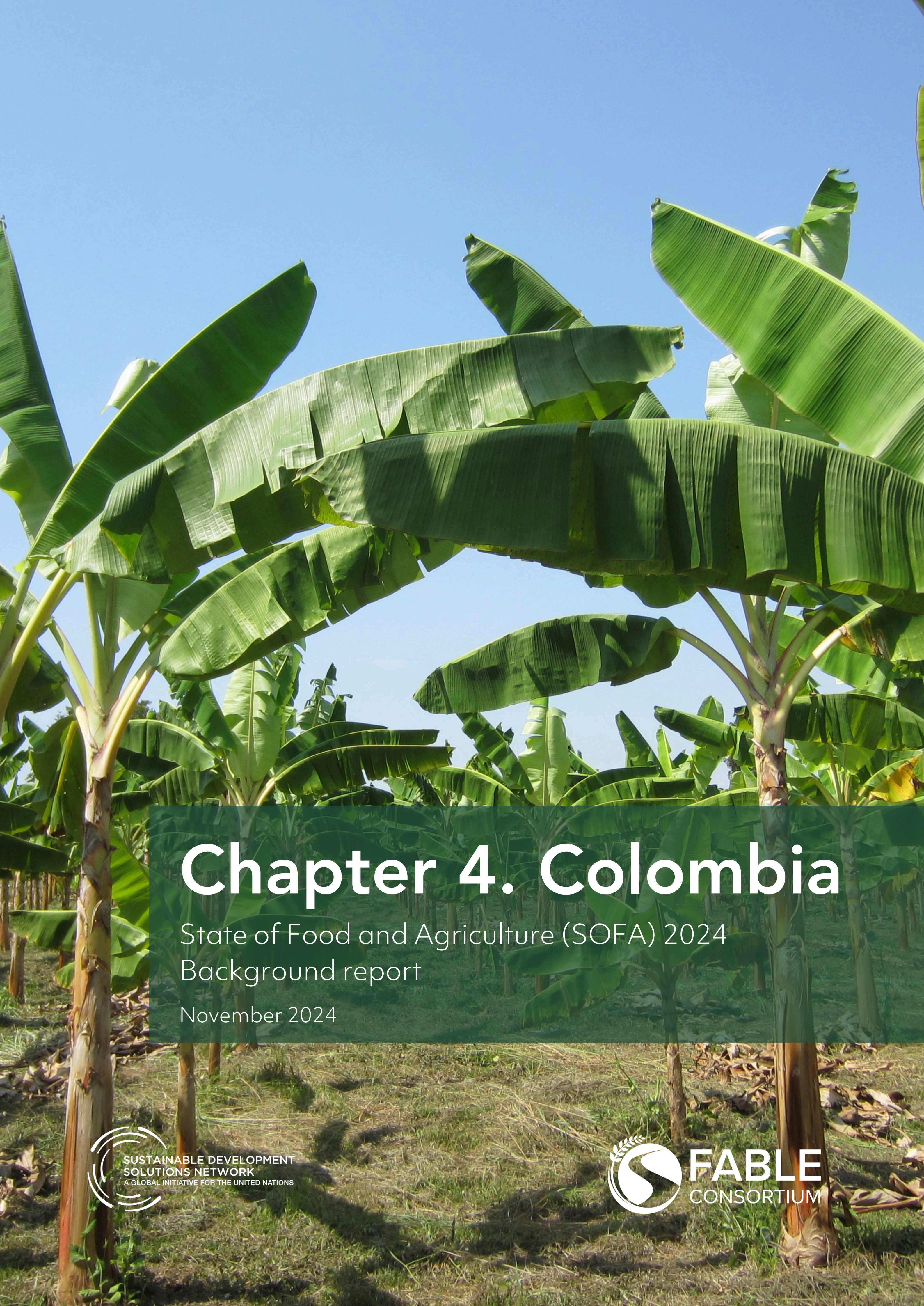

Chapter 4. Colombia

State of Food and Agriculture (SOFA) 2024
Background report

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SUSTAINABLE DEVELOPMENT
SOLUTIONS NETWORK
A GLOBAL INITIATIVE FOR THE UNITED NATIONS

FABLE
CONSORTIUM

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Highlights

- We study alternative pathways for the Colombian agrifood system's hidden economic costs. For this, the FABLE Calculator, a pathway development and analysis tool, is integrated with the True Cost Accounting methodology developed for SOFA 2023.
- The estimated hidden costs for 2050 under the Current Trends pathway are sizeable, representing more than 2% of GDP. These costs decreased by 3.8% and 39% in the National Commitments and Global Sustainability pathways.
- Cost reductions are due to several measures. Mainly, dietary changes that reduce the potential burden of disease of the population, and reductions in CO2 emissions, nitrogen run-off, and NH3 emissions to the air.
- Maintaining the status quo, as implied in the Current Trends pathway, is costly for the economy. To decrease the hidden costs, action is required on several fronts well beyond the set of measures embodied in the National Commitments pathway.
- We recommend prioritizing measures that support the development of healthy dietary decisions, as well as rolling-out strong technical assistance to support producers in the sustainable intensification of agricultural production, ensuring sufficient financing for production projects with a strong component in sustainable practices, and improving and keeping momentum for restoration and afforestation.

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4.1 Introduction

This document reports on the results arising from the experience of integrating the TCA with a particular pathway analysis tool, the FABLE Calculator, applied to Colombia.

We reviewed the country results in SOFA 2023 (FAO, 2023) for appraising their perceived adequacy to Colombia's conditions and for assessing the quality of the data that was used, considering the available national data. Then a round of consultations was held with national and international experts to discuss the SOFA 2023 results, the structure of the TCA approach as used in this report, avenues for bettering national data collection that could be useful for improving and enriching the use of the TCA approach, and plausible scenarios for implementation in the FABLE Calculator. With this background, a set of pathways to 2050 was estimated for Colombia that provided the necessary impact quantities that go as input for the TCA. The TCA was run on these and other required data and the estimation of the Colombian agrifood system hidden costs, for the dimensions that the FABLE calculator comprises, was produced for analysis (Lord, 2023).

The Food, Agriculture, Biodiversity, Land and Energy (FABLE) Consortium unites research teams from developed and developing countries to evaluate national food system pathways within global sustainability contexts. In Colombia, the Pontificia Universidad Javeriana has been a long-standing member of the FABLE Consortium, leading the development and assessment of food system pathways for the country (FABLE, 2020). The study presented here had the kind support of the Centre of Studies on Production and Sectoral Trade of the Colombian Central Bank (under the leadership of Margarita Gáfaro) and the Colombia Office of the FAO, who were instrumental in suggesting and convening participants for the consultation process.

The report is organized as follows. Section 2 presents and discusses the initial assessment of the country results from the SOFA 2023 report, including the input from the consultation process and recommendations for a country-tailored hidden cost analysis. Section 3 reports on the definition of the pathways implemented in the FABLE Calculator, presents and discusses the results for the pathways by using a decomposition analysis, and discusses the results of the TCA. Lastly, section 4 lists and discusses the entry points for action for transforming the Colombian agrifood system and the foreseen implementation challenges.

4.2 SOFA 2023 hidden costs analysis

4.2.1 Main cost components and explanation of the results

Results from the SOFA 2023 for Colombia show that hidden costs from the agrifood system amount to more than 12% of GDP in 2020, above the world average (of almost 10%) and slightly above the average for its country grouping (upper-middle income, of 11%). Environmental and health costs are of a similar magnitude, each contributing more than 48% to total hidden costs, while social costs contribute the remaining 2.9%.

In 2020 the highest contribution to environmental costs was through nitrogen flows estimated at 35 billion 2020 PPP dollars while the most important component within the health dimension was the burden of disease (dietary choices) costs estimated at 45 billion 2020 PPP dollars. Nitrogen flow costs have increased by nearly a quarter (23%) compared to 2016 levels while burden of disease costs increased by 14% over the same period. At the subcategory level and compared to the global average, climate, and nitrogen, contribute more to total hidden costs (29% more than in the global average, a difference mostly due to nitrogen that accounts for more than 25% of the difference). On the other hand, water, land, unhealthy dietary patterns, and poverty, contribute less to total hidden costs: 29% less than the global average, with unhealthy dietary patterns accounting for more than 24% of the difference. Lastly, undernourishment contributes about the same share of hidden costs as it does to the global average.

Most of the stakeholders consulted were surprised by the absolute and relative magnitude of health costs and some of them considered that the environmental costs were probably underestimated. The contribution of deforestation to hidden costs was also deemed by some as too low, given its importance for GHG emissions in the country.

4.2.2 Comparison of SPIQ data with national datasets

Impact quantities

We can rely on the data provided by the national authorities in the Second and Third Biennial Update Reports (BUR), using the years 2014 and 2018 as references, respectively (Colombian Government, 2019, 2022). For the comparison with SPIQ quantities, we focus on the Third Colombian BUR because the SPIQ database covers the years from 2016 to 2023. Having an exact match between the data in the BUR and the data in SPIQ is not possible, in some cases, due to the different levels of aggregation used to report the figures.

Given the above, Table 4-1 reports emission levels by gas and item (or item group) in SPIQ and the Colombian BUR. As seen, emissions in SPIQ are higher than as reported in the BUR, being on average 58% above. In terms of composition, land use change contributes 82.3% to CO2 emissions in the SPIQ database while it does so 94.7% in the BUR; farm gate emissions contribute 80% to CH4 emissions in the SPIQ database and 99.8% in the BUR; and farm gate emissions contribute 94.3% to N2O emissions in the SPIQ database and 99.2% in the BUR; Therefore, despite these differences, the composition of emissions by gas and item is roughly preserved.

Table 4-1*: GHG emissions in 2018 in thousands of tonnes of gas*

Item	SPIQ database			BUR		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Farm gate	4,595.7	1,771.5	63.4	682.9	1,651.1	36.7
Land use change	82,452.7	21.3	1.9	59,639.4	-	-
Pre and postproduction	13,104.9	423.1	1.8	2,636.3	2.4	0.4
Total	100,153.2	2,215.9	67.2	62,958.5	1,653.6	37.0

Source: SPIQ database and Colombian BUR 2020

As for levels, the numbers in Table 4-1 for CO_2 farm gate emissions correspond to energy use in agriculture in both sources (IPCC item 1A4c in the case of the BUR), so the difference in level is not affected by classification issues, and the item probably is overestimated in the SPIQ database. In the case of land use, in the SPIQ database, the data come from FAO's item net forest conversion, so it includes net changes between forest land and other land uses (not only agricultural uses), while in the BUR it comes from forest land converted to cropland and pastureland, without accounting for cropland and pastureland converted to forest land (there is no explicit accounting in the BUR for unmanaged pastures). Therefore, it is very likely that the figure in the SPIQ database is an overestimate. Lastly, pre and postproduction CO_2 emissions, in the SPIQ database include items from fertilizer manufacturing emissions to industrial wastewater, while the BUR only comprises energy consumption emissions from food, beverages, and tobacco processing activities. Hence, in this case, the data from the BUR is underestimate.

In the case of CH_4 emissions, emissions at the farm gate in the SPIQ database include those from livestock activities and energy use in agriculture, while the BUR data include livestock activities, biomass burning, rice cultivation, and energy use in agriculture. Despite the inclusion of these items, emissions in the BUR are slightly below those in the SPIQ database. Finally, for pre and postproduction emissions, the situation is the same as reported for CO_2 emissions in terms of items reported, but the level of emissions is higher under the BUR, so this set of emissions is likely underestimated in the SPIQ.

Lastly, for N_2O emissions, the SPIQ database and the BUR's data have a similar coverage. However, the value in the SPIQ database is more than 70% higher. For pre and postproduction apply the same comment as in the cases before, with the particularity that the emissions level in the SPIQ is higher, so it is likely to be a better estimate than that under the BUR.

Several stakeholders agreed on the relative weakness of the estimates of nitrogen flows for the case of Colombia. Estimates are built based on data on fertilizer imports and domestic production and the assumption is made that they are fully consumed in the year of importation or production. However, there is no reliable data on the use of fertilizers by different crops and in different regions, which renders the calculation of emissions rather uncertain. Given this situation, they also raised doubts about the figures that are used by SPIQ.

Costs associated with the climate category in SOFA 2023 show an upward trend that arises from changes in impact quantities. While the upward trend seems correct, the level of impact quantities in the model differs considerably from the one observed in national data. The costs arising from nitrogen emissions in SOFA 2023 may be overestimated as the impact quantities associated with the agrifood system in the model database are considerably larger than those corresponding to national historical data, although the latter also show an upward trend.

Water

Data on water use in the SPIQ database shows figures for blue water withdrawals for 2016 and 2020 in the order of 21,000 and 25,035 million cubic meters (Mm^3), respectively. These figures are closer to total water withdrawals. The preferred data source for Colombia is the National Water Study (ENA for its Spanish language acronym), which provides data for 2008, 2012, 2016, and 2020 (IDEAM 2023). According to the ENA, in 2016 and 2020 total water demand was 20,645 and 19,496 Mm^3, respectively; this includes demands from agriculture and post-harvest activities, aquaculture, and livestock and cattle slaughter. According to the ENA, the blue water footprint in 2016 and 2020 was 9,313 and 7,597 Mm^3, correspondingly, so the SPIQ database may be grossly overestimating this item.

There have been methodological changes in the calculation of water demand in Colombia, as the number of hectares with pasture cover for livestock use was adjusted around 2019, leading to a fall in water demand estimates. The adjusted figures for 2008 and 2012 are 23,198 and 19,463 Mm^3, respectively. Therefore, there is a downward trend in water demand between 2008 and 2020, which may look counterintuitive, especially in the light that the ENA 2022 (which provides the data for 2020) projects an increase in water demand between 2020 and 2040 (IDEAM, 2023).

Land use change

Data on land use change in the SPIQ comes from the HILDA+ model, which provides figures for the eight categories included in it. The main data source on land use in Colombia is the estimation that the IDEAM (the Colombian institute in charge of providing emissions and other relevant data) performs based on the Corine Land Cover Methodology, which currently has data for 2000–2002 (the base period) 2005–2009, 2010–2012, and 2018 (*Metodologia CORINE Land cover – IDEAM*, n.d.). However, there are two difficulties associated with this data (at least at the level of information that is publicly provided in the country). One is that it uses a set of categories that makes it difficult to map to the ones used by SPIQ. The other is that it allows tracking changes through time for each category but does not allow tracking changes among categories, i.e., the required land use changes.

For these reasons, a quick way forward for estimating land use changes among the categories needed is to build them from the reported emissions for the categories of land use changes included in the BUR. This requires using conversion factors that allow to go from CO_2e emissions to hectares and that are dependent on the conditions under which they were calculated. Assuming these conditions remain constant, the conversion factors should provide a good proxy for estimating the areas required.

Table 4-2 shows the number of hectares associated with land use changes for 2018. As can be appreciated, all categories show very large differences that result, in the case of the SPIQ database, in a net gain in forest cover of more than 12 thousand hectares. In contrast, the BUR-based data show small figures for transitions from agricultural uses to forests as well as from forests to cropland, while a large one for transitions from forests to pastures, in line with the stylized facts on land use change in the country. These figures yield a net forest cover loss of almost 116 thousand hectares, which is about 60% of the total deforestation reported for that year.

Table 4-2. *Land use changes in 2018 (hectares)*

Item	SPIQ database	BUR-based
Cropland to forest and unmanaged grassland	13,178	462
Pasture to forest and unmanaged grassland	27,310	2,314
Forest and unmanaged grassland to cropland	5,435	1,635
Forest and unmanaged grassland to pasture	22,627	117,019
Net change (forest – agricultural use)	12,426	-115,878

Source: SPIQ database and estimates based on the Colombian BUR 2020

Nitrogen, dietary choices, and undernourishment

As far as our knowledge goes, there are no available national figures on nitrogen emissions to air, leaching to groundwater, or run-off to surface water, so there is no way to improve the data in the SPIQ database. It is convenient to recall the observation made by some stakeholders on fertilizer use and nitrogen volatilization and lixiviation made above, in the sense of the weakness of these data in Colombia. The same is true for dietary choices, as the National Health Observatory from the Ministry of Health and Social Care refers to the Global Burden of Disease, Injuries, and Risk Factors Study 2013, which is the data source for the SPIQ. (Observatorio Nacional de Salud Revistas Indexadas). This is also the case with the burden of disease due to undernourishment since most of the work done in the country refers to child undernourishment; however, the country produces enough information for the Global Hunger Index (GHI) to be calculated. For 2023 the country had a GHI of 7.0 which is considered low (Colombia – Global Hunger Index (GHI) – Peer-Reviewed Annual Publication Designed to Comprehensively Measure and Track Hunger at the Global, Regional, and Country Levels, n.d.).

However, the high contribution of dietary choices to hidden costs and the upward trend of the latter between 2016 and 2023 are in line with the nutritional situation in the country. According to the 2015 National Demographic and Health Survey (the last one that was conducted), overweight and obesity among children under four increased to 6.3% in 2015 concerning 2010 (4.9%), 24.4% of children between five and twelve years of age were overweighted (an increase of 5.8 percentage points concerning 2010), 17.9% of teenagers were also overweighted, and 37.7% of adults (between 18 and 64 years old) were overweighted and 18.7% were obese. In total, 56.4% of the population was overweight (up from 51.2% in 2010). (Encuesta Nacional de Demografía y Salud – ENDS, n.d.)

Concerning undernourishment, some stakeholders observed that the lack of micronutrients may be an important component of the hidden costs and that it may be underrepresented in the SPIQ database that focuses on the energy deficit.

Poverty

The poverty headcount is just an approximation in the SPIQ database and there is no national data available for improving them. However, processing of the Colombian Integrated Household Survey could be used to perform the necessary calculations, as suggested in the stakeholder consultations. (Gran Encuesta Integrada de Hogares – GEIH | Datos Abiertos Colombia, n.d.)

Instead of processing the survey and as a first approximation for having an estimate to compare with the data in the SPIQ database, data was taken from the national employment matrix for 2020 on the number of full-time equivalent jobs associated with both the agricultural and agroindustry sectors (food, beverages, and tobacco), which are the available categories that can be mapped to the agrifood system (DANE – Matrices Complementarias, n.d.). These were converted to the number of workers by using the average number of hours worked in these sectors (differentiating among salaried workers and self-employed, and by gender). Then poverty incidence rates for the rural and urban populations were used to estimate the number of workers in poverty in the two sectors (assuming poverty incidence within the sectors is the same as that for the whole population), and the number of persons per household (differentiating rural and urban) was used to estimate the poverty headcount associated with the agrifood system. Aside from all the assumptions made, this estimate is likely to overestimate the headcount, as it implies that each person employed maps to one and only one household (i.e. there are no households with more than one worker in the sector).

The result from this exercise yields a headcount of more than 4.8 million people versus almost 3.7 million people registered in the SPIQ database.

Review of unit costs to GDP

Unit costs to GDP in the case of Colombia seem in line with costs for comparable countries and are consistent with the national data on GDP and its long-term projections.

4.2.3 Recommendations for tailored country hidden costs analysis

The main and most immediate avenue for tailoring the analysis is using national datasets on impact quantities wherever viable and to the extent possible. Beyond this, there are some areas in which there may be some improvements in the precision of this data either by building on national data already available or by refining their collection process. Among them, it is worth mentioning:

- Estimate GHG emissions from national production of agricultural inputs.
- Estimate GHG emissions from national food production alone (excluding emissions from beverages, and tobacco products production).
- Estimate GHG emissions from households cooking (distinguishing them from other emission sources).
- Estimate emissions from food waste (within the solid waste category).
- Estimate the poverty headcount associated with the Colombian agrifood system.
- Estimate land use changes with explicit reference to transitions between categories.
- Improve data collection and analysis on fertilizer application and nitrogen flows.
- Improve data collection and analysis on dietary choices and undernourishment for the whole population.

From the consultation process emerged a set of additional activities, actors, or externalities to be considered for deepening the national analysis of the hidden costs of the agrifood system. The most relevant are listed below.

- Estimate emissions and other costs associated with the transportation and distribution of food products in different stages of the supply chain (there is some work already done on this front).

- Consider and appraise the role of international demand for national food products.
- Improve estimates on post-harvest losses (before actual final consumption).
- Consider soil degradation and the costs associated with it.
- Improve estimates of biodiversity loss and its associated costs.
- Introduce differentiation between broad types of agricultural production (peasant/small scale vs. commercial/large scale).
- Consider regional differences among several of the dimensions included in the study, as national averages are deemed of scant use for policy design in a country as socioeconomically and environmentally diverse as Colombia.

4.3 Evolution of hidden costs by 2030 and 2050

4.3.1 FABLE Calculator for Colombia

The collaborative effort involved the employment of the FABLE Calculator (Mosnier et al., 2020) to investigate the complexities of land use and food dynamics. This tool has been progressively adapted to reflect the specific conditions of Colombia by the academic team at Pontificia Universidad Javeriana (FABLE Colombia) in collaboration with the UN Sustainable Development Solutions Network (SDSN) (Mosnier et al., 2020). This adaptation process was centered on updating the data originally included in the Calculator, which primarily originated from global databases supplemented with national information from official institutions and sectoral sources. Specifically:

- Land cover data for the years 2000, 2005, and 2010 were revised using information published by IDEAM.
- Yield values for crops and pastures were adjusted based on data from the 2019 Municipal Agricultural Evaluations published by the Agricultural Rural Planning Unit (UPRA) of the Ministry of Agriculture and Rural Development.
- Population data and projections were updated according to reports from the National Administrative Department of Statistics (DANE).
- National diet information was revised using data from the Food Balance Sheet (HBA) provided by the Colombian Institute of Family Welfare (ICBF).
- Food waste rates were adjusted according to the 2016 reports from the National Planning Department (DNP).
- Areas of crops under irrigation were updated for each crop in accordance with UPRA reports.
- Biofuel consumption scenarios were revised based on reports from FEDEBIOCOMBUSTIBLES, among other minor changes.

This adaptation process ensures the model provides accurate insights relevant to Colombia's unique environmental and agricultural context, facilitating informed decision-making in land use planning and food security strategies.

4.3.2 Scenathon 2023 pathway assumptions

Current Trends pathway

In the context of the current trends (CT) pathway, we envision a scenario influenced by a complex interplay of factors. We project moderate population growth, which is expected to increase from 50.9 million people in 2020 to 57.3 million by 2050. Concurrently, free expansion of the agricultural frontier is foreseen. No further afforestation is anticipated, in line with recent decades' trends. This scenario does not include plans for the expansion of existing protected areas but does project modest improvements in agricultural productivity. The proportion of domestic consumption fulfilled by imports is expected to remain stable. On the economic front, we anticipate a 10% increase in exports for specific agricultural commodities, such as coffee, cocoa, palm oil, bananas, sugar, and other fruits.

In this way, while existing policies and historical patterns may contribute to a modest deceleration in population growth, they are unlikely to effectively address ongoing environmental challenges. This scenario portrays a pathway where some progress is achieved, but significant challenges persist.

National Commitments pathway

In this pathway, food waste is reduced by 30% compared to the CT pathway, and imports of products such as corn, rice, and soybean meal remain stable. Additionally, livestock productivity is projected to increase by 50% by 2050 compared to 2020, while the stocking density remains the same as in the CT pathway. Crop yields are expected to close a 10% yield gap, and the area under agroecological practices is diversified and increased to 10% of the total agricultural area. Efforts continue to achieve the goals established by the Bonn Challenge, aiming to restore 1 million hectares of forest.

The NC pathway represents a balanced approach to economic growth, resource management, and environmental conservation, offering a roadmap for a transition toward a more sustainable future but with room for significant improvements.

Global Sustainability pathway

In this pathway, GDP is projected to increase by 5% annually, and the population is expected to reach 58.7 million. Diets play a crucial role in driving change, with a partial implementation of the EAT-Lancet diet at 40% of the minimum quantities for each food group. Food waste is reduced by 15% compared to the CT pathway. Imports of key products such as corn, wheat, rice, and soybean meals are projected to decrease by 50% compared to CT. Livestock productivity is expected to increase by 80% by 2050 compared to 2020 levels. Crop yields are anticipated to close a 40% yield gap, and the area under agroecological practices is diversified and increased to 10% of the cropland area. Additionally, stocking density would increase by 35%, reaching one head of cattle per hectare by 2050. Efforts continue to achieve the goals established by the Bonn Challenge, aiming to restore 1 million hectares of forest.

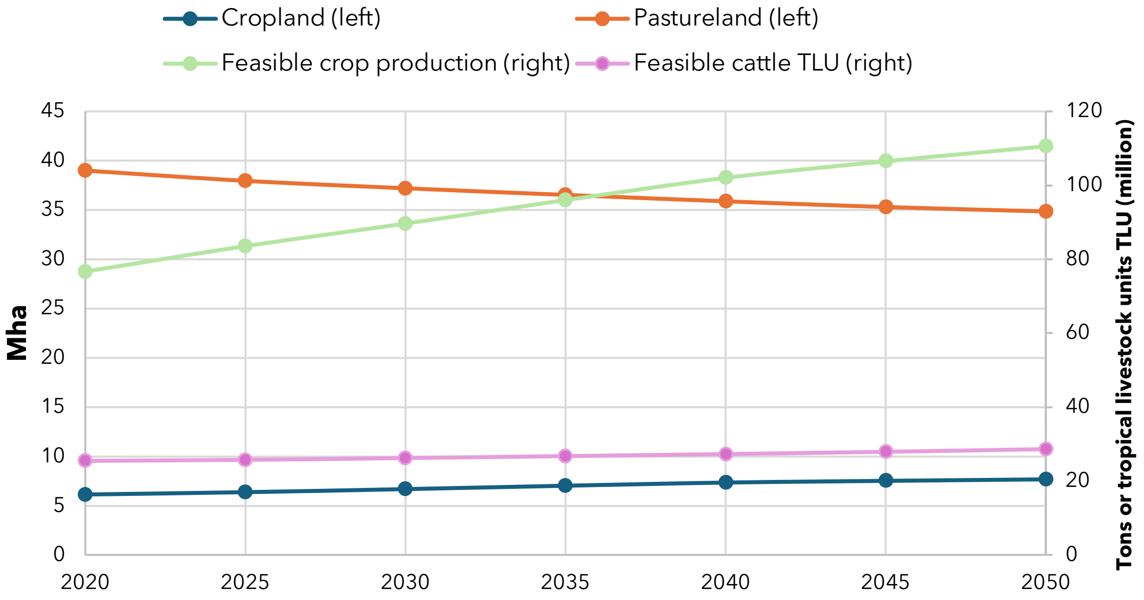
However, it is worth noting that water consumption is expected to increase by 25% from 2020 to 2050 due to intensified productivity processes. This sustainable pathway outlines a promising future where Colombia's commitment to sustainability and strategic policy implementation leads to enhanced economic, environmental, and social outcomes.

4.3.3 Results across the three pathways

To illustrate the results from the simulations, we first select a set of model outcomes and discuss their behavior under the CT pathway and then use a decomposition analysis to show both how they change from the CT to the NC and GS pathways, and to identify what factors generate these changes.

Figure 4-1 shows the path followed by cropland and pastureland areas and by feasible crop production and feasible cattle stocks. As follows from there, cropland will increase from 6.13 million in 2020 to 7.7 million in 2050 in response to the projected increase in demand that arises from population and per capita income growth. Feasible crop production increases too, at a higher pace than cropland, reaching almost 111 million tonnes, as the pathway contemplates a modest increase in physical productivity. Pastureland decreases almost 12% between 2020 and 2050 keeping with the most recent historical trend (associated with rising consumer prices) and because the pathway posits a slight increase in productivity.

Figure 4-1: *Area for cropland and pastureland under the Current Trends pathway*



The dynamics associated with the above trajectories lead to a general increase in emissions. As follows from Figure 4-2 and Figure 4-3, total GHG emissions increase by 14% between 2020 and 2050, representing 86.6 Mt CO_2e at the end of the period. Methane is the largest contributor to the increase in absolute terms, but it is the gas with the lowest relative increase. CO_2, N_2O, and total nitrogen (organic and synthetic) emissions grow faster than those of methane, so there is some change in terms of the gas composition of the emissions.

To this, it must add the associated land use changes and their corresponding emissions. The combined effect of the increase in cropland and the decrease in pastureland discussed above leads to a net decline of 1% in forest land between 2020 and 2050, an increase of new ‘other land’ (former pastureland) of 132% during the same period, and an increase in urban land of 60%, whose dynamics are independent of land used for productive purposes and is an independent scenario. The behavior of GHG emissions from land use change (LUC) is presented in Figure 4-3. As noticed, there is a major drop in reported emissions from 2020 to 2025 because 2020 is the last year based on historical data and includes emissions from deforestation and other LUC that originate in sources other than agricultural activities (such as illegal mining, illicit crops cultivation, land cleared for land-grabbing, etc.), while the figures from the simulation (from 2025 on) only capture the portion of emissions that is due to LUC from agricultural activity and urbanization. Given this, it is observed an overall increase in emissions from deforestation and other LUC, as well as an increase in sequestration associated with regeneration of abandoned agricultural land.

Figure 4-2: *GHG emissions from agriculture under the Current Trends pathway*

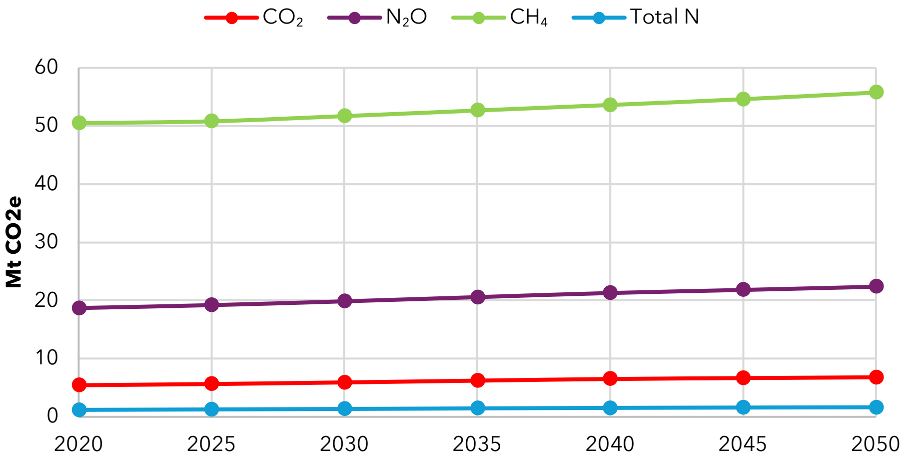
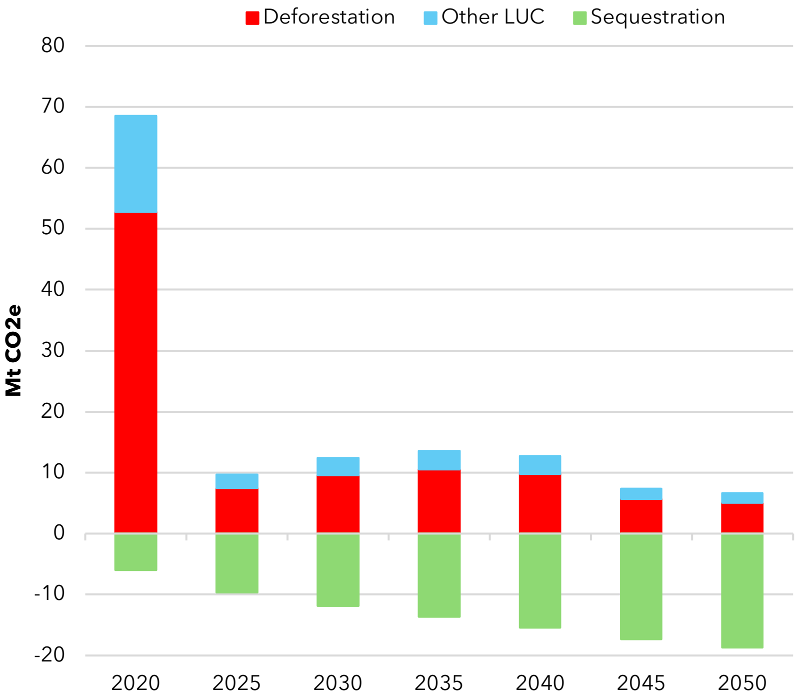


Figure 4-3*: GHG emissions from land use change under the Current Trends pathway*



Lastly, the behavior of farm labor, blue water use, feasible kilocalories, poverty, water use, and nutrition outcomes are important components of the agrifood system's hidden costs. Farm labor, measured in full-time equivalent units (FTE), shows a relatively stable behavior oscillating between a low level of 0.6 million FTE and a high of 6.3 million FTE, with a slight tendency to increase. Bluewater use will increase significantly between 2020 and 2025, as there is an important increase in sugarcane harvested areas (one of the crops with the highest water demands). Feasible kilocalories per capita increase by 11% between 2020 and 2050 in a steady way, because of an increasing availability of food during the period.

4.3.4 What are the most influential factors to reduce the hidden costs by 2030 and 2050?

We now compare the results arising from the NC and GS pathways vis a vis the CT using a decomposition analysis (cf. Section 1.8.4). We compare the results of the decomposition analysis for cropland and pastureland changes under the NC and GS pathways as compared to CT (Figure 4-4).

For the period 2020–2050, cropland decreases 29% under the NC and 56% under the GS pathways, mainly because of the increased crop productivity that is needed for both satisfying an increasing demand but doing so in a sustainable way and decreasing land use change that is to the detriment of carbon sequestration. As can be observed in the left-hand side of the figure, cropland decreases under these two pathways yielding rather similar decreases by the end of the implementation period (2050).

In both cases, the main individual driver of cropland reduction is increased crop productivity which, as described above, rises from the CT to the NC and then again to the GS pathway. On the other hand, the main cause of increases in cropland under both pathways is the trade adjustment effect (i.e., the trade effect arising from the conciliation of trade flows across countries that comes from the Scenathon). As shown, the trade adjustment effect implies a net increase in exports from the country, that must be met with larger production and cropland use. Under the GS pathway, the significant influence of other scenarios is noticeable. This pathway includes as a scenario a change in consumer preferences manifested in a shift to a healthier diet (the average EAT-Lancet diet) that is key to lowering hidden costs associated with health. This scenario also favors a lower consumption of certain foods and an increase of others, that, on balance, require less cropland area. Conversely, the higher increase in irrigated areas that this pathway allows and the increase in ruminant density, which only operates in this case, push cropland use upward as new irrigated land comes into play and demand for feed increases due to higher stocking rates.

For the NC pathway, there is an overall decrease in pastureland of 5% between 2020 and 2050, while for the GS pathway it decreases by 11%. As shown in the figure, under the NC pathway the decrease in pastureland for 2030 is greater than under the CT, but for 2050 the decrease is lower, resulting in a positive value (Figure 4-4).

As protected area expansion is allowed in the NC pathway but not in the CT, the scenario exerts a downward effect on pastureland, that is particularly strong by 2030 but lessens significantly by 2050 as the intensity of the implementation of the scenario decreases as time goes by.

For the GS pathway, there are reductions in pastureland for both 2030 and 2050 when all scenarios are implemented simultaneously (represented by the dot in the graph). The largest contributor to the decline is the increase in ruminant density, which operates in this pathway and not in the others, and directly impinges on the area required for sustaining the animals. The second largest contributor to the decline is the change in diets that decreases the demand for beef (calories originated in red meat must decline by 22% for 2050 according to the implementation of the scenario). The third is the effect of protected areas, which in this pathway (as well as in the NC) are allowed to increase. Lastly, lower post-harvest losses contribute to the decrease in pastureland as a larger portion of the end products can enter the market without changing production levels. As in the NC pathway, in this one livestock productivity, which increases in different degrees in all pathways, generates lower reductions in pastureland and therefore is shown as making a positive contribution.

Figure 4-4: *Decomposition analysis for cropland, pastureland, other land and forest changes*

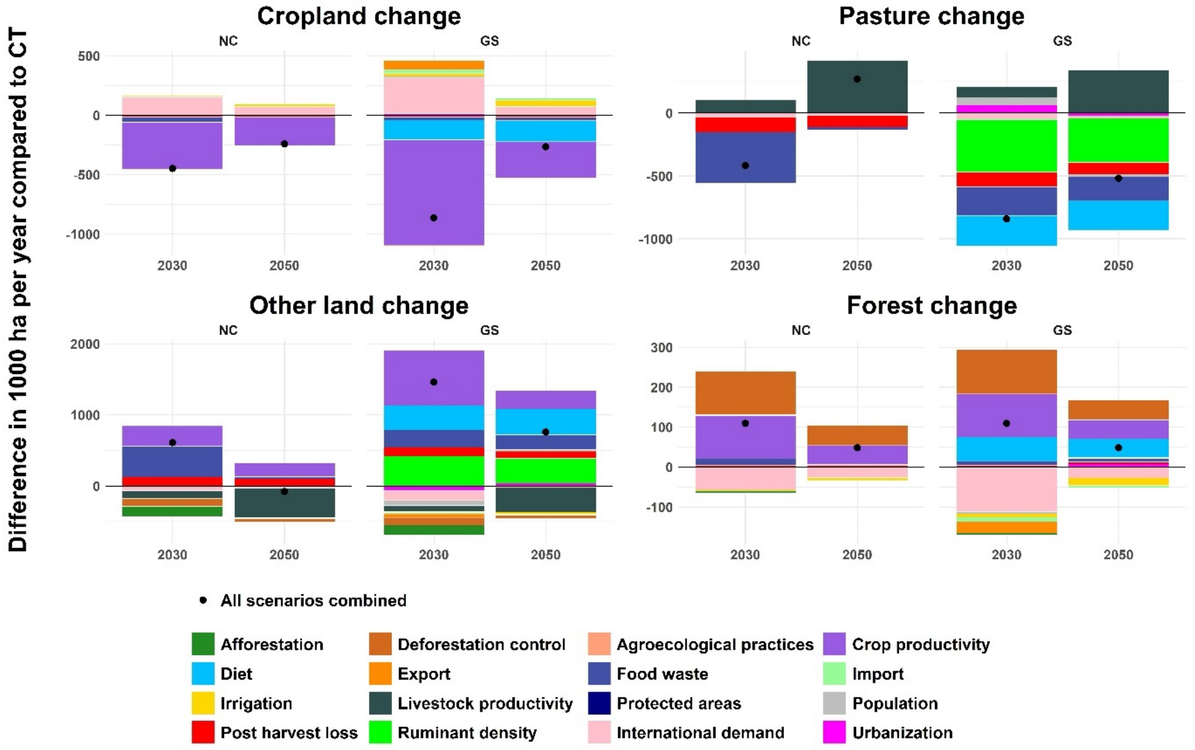
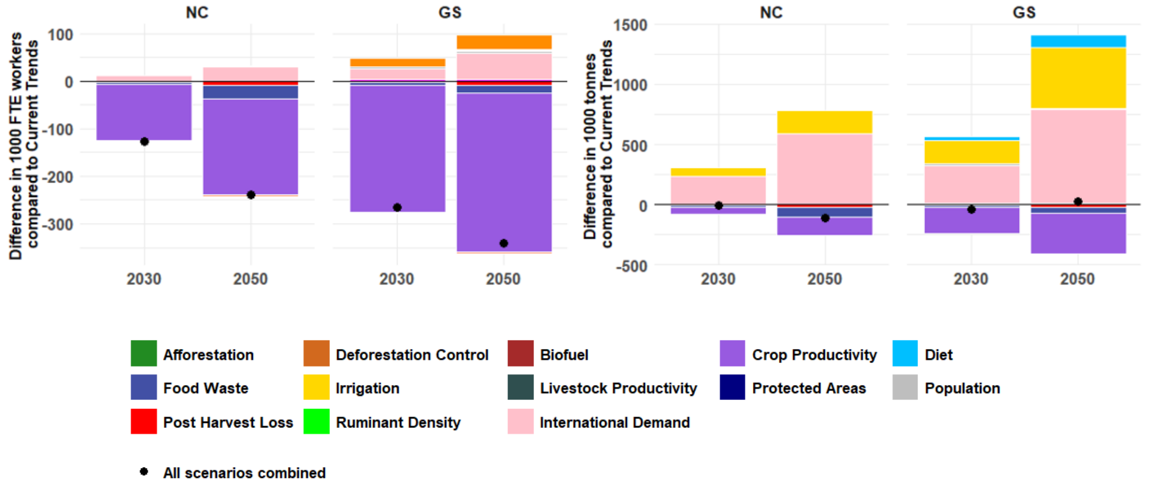


Figure 4-5: *Decomposition analysis for farm labor (left) and blue water use changes (right)*



Consistent with the changes in cropland, farm labor decreases under both the NC and the GS pathways as can be appreciated in Figure 4-5. As could be expected, the main driver of this decline is the increase in crop productivity. In the opposite direction, slowing down the fall in farm labor use, the main driver is the trade adjustment effect that increases net exports. This scenario exerts a stronger effect under the GS pathway, under which the effect of exports in general (aside from the trade adjustment effect) also helps in dampening the decline in farm labor use.

On the other hand, water irrigation requirements remain almost unchanged under the NC pathway and increase by about 27% by 2050 for the GS pathway. As seen in the right side of Figure 4-5, the largest effects on water use arise from the trade adjustment effect that is linked to the dynamics of exports of bananas, sugar products, and other citrus, while the other significant scenario common to both pathways is the increase in irrigated land that is allowed in them but not in the CT. Under the GS pathway, there is also a positive effect arising from dietary changes as cereal consumption is increased and there is a high share of rice cultivation in irrigated lands. Conversely, the increase in crop productivity harms water irrigation requirements.

As mentioned above, the dynamics of LUC reported here refer only to the portion that is directly linked to agricultural activity. As in the NC and GS pathways, it is assumed that Colombia fulfills its commitment to reach net zero deforestation. Forest area decreases in both cases by slightly more than 1% between 2020 and 2050. The main drivers of forest land change are the trade adjustment effect on the negative side and crop productivity, agricultural expansion, and, for the GS pathway, dietary changes on the positive side (Figure 4-4).

For 2030 and 2050, the trade adjustment effect contributes more to the decline of forest land than it does under the CT pathway, with the effect being greater for 2030. The increases in crop productivity contribute more to the decline in deforestation under these scenarios than they do in the CT pathway and the same happens with agricultural expansion (i.e., they increase the amount of land under protection from agricultural expansion) which was not a feature under the CT pathway. Additionally, for the GS pathway, the effect of a partial transition towards a healthier diet also contributes to lowering the decline in forest land.

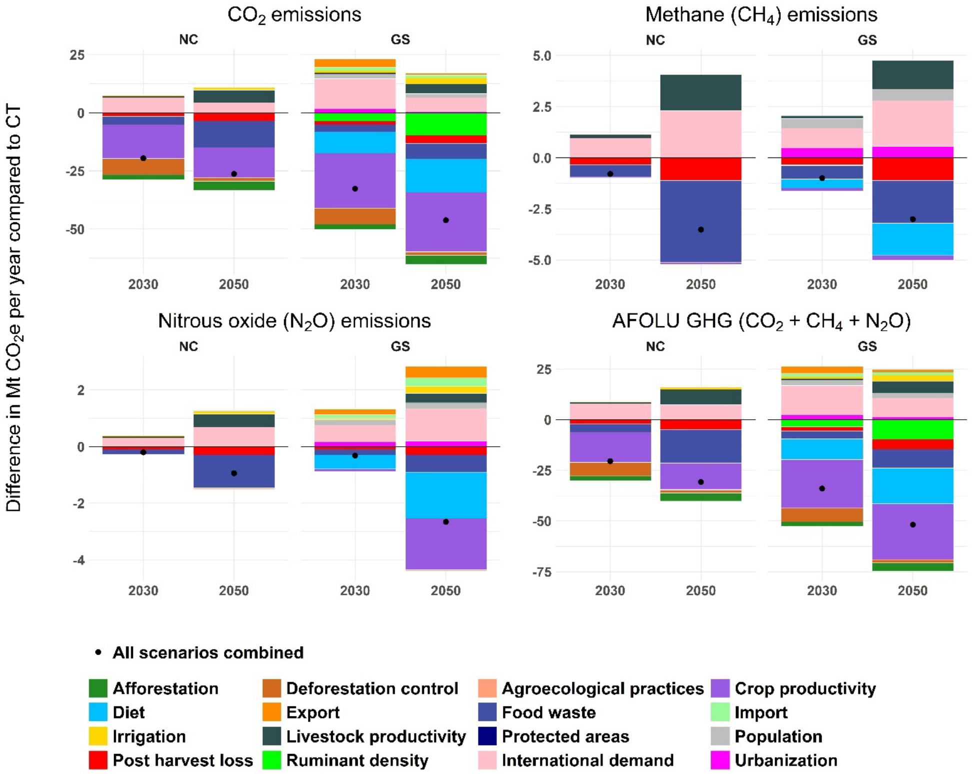
Changes in 'other land' are positive as the category increases more than 33% between 2020 and 2050 in the NC pathway and 92% in the GS.

Several scenarios contribute to the results, the dominant ones being livestock productivity, crop productivity, post-harvest losses, afforestation, and, only for the GS pathway, diet changes (Figure 4-4). While getting into the specifics of these contributions exceeds the needs of this discussion, what is useful to retain is that the dynamics of 'other land' are dependent on the behavior of cropland, pastureland, deforestation, and urban expansion and its increase is largely related to the declines in cropland and pastureland that depend significantly on crop and livestock productivities.

The results of the decomposition analysis for GHG emissions show that, as expected from the scenarios implemented in the NC and GS pathways, emissions decrease across the board for all gases (Figure 4-6). For the NC pathway CO2 emissions decreased by 168% concerning the CT pathway for 2050, while CH4 emissions decreased by 5.6%, N2O emissions by 3.4%, and total nitrogen by 1.6%. In the case of the GS pathway, CO2 emissions decreased by 313% concerning the CT pathway, while CH4 emissions decreased by 10.8%, N2O emissions by 12% and total nitrogen emissions by 25.1%.

Several scenarios have significant effects on CO2 emissions. For the NC pathway, it is worth mentioning crop productivity, agricultural expansion, afforestation, and decreases in food waste among those that lead to declines in emissions, and the trade adjustment effect among those that tend to increase them. To these scenarios we must add, for the GS pathway the increase in ruminant density on the declining emissions side, and exports and urbanization on the increasing emissions side. Lastly, increases in livestock productivity contribute less to the reduction in emissions in these two pathways than under the CT.

***Figure 4-6**: Decomposition analysis for GHG emissions*



The number of scenarios impacting emissions of the other gases is smaller, especially for the NC pathway. For CH_4 emissions, lower food waste and post-harvest losses are the main drivers for reductions (as expected given the chemical processes involved) and in the GS pathway, there is also a role for the change in diets. The trade adjustment effect and livestock productivity scenarios, however, contribute more to emissions reductions under the CT pathway. In the case of N_2O emissions, there is a situation somewhat similar in that lower food waste and post-harvest losses are important in driving emissions down and that changes in diets add to this effect in the case of the GS pathway, while exports and imports tend to contribute less to emission reduction.

As for total nitrogen (Figure 4-7), lower food waste and the trade adjustment effect are the main drivers in the NC pathway, but under the GS pathway changes in diets, exports and imports, and expanded irrigated land come into play.

The last dimension of the analysis that is important to mention given its very significant role in determining the hidden costs is nutrition. Measured as the availability of kcal per capita per day, the amount is above the minimum requirements for all pathways. Given this, the main factor determining changes in kcal availability is the adjustments in the diet that are introduced in the GS pathway. Kcal availability remains constant between the CT and the NC pathways and decreases by 8% for the GS. As shown in Figure 4-7.

There is an increase in kcal originating in animal products, that is more than compensated by a decline in those that are plant-based for a net decline of about 207 kcal per capita per day (Figure 4-8).

***Figure 4-7**: Decomposition analysis for nitrogen use*

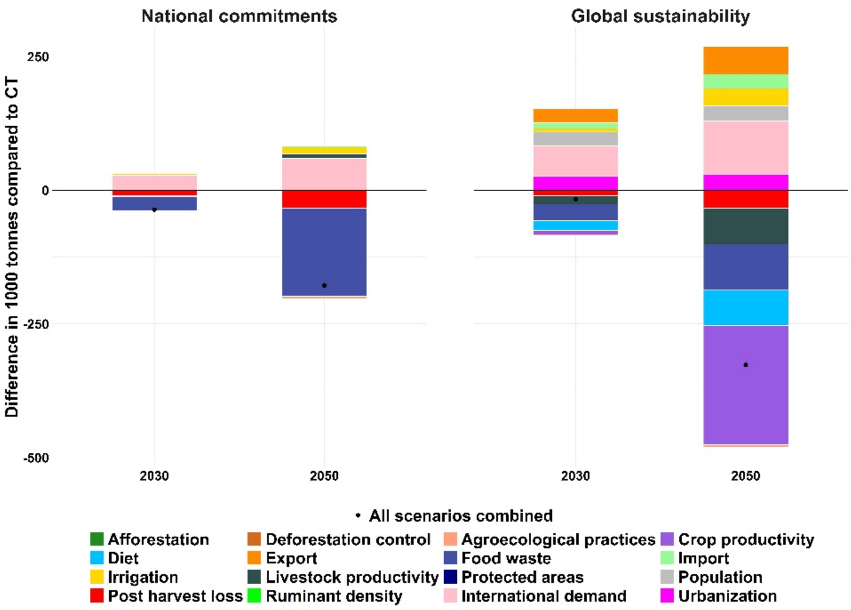
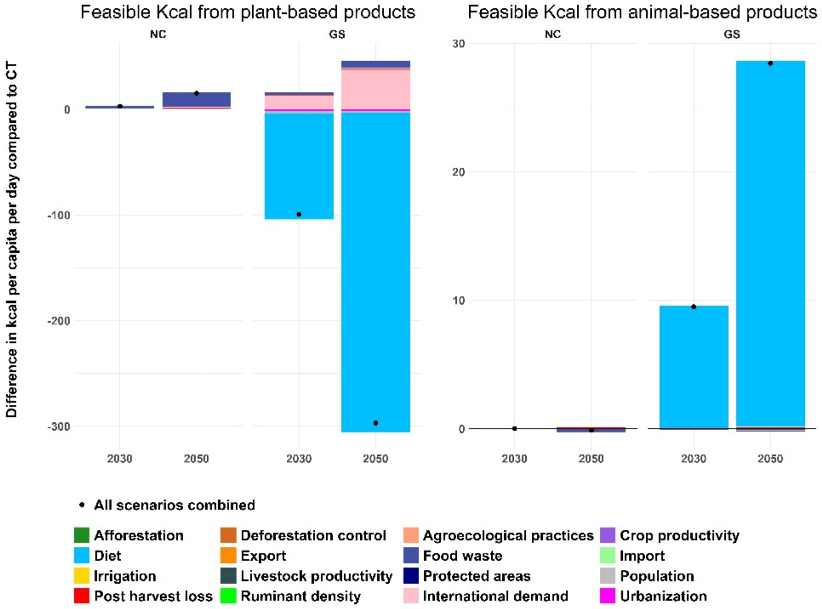


***Figure 4-8:** Decomposition analysis for feasible Kcal from animal and plant origins*



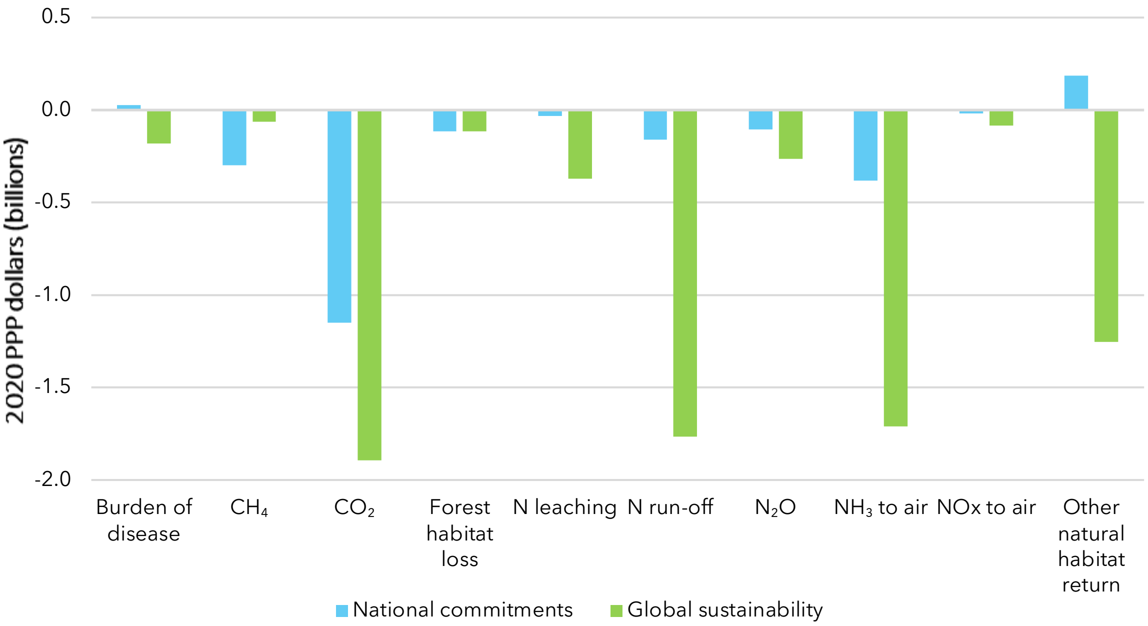
4.3.5 Impacts on the agrifood system's hidden costs

To identify the main factors for reducing the hidden costs of the Colombian agrifood system, the discounted economic costs valued at US dollars of 2020 at PPP were estimated for 2050, using the TCA methodology outlined in the FAO's SOFA 2023 report (FAO, 2023). The estimation was performed for part of the social and environmental dimensions of the hidden costs, comprising burden of disease (undernourishment and dietary patterns), CH_4 emissions, CO_2 emissions, forest habitat loss, forest habitat return, nitrogen leaching, nitrogen run-off, N_2O emissions, NH_3 emissions to air, NOx emissions to air, other natural habitat loss, and other natural habitat return.

This set of costs amounts to 30.4 billion 2020 PPP dollars by 2050 under the CT pathway, representing 2.04% of the estimated Colombian GDP for this year. These costs decrease by 3.8% and 39% in the NC and GS pathways concerning the CT case, amounting to 1.96% and 0.95% of GDP by 2050, so the scenarios implemented in these pathways (especially in the GS pathway) are effective in significantly reducing the hidden costs of the agrifood system.

Figure 4-9 shows the changes in costs between the NC and the GS pathways compared to CT for each of the cost categories. As seen, most changes reflect decreases in costs, being larger in the GS pathway. The exceptions to this are costs associated with the burden of disease (dietary patterns and undernourishment) and 'other natural habitat' return under the NC pathway. The largest decreases (in absolute terms) correspond to dietary patterns, CO2 emissions, nitrogen run-off, NH3 emissions to air, and other natural habitat return (in the case of the GS pathway). In most cases impact quantities decline, but the behavior of marginal costs varies. Marginal costs increase slightly for CO2 emissions, and nitrogen run-off, but decrease for NH3 emissions to air under the NC pathway, while they all decline for the GS pathway. In the case of other natural habitat returns, quantities decrease for the NC pathway and increase for the GS, while the marginal cost decreases under the NC pathway and increases under the GS (leading to an increase in cost in the first case and a relatively large decline in the second, given that this is a negative cost, i.e., a benefit).

Figure 4-9: *Cost changes concerning the Current Trends pathway by cost categories (2050)*



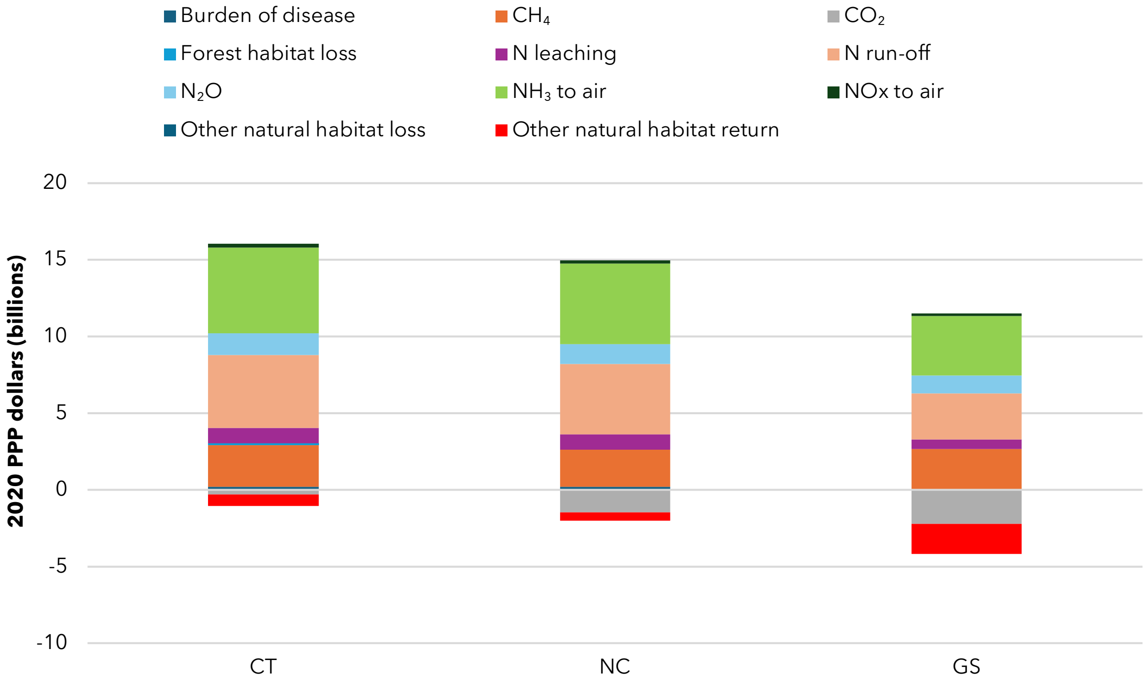
It is important to recognize that the dynamics of LUC reported here refer only to the portion that is directly linked to agricultural activity. This implies that CO_2 emissions in the base year (2020) include those arising from deforestation due to sources other than agriculture, but the simulations do not account for them. As such, there is an overestimation of the reduction in costs due to this source, and benefits arising from negative emissions of CO_2 relate only to avoided deforestation from agriculture.

The costs and benefits by impact category for the three pathways are illustrated in Figure 4-10. Benefits arise from reduced CO_2 emissions from agriculture-related avoided deforestation and from the increase in areas in natural habitat return (restoration) and are found in the three pathways at different levels. Lower costs come from the categories discussed above, which tend to be larger under the GS pathway. Costs from CH_4 emissions decline but the decline is steeper for the NC pathway than for the GS pathway for whom both activity level and marginal cost increase with respect to the NC.

For the GS pathway, the largest contribution to costs in 2050 comes from dietary patterns (49.3%), followed by NH_3 to air (17.2%), nitrogen run-off (13.2%), and CH_4 (11.7%), the rest of the categories (nitrogen leaching, N_2O, and NOx to air), contributing the remaining 5.8% to costs. On the side of benefits, CO_2 abatement from avoided agriculture-related activities and other natural habitat return contribute roughly the same proportions, 52.5% and 47.5%, respectively. More detailed results, particularly regarding the cost effects of the composition of diets and the role of uncertainty are provided in Lord (2024).

Given these results and the decomposition analysis, for the set of impact categories included in the analysis, the main factors for reducing the hidden costs of the Colombian agrifood system are increased crop productivity, forest restoration, and protected areas, lower post-harvest losses, and diet change.

Figure 4-10: *Mean costs and benefits by impact category by 2050*



4.4 Entry points for action and foreseen implementation challenges

The importance of dietary patterns for hidden costs is strongly highlighted by both their share in total hidden costs and their contribution to lowering them in the GS pathway, as instrumented through the simulated change in diets. Consistently with this, the stakeholders consulted considered that the set of actions that have been envisaged by the government in terms of creating an enabling environment for **the development of healthy dietary decisions should be prioritized**. This effort comprises a broad range of measures, going from adequate food labeling and healthy taxes to education campaigns and education programs starting from primary school. The principles of this policy are set out in the National Council for Economic and Social Policy's document 113 of 2008 (Política de Seguridad Alimentaria y Nutricional – PSAN, 2008).

Implementation of the policy needs reviewing and adjusting, including the institutional dimension. An evaluation carried out in 2015 found an imbalance in its main components, that, among other implications, led to prioritizing only vulnerable groups of the population to the detriment of other interventions. It also identified a lack of intersectoral actions and disarticulation between national and territorial plans and the usual operations of the public administration, as well as an inability to secure financial resources for implementation (G-Exponencial, 2015). Furthermore, an evaluation by the World Food Program found that 30% of Colombians experience high levels of food insecurity and that structural and conjunctural factors have worsened food insecurity in the country, implying that tackling the sources of the increasing levels of vulnerability is required (WFP, 2023).

The second entry point is the roll-out of **technical assistance to support producers in the sustainable intensification of agricultural production** that is required to satisfy an increasing demand while also reducing GHG and nitrogen emissions, soil degradation, and water pollution. Sustainable agricultural intensification is key for preventing or reducing agricultural expansion into forest land and other land uses that are significant carbon sinks. Current efforts include the sustainable livestock program included in the Colombian Nationally Determined Contribution, several small-scale projects for enhancing agroecological practices, and the recently proposed (but not yet approved) law for the promotion of agroecological practices (AGROECOLOGÍA | Camara de Representantes, n.d.; Documentos Oficiales Contribuciones Nacionalmente Determinadas, n.d.). The roll-out of the extension service could be supported by its current financing system, but it would certainly require a larger budget allocation.

A third entry point is **ensuring sufficient financing for establishing production projects that have a strong component in sustainable practices**, covering the spectrum of available technologies (agroecology, agroforestry, sustainable cattle ranching, implementation of biodigesters, etc.). This implies not only reviewing credit priorities, conditions, and incentives (e.g., subsidized interest rates, temporary rent tax forgiveness) but also integrating the programs envisioned in the comprehensive climate change management plans at the sectoral and regional levels with the planning of the national agricultural credit program.

An interesting possibility is to **coordinate actions on these three entry points** with the United Nations' initiative for transforming food systems (Home | UN Food Systems Coordination Hub, n.d.). In the case of Colombia, the latter intersects with food production diversification; the improvement of national food markets and promotion of fair trade for producers and consumers; the promotion of family agriculture, including through the valuation of their traditional knowledge; agroecology; food security and nutrition, including policies focused on vulnerable groups such as pregnant women and children; sectoral plans for adaptation to climate change and reduction of carbon emissions in agriculture; strengthening resilience to climate change, pandemics and conflicts; and professionalization and digitization of public services for agriculture and agribusiness. An effort in this direction would be of great help by providing much-needed coordination among plans and programs that otherwise have low interaction and tend to create an undesirable dispersion of efforts.

Lastly, **improving and keeping momentum regarding restoration and afforestation** is key. The National Plan for Ecological Restoration, Rehabilitation, and Recovery of Degraded Areas, the National Policy for the Integral Management of Biodiversity and its Ecosystem Services and Law 2173 of 2021 for promoting ecological restoration are important instruments to enhance and preserve mega biodiversity and ecosystem services in our country. Therefore, it is imperative to sustain the implementation of programs such as Forests of Peace, the Adaptation to Climate Change project in High Mountain Ecosystems (Páramos), the REDD+ program, and others. Moreover, decision-makers must consider the following anticipated challenges, such as:

- Deforestation and ecosystems degradation: Despite significant efforts by the current government, Colombia continues to experience high deforestation rates, particularly in the Amazon and Andean regions. This deforestation is primarily driven by agricultural expansion, illegal crops and mining, and infrastructure development.
- Climate change: The increased frequency of extreme weather events, such as fires and floods, poses additional challenges to restoration efforts.
- Funding: Securing adequate funding and resources for large-scale restoration projects remains critical. This challenge includes financial resources and the necessary technical expertise to implement effective restoration strategies.
- Community engagement: Ensuring the active participation and engagement of local communities, Indigenous groups, and other stakeholders is essential for the long-term success and sustainability of restoration projects. Their involvement is crucial for fostering ownership and ensuring that restoration efforts are aligned with local needs and knowledge.

By addressing these challenges, Colombia would take great steps towards continuing its leadership in ecological restoration, leveraging its rich biodiversity and commitment to sustainable development. Articulation and strengthening of policies, increasing investment in restoration projects, and fostering collaboration between the government, NGOs, academia, and local communities will be crucial for advancing these efforts.

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