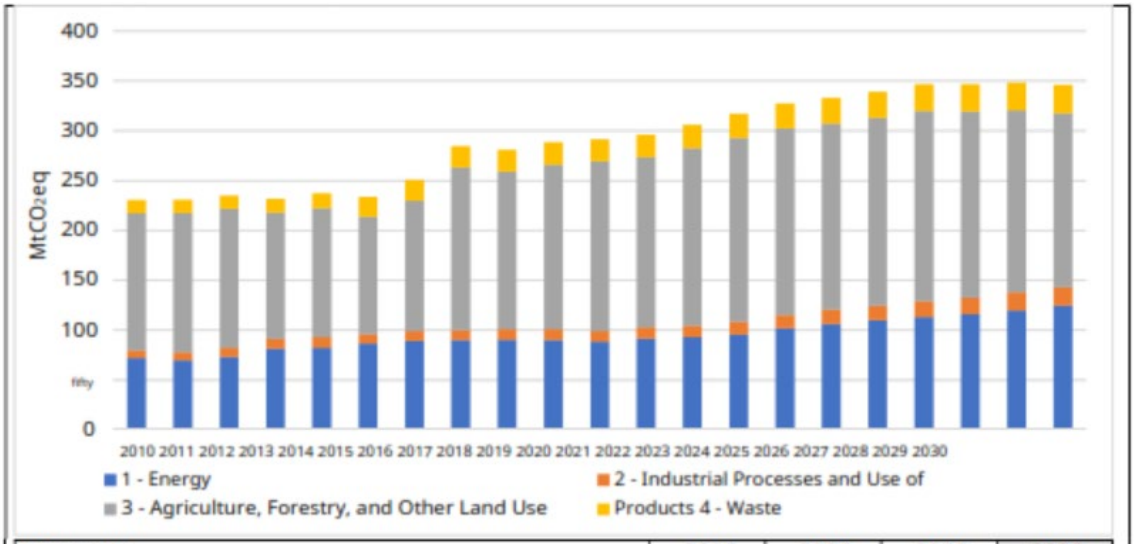
The NDC states that the design process included experts from public and private entities, academia, and civil society and that it adhered to the Paris Agreement's principle of progression and no regression. It is also regarded as the most up-to-date information available. The approach is described as both top-down (based on macroeconomic projections and official national data) and bottom-up (with decentralized leadership between sectors and territories of mitigation and adaptation measures, coordinated with and aggregated at the national level). The NDC specifically mentions public consultations and a survey aimed at specialized audiences as participation mechanisms. It also mentions that food system actors included domestic consultation processes that have probably led to covering the gaps in food systems in the NDCs. The public consultations sought feedback on the NDC and its measures and targets, while the survey gathered technical input to help strengthen the update. The results of such processes informed the NDC revision and adjustments of its targets and measures.

It is stated that the NDC update was a government-led process carried out by technical teams from ministries and other entities involved in capacity building and strengthening. The process was carried out within the framework of the National Climate Change System, with the Inter-sectorial Commission for Climate Change serving as the guiding body. Parallel to the development of the Long-Term Strategy, it was evident that Colombia has begun a gradual process for engaging the private sector in climate-change targets so that the two processes can inform each other.

2.2. Scientific basis and data used.

IDEAM prepared the National Greenhouse Gas Inventory for 2010 in conjunction with the First Biennial Update Report and the Third National Communication on Climate Change, following the IPCC 2006 guidelines. The BAU scenario includes efforts to increase energy efficiency in the industrial, residential, and commercial sectors, including emissions from reduced oil and coal production, and post-conflict deforestation trends. The BAU scenario projections were made independently for each of the productive sectors, based on macroeconomic assumptions, an analysis of current and prospective policies, and official IDEAM data on the historical path. The information on deforestation was projected considering the 2013–2017 Forest Reference Emissions Level for the Amazon region presented to the UNFCCC in December 2014. An aggregated analysis was then made to estimate the sectorial emissions projection at the national scale.

Figure 3 below shows the breakdown of emissions according to their IPCC classification for the reference scenario, projected to 2030.

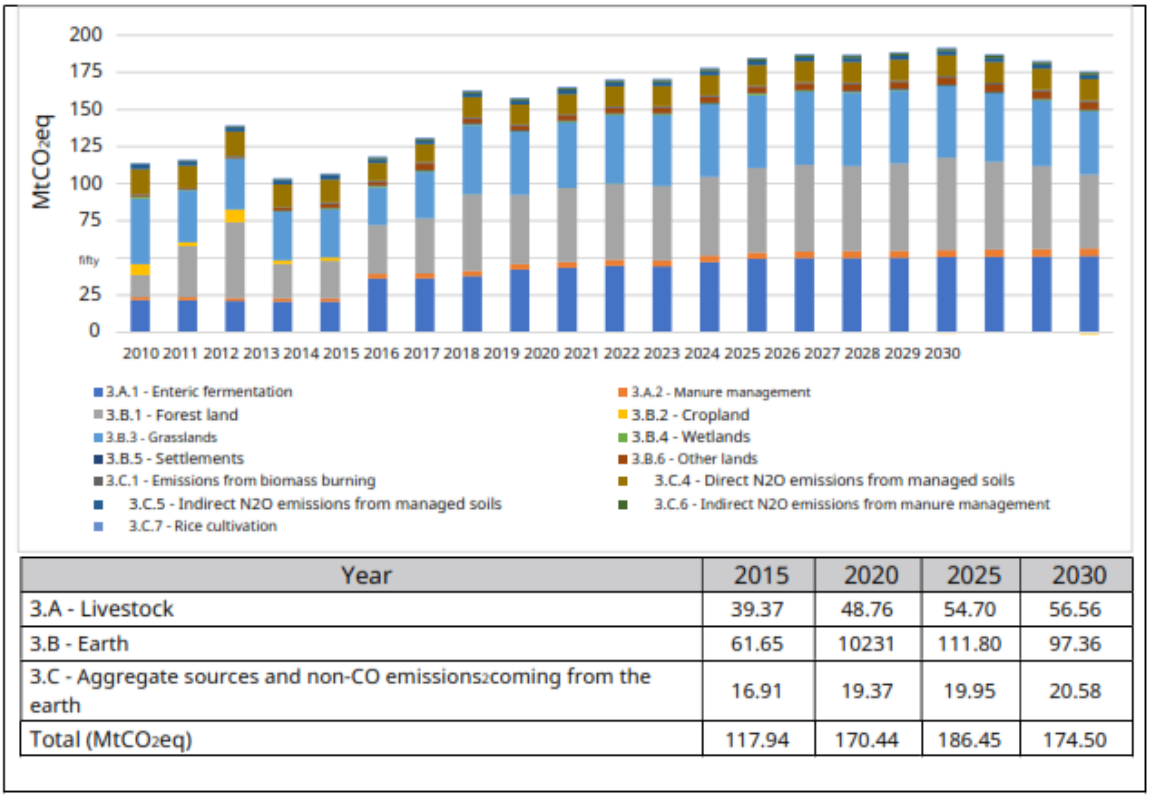


IPCC level 1	2015	2020	2025	2030
i{1} Energy	86.67	88.60	106.47	124.80
i{2} Industrial Processes and Product Use	9.42	10.66	14.54	18.41
i{3} AFOLU (Agriculture, Forestry and other land uses)	117.94	170.44	186.45	174.50
i{4} Residues	19.55	21.60	25.24	28.09
Total ($MtCO_2eq$)	233.58	291.30	332.70	345.80

Figure 3: Disaggregation of emissions according to their IPCC classification

The economy-wide target includes the AFOLU sector (agriculture, forestry, and other land use). In its updated NDC, Colombia provided a sectoral breakdown for its BAU projections, including disaggregating its net AFOLU emissions by IPCC category. According to the 2010 National Greenhouse Gas Inventory (INGEI 2010), the economy-wide target covers 100% of national emissions, includes the six gases recognized by the Kyoto protocol: CO_2, CH4, N2O, HFCs, PFCs, and SF6, covers all emission sectors recognized by the Intergovernmental Panel on Climate Change (IPCC), and covers the entire national territory. The projected BAU scenario serves as the reference level.

For Colombia, emissions from the AFOLU sector represent an important proportion of the national inventory, and its breakdown is shown in Figure 4 below.



Year	2015	2020	2025	2030
3.A - Livestock	39.37	48.76	54.70	56.56
3.B - Earth	61.65	10231	111.80	97.36
3.C - Aggregate sources and non-CO emissions2coming from the earth	16.91	19.37	19.95	20.58
Total (MtCO2eq)	117.94	170.44	186.45	174.50

Figure 4: Disaggregation of emissions from the AFOLU sector in Colombia

Estimates from the National Greenhouse Gas Inventory (INGEI) of the 2nd Biennial Update Report (BUR) are used as historical data for the period 2010–2014 as the base period for the projection from 2015 to 2030, according to the technical characteristics of the update of the reference and mitigation scenarios. The scenarios respond to two types of disaggregation: IPCC categories for use in international communications, and portfolios (ministries) for monitoring sectoral commitments using sectoral growth rates. Other features include the use of global warming potential values from the 5th IPCC Report, page 731 (GWP- AR5). (IPCC, WG1, 2013), country-specific emission factors from national research (Methodological Tier 2) that are used whenever possible, and IPCC database factors (Methodological Tier 1) that are used in all other cases.

It was clear that the scenarios were built using the most recent official data for each portfolio sector, adjusted to the IPCC categories, as sources of information. For the deforestation category, the UNFCCC-submitted National Reference Level of Forest Emissions (NREF) projections (IDEAM, 2019) were used, with the remaining carbon deposits after deforestation incorporated into the calculations. Furthermore, the reference scenario included the estimated economic impact of COVID-19, with a -5.5% of GDP economic decline rate in 2020. Similarly, emission reductions associated with mitigation measures implemented before January 1, 2015, are included in the reference scenario.

The review of the NDC reveals that the information presented as part of the updated NDC is based on previous UNFCCC communications and reports. The national data of the baseline scenario were consolidated by calculating and aggregating sectoral emissions based on data available at the national level, covering all sectors of the economy and 100% of emissions and IPCC categories. According to data from the INGEI (IDEAM, PNUD, MADS, DNP, CANCILLERA, 2016), improvements were made in 2014, including updating the values of global warming potential from GWP-AR2 to GWP-AR5, as well as methodological improvements for some subcategories of the AFOLU module.

Colombia's sectoral mitigation potential was calculated using assessment models developed through the Low Emissions Analysis Platform, an integrated, scenario-based modeling tool. A technical research team from the Flemish Institute for Technological Research, the University of the Andes, the International Center for Tropical Agriculture, Wageningen University, the Stockholm Environment Institute, and Energy Super Modelers and International Analysts created the updated mitigation scenario. While agricultural production and refrigeration were included in the reference and mitigation scenarios, other sectors, such as food loss and waste, as well as food transport, were not included due to a lack of data.

The mitigation actions proposed are also based on some sound scientific basis. The NAMA for livestock was informed by scientific evidence of low emission livestock development in Colombia. Studies show that the use of improved feed in a combination of fodder and grasses can reduce enteric methane emissions from cattle in Colombia (Ruden et al., 2018, Arango et al., 2020). Colombia's livestock federation also uses these results to strengthen its sustainable livestock strategy and improve pasture lands.

The country has significantly improved the information for characterizing and quantifying emissions and removals in this sector, and it will continue to make efforts to obtain better activity data, emission factors, and projections. These efforts may result in the fine-tuning of this information, for example, in agroforestry and silvopastoral systems, both of which offer significant mitigation potential in the country. Carbon emissions and removals from forest plantations and permanent crops are included in the BAU and emissions reduction scenarios; removals from natural forests that remain natural forests are excluded.

In terms of adaptation, the NDC states that Colombia has improved its understanding of the country's vulnerability and risks as a result of climate change through initiatives such as the analysis of vulnerability and risks due to climate change in the floodplains of the Magdalena-Cauca macro-basin; this allowed the country to create high-quality hazard, vulnerability, and risk maps. The NDC includes three maps depicting climate vulnerability and risks as a result of climate change. The "Planes de Ordenamiento Territorial - POT" (Territorial Planning Plans) and their importance in climate adaptation are frequently mentioned in the NDC.

2.3. Analytics behind NDC targets

a) Adequacy of mitigation targets

By 2030, the country intends to reduce GHG emissions by 51%. Colombia's NDC has significantly increased its mitigation target and presented a type of contribution that can be classified as "deviation from business as usual (BAU)" for its NDC. A total of thirty-three measures prioritized by the ministries will allow the country to reduce emissions by 22.8% by 2030. The reduction potential could be greater with ten additional measures that have yet to be quantified. The overall goal is to achieve 153.71 Mt CO_2 eq by 2030 (equivalent to a 51% reduction in emissions compared to projected emissions in 2030 in the reference scenario), kicking off a reduction in emissions between 2027 and 2030 that will lead to carbon neutrality by mid-century. Other goals include setting carbon budgets for the period 2020–2030 no later than 2023 and reducing black carbon emissions by 40% compared to 2014 levels. However, with international cooperation, this goal can be increased by up to 30%, achieving additional reductions of 33.4 Mt CO_2 e.

In Colombia, agriculture contributed 65.2 MtCO2e of GHG emissions in 2019, accounting for 34.82% of total emissions excluding land-use change and forestry (187 Mt CO_2 e), and 24.12% including LUCF (271 Mt CO_2 e). The commitment to reduce GHG emissions in agriculture and LULUCF for 2030 is 22.145 mt CO_2 eq, which is only 14% of the projected emissions of 174.5 mt CO_2 eq. In the livestock sector, the government pledges to reduce GHG emissions by 11.15

mt CO_2 eq by 2030, or 20% of the total of 56.56 mt CO_2 eq. On the other hand, agriculture does not provide additional information about subsectors or activities in its mitigation efforts. Colombia has proposed agricultural mitigation measures, either as part of a target or as stand-alone action-based contributions, while explicitly mentioning livestock.

Table 4: Analysis of the NDC in terms of adequacy of the target on Food systems

Categories	Emissions scenario 2030 (Mt CO_2 eq)	The target for emission reduction 2030 (Mt CO_2 eq)	Difference (Mt CO_2 eq)	% Of gaps
Overall	345.8	169.44	176.36	49%
Agriculture and LULUCF	174.5	22.145	152.355	86%
Crops	NA	0.08	NA	NA
Livestock	56.56	11.15	45.41	80%
LULUC (forest, cacao, coffee, Panela)	NA	10.915	NA	NA

Colombia has set GHG mitigation targets in the rice sub-sector, which are defined as commitments to reduce emissions by a specific amount and timeline. Although the rice mitigation potential is 0.77 Mt CO_2 eq from 2021–2030, the commitment is only 0.08 Mt CO_2 e due to lower N2O emissions, and to lower fertilizer consumption (in rice production), which is largely underestimated) (Roe et al. 2021).

Overall, the NDC scores medium to high in many categories, indicating that it provides specific indications of actions to reduce emissions in the AFOLU sector, as well as information on policies, spatial information, and technology development and that it requires progress toward these actions and implementation of the NDC (refer to Table 5). At the national and territorial (subnational) levels, detailed strategies, actions, and specific targets are provided for agriculture and LULUCF. This includes providing information on baselines and targets, relevant strategies and/or plans for carrying out the envisioned actions, and the institutions in charge of carrying them out. Climate-change plans at the sectoral (PIGCCS) and territorial (PIGCCT) levels, for example, are mentioned throughout the document, frequently concerning actions in the AFOLU sector.

Table 5: Qualitative assessment of the food system inclusion in NDC

Systems	What is included	Adequacy of the NDC (High, Medium Low)
Production activities	• Climate-smart agriculture: Climate-smart coffee-growing pilot program in the Serranía del Perijá and the Sierra Nevada de Santa Marta • Strategies to reduce GHG emissions in the life cycle of cocoa production: increase the area dedicated to cocoa cultivation under agroforestry systems, as well as its renewal and rehabilitation, to increase the carbon stock; implement agroforestry systems on the farms where coffee is grown • Quantification of ecosystem services for the energy mining sector	NDC lists essential actions, including specific commitments, strategies, or funding related to the critical transition. **Overall Rating: Medium**

Food processing, transportation	No specific information on food processing or transportation	NDC does not mention any specific information on policy interventions for the critical transition. **Overall Rating: Low**
LULUC	A dedicated section on water, ecosystems, biodiversity, local biodiversity of the country, and measures for the conservation of biodiversity through the protection of ecosystems and their ecosystem services. Nature-Based Solutions (NBS) measures are prioritized in climate-change adaptation inventories. - Five livestock production systems improved in 11,666 hectares of pasture with conversion to AgroSilvoPastoriles System (SASP). - Environmental conversion of traditional livestock systems to sustainable livestock. - Implementation of at least six pilot projects for conservation, protection, or management in the watersheds and/or supply sources of municipalities most susceptible to water shortages, and carry out their monitoring to evaluate their effectiveness and replicability.	NDC lists essential actions, including specific commitments, strategies, or funding related to the critical transition. **Overall Rating: High**
Marketing and consumption	Colombia published in 2019 its National Circular Economy Strategy, to address the negative impact on health and ecosystems of the linear management of extraction, transformation, consumption, and disposal of resources, as well as its contribution to climate change. There is a dedicated circular economy section but no explicit mention of the food and land sector.	NDC lists essential actions, including specific commitments, strategies, or funding related to the critical transition. **Overall Rating: Medium**
Reducing food loss and waste management	Recovery of waste in the agricultural subsector, use of 84,019 tons of organic waste generated in poultry processes: Implementation of recovery techniques for the decomposition of organic material, such as composting; expanding the coverage of good practices and proper management techniques; Measures framed in the comprehensive management of municipal solid waste that is related to complementary activities to final disposal, within the framework of the PIGCCS (includes organic waste).	NDC lists essential actions, including specific commitments, strategies, or funding related to the critical transition. **Overall Rating: Medium**

Note: High: Highly sufficient and highly adequate interventions proposed; medium: adequate and sufficient; Low: inadequate and insufficient

The NDC includes some measures to encourage diverse food production that is tailored to different microclimates and sociocultural contexts. These include the Ministry of Agriculture and Rural Development's national food production targets. Furthermore, the NDC includes territorial food production measures proposed by respective departmental and city governments and tailored to local realities. Sectorial Mitigation Action Plans (SMAPs) for food production are included in the NDC, to maximize nomic activities at the national and sectoral levels. In terms of adaptation, the goal is to reach 1 million producers with agroclimatic information to help them make agricultural decisions.

There are no official statistics or comprehensive studies on food waste associated with household consumption in Colombia. The Organization for Economic Cooperation and Development (OECD) (2019) expects an increase in meat consumption from 2017 to 2027 — beef and veal: by 7%, from 11.47 kg/cap to 12.34 kg/cap; — poultry: by 10.6%, from 28.61 kg/cap to 32.01 kg/cap; — pork: from 7.09 kg/cap to 8.02 kg/cap. Assuming strong commitment from the government and relevant stakeholders to developing comprehensive and ambitious policies on the issue, the final percentage of household meat consumption can be expected to decrease by 5% by the year 2050 (Sarmiento et al., 2019).

While the NDC does not include targets or measures for reducing food waste and loss, Colombia has enacted a comprehensive new law to address both issues. Due to a lack of empirical data, food loss and waste were not included in the model reference scenario. As a result, the NDC contains no targets or measures for reducing food loss and waste. However, in 2019, the Colombian government approved a law aimed at reducing food loss and waste at every stage of the supply chain. Nevertheless, despite pledges made at the UN climate meeting in Glasgow last year, Colombia's NDC did not fully account for emissions from food imports, particularly those linked to deforestation and the destruction of nature and ecosystems.

The NDC contains enough measures to encourage agroecology and regenerative approaches. More specifically, the NDC includes measures to reduce GHG emissions from cocoa, coffee, and unrefined sugar lifecycles. Furthermore, it encourages the adoption of rice production technologies as well as the implementation of fertilizer abatement technologies. Among other things, the NDC includes a measure to reduce GHG emissions from livestock through sustainable management, silvopastoralism, restoration of degraded grazing areas, and energy generation from waste.

According to the review, Colombia has policies in place to promote agroecological and regenerative locally-led agriculture practices. The NDC includes LUCU measures such as protecting, conserving, and recovering natural resources and ecosystems, as well as strengthening its protected areas. The NDC, in particular, includes a measure to restore, rehabilitate, or recover 18,000 hectares of degraded land in protected areas. The NDC also includes adaptation measures to protect paramos, watersheds, mangroves, and seagrass fields. Finally, the NDC includes mitigation measures to promote sustainable livestock, such as by encouraging the conservation and restoration of natural ecosystems that have been used as cattle pastures.

b) Adequacy of adaptation targets

Overall, the NDC rates medium to high across many categories, meaning that it provides specific indications of actions to address risk and vulnerability in the AFOLU sector, as well as information on policies, spatial information, and technology development, and needs to make progress against these actions and implement the NDC. Detailed strategies, actions, and specific targets are provided for both agriculture and LULUCF at the national and territorial (subnational) levels. This includes providing information on baselines and targets, relevant strategies and/or plans to implement the envisioned actions, and the relevant institutions in

charge of the implementation. For example, climate-change plans at the sectorial (PIGCCS) and territorial (PIGCCT) levels are mentioned throughout the document, often related to actions in the AFOLU sector.

Table 6: Analysis of the adequacy of Adaptation targets

Category	Overall Rating
A. Future climate risk and vulnerability in the agriculture sector (2030)	**Overall Rating: Very high (5)** Extreme weather events such as droughts negatively impact agropastoralists' livelihoods due to the loss of productive assets, severely affecting their food security. Projections suggest that by 2050, climate change in Colombia will impact 14% of the GDP corresponding to agriculture and that without adaptation, 80% of the country's crops could be impacted in more than 60% of their current areas of cultivation, especially high-value perennial and export crops. Further, highly specialized niche crops such as coffee, cocoa, and other fruits will see critical changes in the prevalence of pests and diseases.
B. Adaptation target ambitions for 2030	**Overall Effort rating: Medium (3)** Despite having lower resources and capacity allocated in the NDC for the development of adaptation than for mitigation, the adaptation component shows a clear increase in ambition from the previous NDC and puts forward a roadmap for adaptation with extensive sectoral engagement. It contains three adaptation goals in the agriculture sector.
Differences in the degree of risk and level of adaptation efforts = Gap	**Overall Gap rating: Low (2)**

Note: Rating: Very high (5), high (4), moderate (3), low (2), very low (1)

According to the analysis, the actionable gap is low, indicating that Colombia has included adequate adaptation actions that address the sector's key risks and vulnerabilities. However, the majority of the adaptation actions are policy targets that will be difficult to measure and account for, implying that the actions will be difficult to implement. It is also clear that the NDC does not consider loss and damage data, as well as potential future risks of extreme climate events and climate-induced disasters in agriculture.

c) Feasibility of achieving the target

Overall, achievement of the targets set by Colombia seems feasible. Colombia unconditionally commits to a reduction by 2030 of 51% of the emissions projected in the reference scenario. Colombia has moved from conditional to unconditional targets. Furthermore, the actions are aligned with national economic and development priorities and objectives as it has presented an economy-wide target. The interventions proposed can be implemented and enforced, given the current and anticipated political, legal, and regulatory context of the nation. The government is currently constructing the NDC Implementation Plan, which comprises a series of participation processes with key actors (private sector, experts, communities). According to Climate Action Tracker, the update is 6–22% stronger than the first NDC's unconditional target of 20% below BAU in 2030.

The review also shows that while the AFOLU sector will be the primary driver behind reducing GHG emissions in both the NDC and net-zero scenarios, a reduction is needed across all subsectors in the region to achieve carbon neutrality after 2030. Action on land use alone is insufficient without greater ambition in the transportation and other sectors. There are obstacles to reducing AFOLU emissions, and the resulting uncertainty calls for a more diversified strategy. For example, deforestation in Colombia has increased despite its NDC goal to reduce deforestation by around 35 percent between 2020 and 2035 (UNDP 2022).

In addition, there is limited fiscal or financial support available to implement these strategies. Moreover, the country currently lacks adequate state capacity in areas such as enforcement and monitoring, which makes the achievement of the target difficult. But there is positive development in some areas. The Colombian Government is seeking international partners and financial support to implement the Livestock NAMA, with plans to develop a public–private financing alliance, including the National Federation of Cattle Ranchers, the Global Environment Fund, and bilateral and multilateral financing institutions. In all cases of investment, the integration of diverse financial sources not only supports the leverage of finance but also of expertise and capabilities for diversifying, managing, and rebalancing risk-return profiles (Khatri-Chhetri et al. 2021).

Chapter Three: Missing data gaps

The country is undergoing a process of technical evaluation with various sectors to define the level of ambition in mitigation and adaptation under the non-regression principle and the use of the best available information. The strategy for the "just transition of the workforce toward a resilient and low-carbon economy" is referred to in the NDC. The strategy will be developed by 2023, with the participation of the country's economic sectors and their workforce and will be led by the Ministry of Labor. It will aim to improve the population's quality of life and socioeconomic inclusion, and will include monitoring indicators to that end.

The review of the NDC reveals that the data and information presented as part of the updated NDC is based on previous UNFCCC communications and reports. According to data from the INGEI (IDEAM, PNUD, MADS, DNP, CANCILLERA, 2016), improvements were made in 2014, including updating the values of global warming potential from GWP-AR2 to GWP-AR5, as well as methodological improvements for some subcategories of the AFOLU module. However, the scientific analyses and accounting methodologies did not address all food system components in an integrated manner. The NDC assessed has not proposed an accounting methodology that considers emission reductions and removals from food systems in a systematic manner. This is largely because most GHG accounting in NDCs is calculated per economy sector rather than per system.

As mentioned earlier, the NDC lacks specific data on food system sub-sectors. Food loss and waste data and analysis were excluded from the modeling scenarios due to a lack of available data. Food systems are not holistically accounted for because the necessary knowledge and data on issues such as food loss and waste, as well as consumption patterns, are unavailable. As a result, the Colombian NDC makes no recommendations to reduce food waste and loss.

Land conversion alone accounts for approximately 1.7 Gt of CO_2 eq emissions in Colombia each year. Despite this, Colombia continues to use default emission factors to estimate emissions from forest and non-forest land transitions to other types of land use due to a lack of country-specific data. As a result, AFOLU sector calculations, and thus a major component of national inventories and projections, implicitly exhibit a high degree of uncertainty, which can be attributed largely to insufficient estimates of transition rates between different post-deforestation uses, associated emissions/removals, legacy fluxes, and potential carbon storage in non-forest land (e.g., grassland, cropland, and secondary vegetation).

One of the most critical aspects for improving the quality of information on emissions and removals in agriculture and forestry sectors is the lack of information, in the case of AFOLU, related to carbon stocks and flows in different ecosystems and, consequently, emission factors to evaluate the impact of the transformation of natural ecosystems into other land use categories. Given that the AFOLU sector accounts for half of Colombia's net emissions, addressing data gaps in these areas would quickly result in improved inventories and emission scenarios.

Therefore, there is an urgent need to develop spatially explicit data sets to assess land cover changes for all IPCC 2006 land classes, as well as more accurate and complete data on forest use, forest degradation, and agricultural activities, which are key sources of emissions and removals.

There are, however, some opportunities for data enhancement and management. Colombia has developed an accounting system for GHG emission reductions and removals as part of its NDC, which takes agriculture and land use into account. The accounting system is made up of processes, technologies, protocols, and rules that govern how emissions, emission reductions, and emission removals are recorded. While some food system elements, such as agriculture and land use, are included, it is unclear whether and how other food system elements are accounted for. Colombia's NDC has also specifically mentioned its data and information management strategy (Table 7).

Table 7: Analysis of the data and information reflected in the NDC.

Data and information management	focus of NDC
Availability of information to estimate targeted emissions level	The NDC gives sufficient information to estimate the targeted GHG emission level. The NDC includes the targeted absolute GHG emissions level.
Followed guidance given in Decision 4/CMA.1 on facilitating clarity, transparency, and understanding in presenting information in NCDs	Colombia followed the Decision 4/CMA.1 guidance on transparency to a large extent, but the NDC does not present the information in the common tabular format.
Accounting modalities	The NDC describes most of the accounting modalities clearly. The NDC uses the GWP values from the IPCC's AR5. Country-specific emission factors from national research were used where possible and IPCC emission factors were used in other cases. The NDC describes how LULUCF emissions were considered. Colombia will use Article 6 following the relevant decisions and with the environmental integrity approach indicated by the San José Principles
Digital revolution	NDC lists essential actions, including specific commitments, strategies, or funding, related to the critical transition. It mentions that by 2030 the country will have an Integrated Information System on Vulnerability, Risk and Adaptation to Climate Change (SIIVRA), which will allow monitoring and evaluating adaptation to climate change in Colombia articulated with the National Climate Change Information System (SNICC)

Colombia has established, within the framework of SISCLIMA, a homologation of GHG emissions between the IPCC categories and the portfolio sectors, which corresponds to the competencies of the portfolio sectors in the framework, to effectively assign responsibilities to the actors in charge of implementation. Furthermore, accounting rules for the monitoring and recognition of GHG emission reductions and removals within the framework of sectoral mitigation commitments have been agreed upon[2].

According to Colombia's NDC, the government intends to report monitoring indicators for both GHG emissions and GHG emission reductions in Biennial Transparency Reports for NDC compliance. The National Inventory of Greenhouse Gas Effects will be used as the primary

[2] https://www.minambiente.gov.co/wp-content/uploads/2021/10/INFORME_GESTION_MINAMBIENTE_2020.pdf

source for emissions, and the National Emissions Reduction Registry (RENARE) will be used as the primary source for emission reductions.

Advancements in measurement and assessment can help reduce costs and complexity while improving quality, efficiency, and automation through technology. Most MRV systems currently being used to measure and assess greenhouse gas (GHG) emission reductions are costly, complex, and fragmented. A coherent approach is taken for implementing and monitoring the NDC. Several elements are considered necessary for implementation and monitoring of the NDC. To begin, the implementation process will entail consolidating information systems and databases, as well as keeping track of the research, technological development, and innovation required for implementing measures. Second, the process will include capacity-building, education, and awareness-raising. Third, key features of implementation include financing and economic instruments, as well as planning. The National Climate Information System is in charge of monitoring, reporting, and verifying mitigation measures, as well as monitoring and evaluating adaptation measures, including those addressing food system elements.

There are opportunities for filling the data gap in the future. Colombia hopes to optimize the information and data collection process and standardize the preparation of reference and mitigation scenarios in the coming years. The country considers changes in factors that may significantly modify the projections and estimates that serve as the foundation for the scenarios for each update but does not use a dynamic baseline.

Chapter Four: Additional mitigation options and their abatement potential for the possible update of NDC

4.1. General recommendations

- **Further increasing ambitions in the 1.5-degree world:** To be 1.5°C compatible, Colombia's GHG emissions should be reduced by 89% below 2015 levels by around 2050, or reach levels not higher than 17 $MtCO_2$ eq per yearby 2050. On the road to net zero, the country will need to balance its remaining emissions through the development of land-based sinks. This means that stringent policies will be needed to reduce LULUCF emissions, currently a source of emissions that accounted for close to a third of total GHG emissions in 2014, in order to become net negative in the future. CO_2 emissions would need to be at zero by 2050 and in some scenarios, by 2040. There is potential within the current NDC to raise ambitions. For example, for the ten additional measures, included in the NDCs, that are not yet quantified, the reduction potential could be greater.
- **A detailed sectoral NDC implementation plan would help to translate the NDC into action:** This process would allow Colombia to further increase its ambitions in the different sectors and in particular the food system. In doing this, there is a need to ensure that in addition to national data, studies that shed light on the sub-national and local context of food systems across the country inform the NDC.
- **A focus on strengthening Research and Development:** As discussed in the earlier chapter, there are key data gaps in the agriculture and food systems sector. Although information is available on livestock and a few agriculture crops in terms of GHG scenarios and emission reduction potential, information on mitigation potentials in food processing, food storage, food marketing, food consumption, food transportation, and food loss is not evident. Therefore, the government needs to invest in generating data and information on the analysis of GHG trends and scenarios and mitigation potentials in the sub-sectors of food systems, including the existing cropping systems, and the use of technology and practices.
- **A focused approach to low carbon in the agriculture sector:** This includes a) Supply side: Emissions from agricultural soils, land-use change, land management, and crop and livestock practices can be reduced, and terrestrial carbon stocks can be increased by increased production efficiency and carbon sequestration in soils and biomass, while emissions from energy use at all stages of the food system can be reduced through improvements in energy efficiency and fossil fuel substitution with carbon-free sources, including biomass; b) Demand side: GHG emissions could be mitigated by changes in diet, reduction in food loss and waste, and changes in wood consumption for cooking (Mbow, C et al. 2019).

4.2. Recommendations for adopting additional mitigation options.

- **Increase ambitions to reduce emissions from rice cultivation:** From 2021 to 2030, rice has a mitigation potential of 0.77 Mt CO_2 eq. The GHG emission reduction interventions need to be promoted by encouraging farmers to use low-methane rice and flood-stress-tolerant rice varieties; encouraging early-season drainage with mid-season drainage systems; and encouraging improved management practices, such as alternative wetting and drying practices.
- **Increase ambitions in the livestock sector**. Colombia can raise its livestock ambitions to the highest extent possible. Considering mitigation, the livestock sector produced 26% of Colombia's total GHG emissions (258.8 Mt CO_2 e/yr) in 2012 (IDEAM, 2017). This was 42% of the emissions of the AFOLU sector (158.6 Mt CO_2 e/yr), with cattle producing 95% of the livestock sector's emissions. Cattle, therefore, offer the greatest potential for mitigation in the agricultural sector, estimated at 83% of

the proposed national goal of emission reduction of 13.46 Mt CO_2 e/yr by 2030 (Tapasco, J. et al. 2019).

- **Promote climate-smart agriculture technologies.** The most promising climate-smart agriculture (CSA) technology clusters for the country include intercropping, green manures/cover crops, organic inputs, mulching, improved pastures, stress-tolerant crops, and adequate management of grazing, fertilizer, and water use. Local strategies are also key to tailoring CSA innovations to farmers' needs, including preserving or improving genetic diversity to strengthen resilience, and applying alternate wetting and drying (AWD) for water-use efficiency and emission reductions (Swinnen, et al. 2022). For example, initial estimates, using the International Rice Research Institute's investment model, suggest that investing US$ 1.4 billion to implement AWD and related techniques could reduce emissions from rice production by 6.8 MtCO_2e relative to BAU by 2030)[vi].
- **Include interventions that promote sustainable intensification of the agricultural sector with the use of agricultural technologies:** GHG emission reductions from the adoption of Low-Emission Climate Resilient Agriculture (LECRA) technologies, which are promising for Colombian agricultural production, will help mitigate the need for expanding the agricultural frontier. It will also generate co-benefits such as increased physical productivity per unit area, increased nitrogen retention in the soil, and increased water retention capacity in the soil.
- **Include interventions to reduce land-use change and conversion of natural habitats**: One opportunity is to transition towards a sustainable oil palm expansion in areas with low carbon stock or areas suitable/available for the crop (e.g., cropland, pastureland). This has the potential to achieve a 55% reduction in GHG emissions in the agriculture sector (Ramirez-Contreras et al. 2020). In addition, a pilot project funded by the World Bank in Colombia's Vichada municipality found that land management techniques paired with the implementation of a tropical grass species increased carbon storage in the soil by more than 15%, while also avoiding the need for cyclical burning of the savanna[7] Likewise, an improved variety of grass combined with a rotational grazing system can boost levels of soil carbon on tropical savannas by 15 per cent compared to degraded pasture, a new study performed by the Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT), the University of Stuttgart, and the World Bank has found[vii]. In addition, the adoption of agroforestry systems plays a leading role, as crop rotation and improved pastures can represent a GHG mitigation opportunity for sustainable agricultural production at the farm level in Colombia (Silva-Parra, A. et al., 2021).
- **Increase ambitions for reducing emissions from livestock (enteric fermentation and manure):** Improved feed with fodder production, grazing land management, dairy plant retrofit, and manure management show a large GHG mitigation potential from the livestock sector, including economic and social benefits. (Zomer et al., (2019) reported an average biomass carbon stock of 53 Mg ha−1 in Colombian arable land in 2000, demonstrating that trees in productive systems can significantly increase carbon stocks in Colombia. In addition, the sustainable management of silvopastoral systems is a good option that could provide up to 77% of the national goal of the NDC for the agricultural sector, but intervention would be necessary on 3.82 Mha (Tapasco, J. et al. 2019). Furthermore, the implementation of silvopastoral systems in Colombia could reduce GHG emissions by 2.36 Mt CO_2 eq ha−1 yr−1 compared to the current practices, while increasing agricultural productivity and income (Landholm et al. 2019). Other research also suggests that promoting balanced feed rations could provide important opportunities to increase milk production and reduce emission intensity (Wilkes et al., 2020b).
- **Integrate the actions on handling and storage of food**: The interventions should include promoting infrastructure and technology investment to prevent post-harvest losses; aiding agricultural research in the development of technologies to reduce post-

harvest food waste; constructing and supplying low-cost storage silos for small-scale farmers to store their harvest; increasing infrastructure investment; promoting urban-rural connections and connecting farmers to markets; repurposing unused food as animal feed; and reusing organic or agricultural waste to generate energy, e.g., biogas.

- **Include targets to reduce food loss and waste**: The five food products with the highest sum on Food Loss and Waste (FLW)- andassociated GHG emissions and nutrient losses are bovine meat, milk, rice, and poultry. From the bovine meat chains, 0.13 million tons of FLW represents 4.7 Mt CO_2-eq emissions. From rice, 0.77 million tons of FLW are generated, producing 2 million tons of CO_2-eq. GHGEs (Axmann, H et al. 2022). Therefore, there is a need for targets to reduce food loss and waste. Interventions include measuring national food loss and waste baselines to understand the scope of the problem and opportunities for cost savings and GHG reductions, as well as identifying hotspots of loss and waste along the value chain; putting in place educational programs to prevent and reduce food waste; promoting the use of food waste as animal feed and organic fertilizer; and using composting and energy recovery to promote the conversion of food waste into biogas.
- **Include targets and interventions to reduce consumption of emission-intensive food:** This includes stricter guidance for government procurement; mandating food labels and sustainable labeling frameworks to increase consumer awareness and transparency; advancing research into alternative proteins (for example, algae); Taxing animal proteins to discourage consumption; providing long-term dietary training to all medical professionals to educate patients; food education, including making school gardens; and promoting public procurement of food for schools to promote more sustainable and healthy diets, with a focus on plant-rich diets.
- **Place more emphasis on improving information and access to technology**: Recommendations include ensuring that non-discriminatory trading rules for agriculture and food are aligned with climate-smart policies while investing in low-emission solutions for safe, efficient storage and transportation along value chains.

- **Provide a supportive policy environment to increase the overall implementation of NDC targets in the agriculture systems**: Innovative financing mechanisms and instruments that integrate climate finance, agriculture development budgets, and private sector investment can improve and increase farmers' and other value chain actors' access to finance while delivering programs. The implementation of mitigation options in agriculture can be achieved through unlocking additional sources of public and private capital, strengthening the links between financial institutions, farmers, and agribusiness, and coordinating actions across multiple stakeholders.

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[iii] https://news.mongabay.com/2022/12/to-cut-emissions-from-cattle-ranching-beef-up-the-soil-study-says/

[iv] https://alliancebioversityciat.org/stories/planting-and-management-improved-grass-tropical-savannas-can-increase-soil-carbon-15-cent

[v] Panela, or unrefined non centrifugal brown sugar, is a natural sweetener obtained from the evaporation and concentration of sugarcane juice (Saccharum officinarum), essential for food security, agricultural economics and rural development in Latin America.

[vi] https://documents1.worldbank.org/curated/en/099355507062229876/pdf/P17724103036ee07909701028a237b6d18b.pdf

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