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Bolivia's Net Zero path: Investment needs, challenges, and opportunities

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Due to high levels of deforestation, Bolivia's per capita CO_2 emissions are currently among the highest in the world. Indeed, at more than 25 tCO_2eq/person/year, they far exceed the per capita emissions of the United States and the United Arab Emirates. Achieving Net Zero would require a complete change of the current resource-intensive development model and would especially have to adjust the incentives that are promoting the rapid expansion of soybean farming and cattle ranching in the Bolivian Amazon and Chiquitano forests. This paper identifies the main sources of emissions in Bolivia and the most cost-effective measures to reduce them, under the condition that the selected measures do not decrease average incomes nor increase poverty compared to the Business-as-Usual scenario. The paper estimates the magnitude of the investment needed to reduce net emissions to zero by 2050 at about \$150 billion or 7.8% of Bolivia's GDP between 2022 and 2050. To make sure that poor people are not hurt by the Net Zero strategy, most of the funds should be used to promote alternative and more sustainable economic opportunities for Bolivians, including resilient and diverse agro-forestry activities, zero-deforestation beef production, nature-based tourism, high value-added wood products, scientific research, etc. These alternative opportunities should include women as much as possible, so as to provide more gender equal opportunities than the traditional activities at the agricultural frontier. The paper reviews different financing options and proposes a simple, easily verifiable, performance-based mechanism, that shares the costs and benefits of reduced deforestation fairly. Finally, the paper discusses the main social, economic, and political challenges to achieving these goals.

KEYWORDS
climate change, greenhouse gas emissions, NDCs, mitigation, deforestation, Net Zero, Bolivia

Introduction

Bolivia's CO_2 emissions from fossil fuel consumption and cement production amount to around 2.1 tCO_2 per person per year, which is fairly typical for a lower-middle income country.[1] However, these emissions are dwarfed by the emissions caused by deforestation. According to Global Forest Watch,[2] between 2001 and 2021, Bolivia lost 6.67 million hectares of forest cover, causing the emissions of 3.01 Gt of CO_2 emissions. This corresponds to average emissions of 451 tCO_2 per hectare of forest burned. Deforestation in Bolivia has increased steadily over the last two decades, reaching a peak of 852,000 hectares of forest loss in 2019. In 2021, forest loss was the second highest ever recorded at 558,000 hectares, causing emissions of 259 million tCO_2.[3] With a Bolivian population of 11.82 million, this corresponds to about 21.9 tCO_2 per person from deforestation alone in 2021.

When adding emissions from all other sources of about 6 tCO_2eq per person (see Section Main sources of greenhouse gas emissions in Bolivia, 2021–2050), we arrive at total per capita emissions of almost 28 tCO_2eq/person in 2021. This is considerably higher than per capita emissions in the United States of America and United Arab Emirates (both around 15 tCO_2eq/person)[4] and more than five times higher than the global average (around 5 tCO_2eq/person).

Greenhouse gas emissions per unit of GDP are even more worrying. Dividing Bolivia's emissions of 327 million tCO_2eq (27.6 tCO_2eq/person $\times$ 11.82 million persons) by its GDP of 106.86 billion PPP$ in 2021,[5] we get an emissions intensity of 3.1 $kgCO_2$/PPP$, which is 10 times higher than the global average of 0.3 $kgCO_2$/PPP$.[6]

As Bolivia grows richer and more populous over the coming decades, greenhouse gas emissions are expected to increase further under the Business-As-Usual (BAU) scenario, although emissions intensity is expected to fall, following the trend of the rest of the world. Reaching Net Zero, will require a dramatic deviation from the current emissions trajectory.

The remainder of the paper is organized as follows: In Section Main sources of greenhouse gas emissions in Bolivia, 2021–2050, we develop a BAU emissions scenario for 2022 to 2050, for each of the emissions sources in Bolivia. This allows us to visualize the main greenhouse gas emissions which will have to be tackled in order to reach Net Zero. Section The most cost-effective path to Net Zero outlines the optimal path to Net Zero, focusing on the biggest and lowest-hanging fruits first (deforestation and fossil fuel subsidies), while waiting a while for global technological advances to take place before investing massively in electrification of the transport sector and the industrial sector. Section Total financing needs for Bolivia's Net Zero path estimates the total costs of moving from the BAU path to the Net Zero path, as well as the type of investments needed to achieve it. Section Financing options discusses different financing options, and proposes a simple, easily verifiable, performance-based mechanism, that shares the costs and benefits of reduced deforestation fairly. Finally, Section Concluding remarks provides some concluding remarks concerning the likelihood of Bolivia reaching Net Zero by 2050, and the main factors that can influence this likelihood.

Main sources of greenhouse gas emissions in Bolivia, 2021–2050

In this section we develop the Business-As-Usual (BAU) scenario for total greenhouse gas emissions in Bolivia, and its main components, from 2021 to 2050, as this will indicate the main emissions sources which need to be tackled in order to reach Net Zero.

The main source of emissions data comes from the Third Official Communication regarding Bolivia's greenhouse gas emissions (Estado Plurinacional de Bolivia, 2020). Unfortunately, it only has estimations until 2008, but it is still useful for obtaining the parameters needed to calculate the emissions scenarios needed for this paper.

Most of the economic information for the BAU scenario are obtained from Andersen and Jemio (2015), which developed a BAU scenario for Bolivia from 2001 to 2100 in order to estimate the impacts of climate change on the different sectors of the Bolivian economy. Their BAU scenario includes expected population growth (reaching 16.7 million inhabitants in 2050), the demographic transition, rural-urban migration, expansion of the agricultural frontier, increased education levels, and other ongoing structural changes. Everything was modeled in a dynamic-recursive computable general equilibrium model, BOLIXXI, to make sure that the BAU scenario was both theoretically feasible and internally consistent. Their projection of BAU deforestation levels was particularly thorough, taking into account the demand for agricultural output and land, availability of capital and labor, as well as topography, road access, distance to markets, protected areas, and other geographical limitations, in order to estimate deforestation levels in each municipality every year from 2001 to 2100. These deforestation projections will be used in the BAU scenario

1 See Our World in Data: https://ourworldindata.org/grapher/co2-emissions-vs-gdp?xScale=linear&time=latest&country=\simBOL.

2 See Global Forest Watch: https://www.globalforestwatch.org/dashboards/country/BOL/.

3 See Global Forest Watch: https://www.globalforestwatch.org/dashboards/country/BOL/.

4 See Our World in Data: https://ourworldindata.org/co2/country/china?country=USA\simARE.

5 See the World Bank's World Development Indicators: https://data.worldbank.org/indicator/NY.GDP.MKTP.PP.CD?locations=BO.

6 See the World Bank's World Development Indicators: https://data.worldbank.org/indicator/EN.ATM.CO2E.PP.GD.

for this paper, as will the projected growth rates of real GDP until 2050.

Information about the initial investments and operating costs associated with different measures to reduce emissions are obtained from Gonzales et al. (2022), which evaluates the economic impacts of Bolivia's most recent Nationally Determined Contributions (NDC).

The remainder of this section summarizes historical and expected future emissions from the main emission sources in Bolivia. Details are available in the Supplementary material.

Historical and expected emissions from deforestation

Deforestation rates vary considerably from year to year, depending mainly on climatic conditions, but the general trend in annual deforestation in Bolivia over the last two decades has been exponential growth of more than 5.5% per year. In 2021, Bolivia lost 558,393 hectares of forest, of which 291,000 hectares were humid primary forest, which is the highest loss of primary forest ever registered in Bolivia in 1 year.[7] However, such growth rates cannot be sustained over the long run, as the country would simply run out of forest.

Andersen and Jemio (2015) developed a more realistic BAU scenario for long run deforestation trends in Bolivia, taking into account increased demand for agricultural production, but also limitations on the availability of labor and capital, as well as physical restrictions on the availability of forest and the increasingly difficult access to it. They used a combination of a dynamic-recursive computable general equilibrium model, BOLIXXI, and a GIS model, the first of which secured that capital and labor restrictions were adequately taken into account, while the latter took into account geo-physical restrictions.

The BOLIXXI projections assumed that no deforestation would take place within protected areas, an assumption which turned out to be unrealistic, as there has been considerable deforestation within protected areas the last several years. During the 2016–2020 period, an average of 128,658 ha of forest within protected areas was lost per year, resulting in CO_2 emissions of 28 million tCO_2 per year.[8]

Figure 1 compares actual forest loss during 2001–2021, with the projections of the BOLIXXI model of Andersen and Jemio (2015). If anything, the projection has been too conservative compared to reality. According to the projection, Bolivia will lose about 24% of its current forest cover between 2022 and 2050. This is not unrealistic given current policies, which aim to substitute diesel imports with biodiesel generated from locally produced soybeans, and also aim to replace dwindling natural gas exports with increasing meat exports (Estado Plurinacional de Bolivia, 2021; Fundación Solón, 2021). For the purposes of quantifying emissions for the BAU scenario, we will adopt the BOLIXXI projection, although it may be slightly too conservative.

According to Global Forest Watch, over the last two decades the average emissions per hectare of deforestation in Bolivia has been 451 tCO_2, and we will assume that the same number holds for the next three decades as well. This leads to emissions from deforestation slightly dropping from 252 million tCO_2 in 2021 to 218 million tCO_2 in 2050.

Historical and expected emissions from agriculture

Apart from deforestation, by far the most important source of greenhouse gas emissions from the agricultural sector in Bolivia is methane from cattle. According to Estado Plurinacional de Bolivia (2020), cattle-related methane emissions in 2008 amounted to 13.9 million tCO_2eq, while nitrous oxide emissions and methane emissions from non-cattle-related agriculture amounted to only 1.0 million tCO_2eq. We can therefore assume that greenhouse gas emissions from agriculture is proportional to the number of cattle in the country. According to FAOSTAT, the number of cattle in Bolivia increased steadily from 6.5 million heads in 2001 to 10.1 million heads in 2020, corresponding to an average annual growth rate of 2.25%.

According to Bolivia's Economic and Social Development Plan 2021–2025, the plan is to increase the number of cattle to 18.3 million heads by 2025 (Estado Plurinacional de Bolivia, 2021, Action 3.2.6.1), which will require average annual growth of 12.5% for a while. But such rapid growth is unrealistic in the long run, so we will assume that the growth rate of the cattle herd reverts to 2.25% per year after 2025. This implies total methane and nitrous oxide emissions from the agricultural sector of 61 million tCO_2eq by 2050.

Historical and expected emissions from electricity generation

Bolivia has a relatively clean energy matrix with 62% of electricity generated from natural gas, 30% from hydroelectric plants, and 8% from alternative sources, such as biomass, solar and wind (AETN, 2022). Total electricity consumption

7 See Global Forest Watch: https://www.globalforestwatch.org/dashboards/country/BOL/.

8 According to the proposal submitted by the Plurintational State of Bolivia to LEAF (Lowering Emissions by Accelerating Forest Finance) on 28 July 2022. Deforestation estimates were based on the Hansen Global Forest Change v.1.8 (2000–2020) dataset, above and below-ground carbon contents were obtained from Spawn et al. (2020), and shapefiles of Protected Areas were retrieved from GeoBolivia in July 2021.

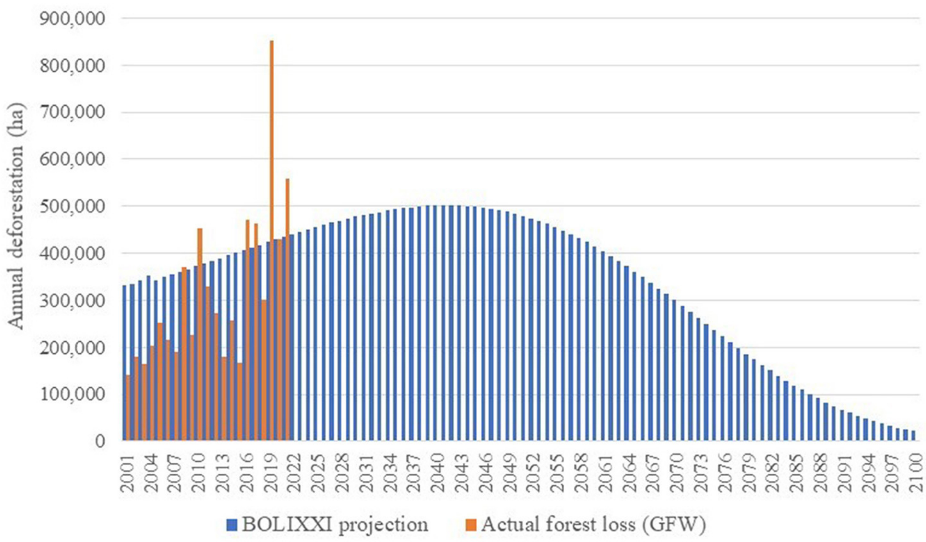

FIGURE 1
Actual forest loss vs. BOLIXXI projected forest loss in Bolivia, 2001-2021-2100. Source: Authors' elaboration based on data from Global Forest Watch and projections from Andersen and Jemio (2015).

increased from 3,762 GWh in 2001 to 10,879 GWh in 2021, corresponding to an average annual growth rate of 5.5%.

According to Bolivia's latest Greenhouse Gas Inventory, the electricity sector was responsible for 2.0 million tCO_2 of emissions in 2008 (Estado Plurinacional de Bolivia, 2020). If we attribute all these emissions to natural gas power plants (thus assuming no emissions from hydro, biomass, solar and wind), we can calculate average emissions per MW of installed capacity of natural gas power plants. In 2008, Bolivia had a total natural gas power plant capacity of 994 MW, so on average each MW of natural gas power emitted 2.04 tCO_2 per year. By 2021, natural gas power plant capacity had increased to 2,596 MW, meaning that emissions from the electricity sector had grown to about 5.3 million tCO_2. For our BAU scenario, we assume that the energy matrix maintains the current structure and that emissions keep increasing by the same rate as real GDP, leading us to 33 million tCO_2 by 2050.

Historical and expected emissions from the transport sector

According to Bolivia's latest Greenhouse Gas Inventory, the transport sector was responsible for 5.3 million tCO_2 of emissions in 2008 (Estado Plurinacional de Bolivia, 2020). At that time, Bolivia had a fleet of 842,857 vehicles,[9] meaning that average annual emissions amount to about 6.25 tCO_2 per vehicle. By 2021, the Bolivian fleet had increased to 2,226,662 vehicles, corresponding to an average annual growth rate of 7.8% between 2008 and 2021. Assuming that average emissions per vehicle have not changed since 2008, by 2021 emissions from the transport sector would be around 13.9 million tCO_2.

Paz (2020) carried out a detailed analysis of the potential for reducing emissions in the Bolivian transport sector, and for the period 2022–2030 we will use his BAU scenario for emissions. After that, we let emissions from the transport sector grow at the same rate as real GDP. With these assumptions, transport sector emissions will reach 39.1 million tCO_2 by 2050.

Historical and expected emissions from industry

According to Bolivia's latest Greenhouse Gas Inventory, the industrial sector was responsible for 16.8 million tCO_2eq of emissions in 2008 (Estado Plurinacional de Bolivia, 2020). Only 7% of these emissions were in the form of CO_2, while 93% come from Hydrofluorocarbon-134a, which is a gas 1,300 times more potent than CO_2 and used mainly in refrigeration and air-conditioning.

For lack of more detailed studies concerning the future of these emissions, for our BAU scenario we will assume that industry-related emissions increase at the same rate as real GDP. This is a somewhat conservative assumption, as emissions intensity typically declines over time. This would particularly be the case if economical coolants with lower

9 Instituto Nacional de Estadísticas: https://www.ine.gob.bo/index.php/estadisticas-economicas/transportes/parque-automotor-cuadros-estadisticos/.

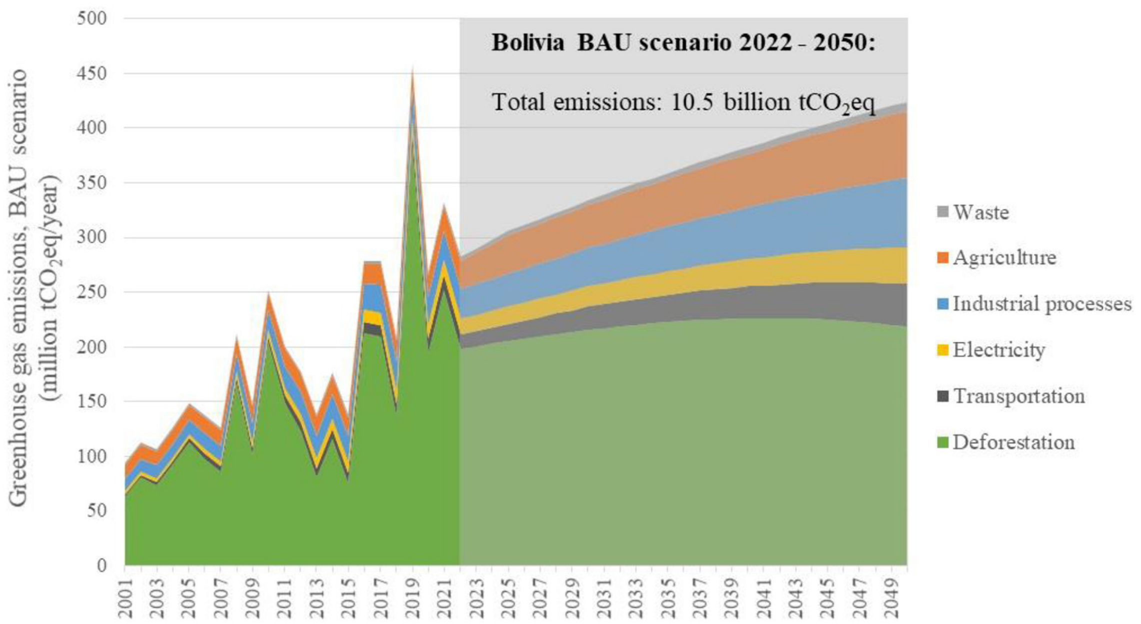

FIGURE 2
Historical (2001–2021) and future (2022–2050) BAU greenhouse gas emissions in Bolivia. Source: Authors' calculations based on assumptions explained in the text.

global warming potential are developed and made available to developing countries.

Historical and expected emissions from waste

Waste is a minor source of greenhouse gas emissions in Bolivia. According to the latest Greenhouse Gas Inventory, waste was responsible for 2.2 million tCO_2eq of emissions in 2008 (Estado Plurinacional de Bolivia, 2020). For our BAU scenario, we will assume that waste-related emissions increase at the same rate as real GDP.

Total BAU emissions in Bolivia, 2021–2050

With the assumptions expressed in the previous sub-sections, we obtain a BAU scenario for Bolivia's greenhouse gas emissions as shown in Figure 2, with historical emissions from 2001 to 2021, and projected BAU emissions from 2022 to 2050. During the 2001–2021 period emissions grew at an average annual rate of 6.52%, while for the 2022–2050 BAU scenario they are expected to grow at an average annual rate of 1.46%.

Future BAU emissions between 2022 and 2050 sum to 10.5 billion tCO_2eq, of which 60.5% is caused by expected deforestation, 12.0% from industrial processes, 12.5% from agriculture, 7.2% from the transport sector, and only 6.3% from the production of electricity.

In order to gradually reach Net Zero by 2050, total emissions would have to drop from 332 million tCO_2eq in 2021 to zero in 2050. The resulting emissions between 2022 and 2050 in the Net Zero scenario sum to 4.0 billion tCO_2eq, which is 6.5 billion tons less than the BAU scenario.

In the following section we will analyze how best to achieve this reduction.

The most cost-effective path to Net Zero

While reaching Net Zero eventually requires changes in all sectors, it is worth focusing on the biggest and lowest-hanging fruits first. In the case of Bolivia, deforestation is by far the biggest contributor not only to greenhouse gas emissions, but also to biodiversity loss and increased risk of droughts and floods. With the right policies and incentives, deforestation can be rapidly reduced to zero, and some formerly deforested land can be allowed to grow back into forest, thus absorbing CO_2 from the atmosphere, offsetting the harder to reduce emissions, such as those from industrial processes. We will analyze the potential contributions of the forest sector in Sections Reducing emissions from

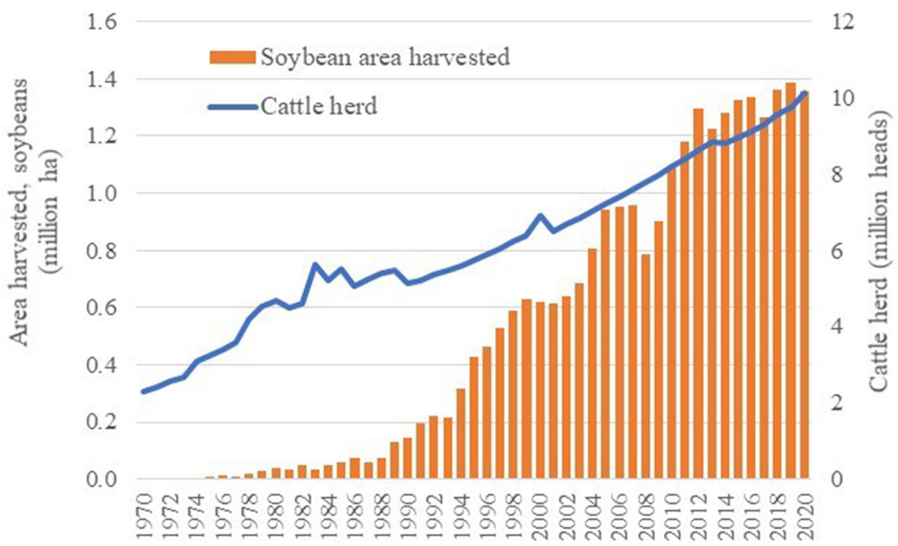

FIGURE 3
Historical growth in soybean area and cattle herd in Bolivia (1970–2020). Source: Authors' elaboration based on data from FAOSTAT.

deforestation and Carbon sequestration from natural forest regrowth below.

Electricity generation is also relatively easy to decarbonize, as Bolivia has plenty of potential for solar, wind and hydroelectric energy generation, and these technologies are rapidly becoming competitive with natural gas-based electricity generation. The problem is that Bolivia heavily subsidizes the price of natural gas for electricity companies, which means that, from the viewpoint of the electricity generating companies, alternative energy is far from being competitive in Bolivia. Thus, to facilitate this transition, Bolivia has to gradually phase out the fossil fuel subsidies. This is necessary anyway as the government is spending most of its natural gas export revenues on subsidizing fuel domestically, and it is a becoming major problem for the government's budget (Medinaceli Monrroy and Velásquez Bilbao La Vieja, 2022). Phasing out this subsidy has been tried before, unsuccessfully, but in Section Reducing fossil fuel subsidies below we will outline a strategy that might make it possible.

Decarbonizing the transport sector is much harder in the short run, but as electric vehicle technology improves in the rest of the world, and the production of fossil-fueled vehicles sooner or later phases out, Bolivia will eventually adopt the technologies that dominate the world market. Meanwhile, the contributions of the various transport electrification initiatives like the urban cable car system in La Paz and El Alto (*Teleferico*) and Bolivia's very own electric cars (Quantum) are mostly symbolic.

Reducing emissions from deforestation

In order to permanently reduce deforestation, without harming Bolivian farmers or the Bolivian economy, a combination of incentives is needed. At the macro-economic level, it is important to ensure that limiting deforestation is in the best interest of the country, meaning that this path provides more foreign currency revenues, more government revenues, more and better jobs for the population, less volatility, and lower risks of climate-related disasters than the Business-as-Usual scenario. At the micro-economic level, a combination of positive and negative incentives needs to be implemented to ensure that the local population also finds limiting deforestation in their best interest.

Macro level incentives

One of Bolivia's main poverty reduction strategies is to encourage people to move from the rural highlands to the rural lowlands. In the rural highlands, most people engage in subsistence farming, but the climate is inhospitable (freezing cold and dry half the year) and over generations landholdings have been divided so many times that the average size of landholdings is just a few hectares, which is not enough for a family to escape poverty (Andersen et al., 2020). In the rural lowlands, on the other hand, a migrant family can obtain hundreds of hectares of forested land for free, and they can immediately insert themselves into an export-oriented

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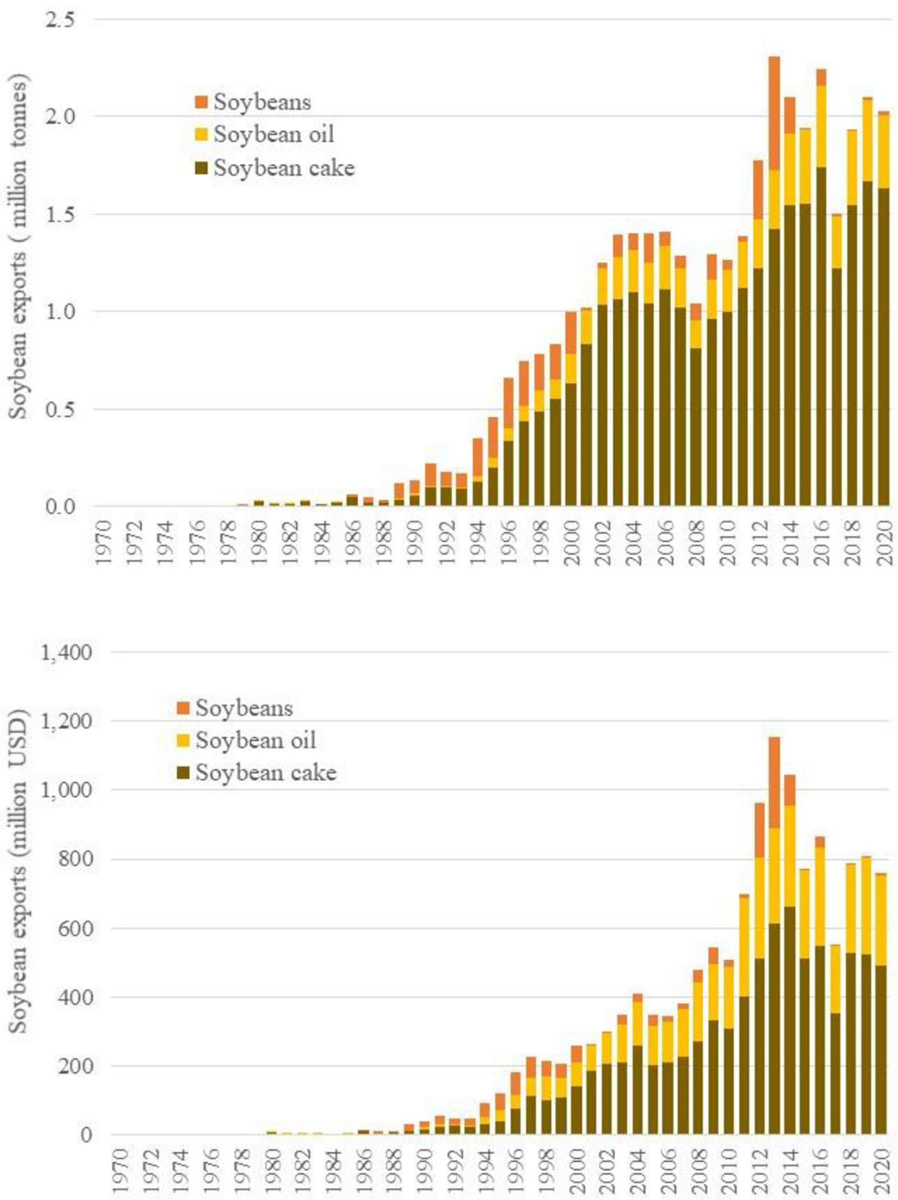

FIGURE 4
Historical soybean exports, quantity and value (1970–2020). Source: Authors' elaboration based on data from FAOSTAT.

agro-industrial complex, either by renting newly-cleared land to large soybean producers, by entering into production-sharing agreements with them, or by working for them as hired labor.

With the abundance of public lands available in the lowlands, this has been an easy way for the government to provide new and better opportunities for poor families, while at the same time boosting agricultural exports.

Figure 3 shows how the area of soybean production has increased from virtually nothing in 1970 to almost 1.4 million hectares in 2020. The other five million hectares deforested since 2001 is used mainly for cattle, which has just passed 10 million heads.

While cattle are mostly for national consumption, soybeans are for export, mainly in the form of soybean cake, but soybean oil is becoming increasingly important. In terms of quantity, soybean exports have averaged about two million tons per year the last several years, and in terms of value it exceeded a billion dollars for the first time in 2013 (see Figure 4). With the recent increases in soybean prices, it is expected to surpass a billion dollars again this year.

On average over the last 10 years, each hectare of soybeans brought in about $650 in export revenues per year (FAOSTAT, 2022). This is not a lot compared to what developed countries generate from a hectare of land, but it is way more than standing forest currently generates in Bolivia. For the low deforestation scenario to become attractive, we need to make sure standing forest generates more than $650 per hectare per year in foreign currency inflows.

A simple way to ensure this would be through a long-term agreement (until 2050) of performance-based international compensation for reduced deforestation. The mechanism should be as simple and transparent as possible and it should be beneficial to Bolivia, the international community, and the environment. It should also reward consistency rather than random fluctuations.

It is important that the agreement is long-term, because it needs to achieve a qualitative shift in economic activities and behaviors, and such shifts take many years. It is not enough to pay people to refrain from deforesting for a few years. They have to be equipped with enough funds and skills and opportunities to create new livelihoods for themselves, so they have no desire to deforest in the future.

The simplest possible mechanism would be to pay Bolivia $9,000 for each hectare of deforestation below an agreed baseline. Since each hectare of forest on average emits 451 tons of CO_2 when deforested, this corresponds to an average CO_2 price of $20/t$CO_2$, which is an attractive price for the international community. It is also sufficient to invest in technology to improve efficiency in the agricultural sector and strengthen institutional capacity to control deforestation.

Micro-level incentives to reduce deforestation

It is not enough that the macro-level strategy of reducing deforestation is sound–incentives also have to be implemented to change behaviors and decisions at the individual level.

The private benefits of deforesting land in Bolivia are 2-fold: (i) agricultural revenues, and (ii) claiming land that is likely to appreciate in value over time.

According to Müller et al. (2014), about half of all deforestation in Bolivia is associated with cattle ranching. Generally, the density of cattle is low, and, according to ongoing research by Conservation Strategy Fund in the department of Santa Cruz, net revenues from cattle ranching is typically in the range of $50–$200 per hectare per year.

The other main driver of deforestation is industrial agriculture, mainly soybean farming, which yields higher returns, typically $200–$600 per hectare per year, which is still very low compared to farming in other countries.

Probably the main private benefit of deforestation is claiming land that is likely to appreciate in value over time. Since the system of land rights in Bolivia is still underdeveloped, a common way of claiming land is to deforest it and put a few cattle on it, so that it looks occupied. In contrast, forested land appears available, and risks occupation by settlers looking for a plot to claim. This means that both land owners and settlers looking to become land owners have an incentive to clear forest to either protect or gain property rights (Colque, 2022).

Currently, it is virtually costless to deforest land in Bolivia. Small land-owners with 50 hectares or less are allowed to clear up to 20 hectares without any paperwork or costs involved. Bigger land owners are supposed to develop plans for their properties and obtain permits to clear forest, but in reality, they usually get away with clearing large extensions of forests without going through these bureaucratic steps, as the government is not really trying to control deforestation. Toward the end of 2019, after a catastrophic year of forest fires, the Ministry of Rural Development and Land informed the public that 1.5 million hectares of former forest land had been "regularized," allocating 611,000 hectares for crops and another 843,000 hectares for cattle, while 51,000 hectares should be reforested (Colque, 2022).

The government can let people deforest with impunity because forests are abundant in Bolivia and the costs for the government is low, while the benefits in terms of food production and exports are significant. However, if the abovementioned compensation of $9,000 per hectare of reduced deforestation were to be implemented, the opportunity cost for the government would suddenly become very high, and it would make sense to start controlling deforestation.

The most logical action would be to start charging farmers $9,000 per hectare they want to deforest, as that would be the true opportunity cost. But that would cause an outrage in Bolivia, and it would completely destroy the poverty-reducing mechanism of the resettlement schemes. Farmers probably need to receive a free deforestation allowance of about 20 hectares, after which they could be charged a fee for additional deforestation permits.

It would also be necessary to consider the transfer of resources from reduced deforestation compensation to the productive sectors linked to the problem of deforestation. In that sense, two programs could be established. One focused on increasing the productivity and value of forest dependent activities (shade-grown coffee, cocoa, açai, Brazilian nuts, eco-tourism, among others). And another focused on increasing the productivity of livestock and agriculture, through the transfer of technology and promotion of best practices. These programs can also help promote deforestation-free Bolivian products in international markets to ensure they are economically viable.

Additionally, to compensate for the higher production costs, and leave farmers at least as well off as in the BAU scenario, they need to obtain recognized land-ownership without necessarily clearing the forest. One way to do that is to give them clear property rights without the need to deforest, and indeed give them the option of enrolling most of their land in a conservation scheme, in which they would get paid an annual amount per hectare for protecting their forest. This gives them both solid evidence of their land ownership, as well as a payment that makes standing forest more valuable to them. They can then use the revenues to intensify and modernize production in a smaller cleared area.

Carbon sequestration from natural forest regrowth

Even if Bolivia managed to reduce deforestation all the way to zero, in order to reach Net Zero for the whole country, it would be necessary to absorb some CO_2 to offset emissions from transportation, industrial processes and other hard-to-reduce emissions. This can be done by increasing the forested area, either by active afforestation or reforestation initiatives, or by simply letting previously deforested areas naturally grow back into forest.

Natural forest regeneration

If deforested land is left alone, it will usually grow back into mature forest in 35–40 years, absorbing CO_2 in the process (Reis and Andersen, 2000; Houghton and Hackler, 2001; Andersen et al., 2016). The rate of regrowth varies over time, being generally faster in the beginning and slowing down as the forest approaches maturity. In a systematic analysis of 13,112 georeferenced measurements of carbon accumulation in naturally regenerating forest, and assuming linear growth during the first 30 years, Cook-Patton et al. (2020) find average predicted values of carbon accumulation of about 17 tCO_2/ha/year for South American rainforest, 12 tCO_2/ha/year for South American moist forest and mountain forest, and 7 tCO_2/ha/year for South American tropical dry forest, which are the four main types of forest relevant for potential regrowth in Bolivia. Following this evidence, we can assume that 90% of the original carbon contents will be absorbed during the first 30 years of regeneration at an average annual rate of 0.9*451/30 = 13.5 tCO_2/ha/year. Further assuming that we let the most marginal land, with the lowest opportunity costs, grow back, the opportunity cost will be similar to reduced deforestation, at \$20/tCO_2.

In order to off-set current emissions from transportation, energy, industrial processes, agriculture and waste of about 80 million tCO_2/year, Bolivia would need 5.9 million hectares of regenerating forest. This corresponds to about 88% of all the land that has been deforested in Bolivia since the year 2000.

Unless Bolivia manages to reduce emissions from transportation, energy, industrial processes, agriculture and waste in some other way, by 2050 the country would need 15 million hectares of regenerating forest to offset the expected BAU emissions of 206 million tCO_2/year. Bolivia does not have that much deforested land available, so it would have to actively plant forest where it has not naturally grown in recent history. This is possible, but it is very expensive, and cannot be a significant part of the optimal path to Net Zero.

Mature forest carbon sink

Due to CO_2 fertilization, even mature forests tend to slowly gain biomass (Phillips et al., 2008; Pan et al., 2011). Phillips et al. (2017) estimated that mature forests in Bolivia absorbed an average of 40.8 TgC/year during the period 1980–2010. Since 1 gC = 3.67 gCO_2, this corresponds to 150 million tCO_2/year. Recent studies, however, suggests that the role of Amazon forests as a carbon sink is declining (Brienen et al., 2015; Hubau et al., 2020; Gatti et al., 2021), not only because there is less mature forest left, but also because some forest ecosystems, especially in the eastern Amazon, are experiencing higher tree mortality due to an intensification of the dry season (Gatti et al., 2014; Doughty et al., 2015).

For now, mature forests in Bolivia offset a significant part of the country's CO_2 emissions, but this carbon capture and storage service is usually not recognized in climate negotiations, probably because then many countries would also be able to take credit for the carbon capture of the oceans. In addition, there is a risk of the entire Amazon reaching a tipping point in which it can no longer sustain itself as a rainforest. The resulting tree mortality would not only cause immense CO_2 emissions and mass species extinction, but it could also change the hydrological cycle across the entire continent. The direct damages of deforestation are much bigger than the indirect damages from increased CO_2 in the atmosphere, which is why reducing deforestation should be of much higher priority than reducing CO_2 emissions from other sources, such as electricity generation, aviation or shipping.

Reducing fossil fuel subsidies

Fuel prices in Bolivia have been fixed since the Supreme Decree 27992 of 28 January 2005: Gasoline at a price of Bs. 3.74 per liter and Diesel at a price of Bs. 3.72 per liter. This stability has been very beneficial for consumers, but it has lately become very expensive for the government, since the true costs are several times higher. Medinaceli Monrroy and Velásquez Bilbao La Vieja (2022) recently calculated the costs of the fossil fuel subsidies in Bolivia and found that the direct annual costs have reached 1.3 billion, which is equivalent to 3% of GDP. However, the overall cost of the subsidy represents 11.6% of GDP. This estimation considers: the opportunity cost of selling production to the domestic market instead of exporting it; the direct importation of gasoline, diesel oil and Liquefied Petroleum Gas (LPG) at high prices for subsequent sale at low prices; the non-updating of the margins of the value chain of petroleum derivatives; the tax sacrifice for not collected Value Added Tax (VAT) and; the incentive given to the operators of the fields in Bolivia.

This subsidy not only generates economic losses to the economy, but also contributes to an inequitable distribution of resources (the poor do not benefit from the subsidy, as do the high-income generating sectors, such as mining and soy bean production), but also generates environmental problems whose costs will be assumed by future generations. Although the economic and environmental cost generated by the subsidy is known, eliminating the subsidy would inevitably face resistance from various sectors and possible social conflicts. For this reason, and considering the failure of previous attempts to eliminate the subsidy, a comprehensive strategy that considers preferential treatment for the most vulnerable sectors will be necessary.

According to Medinaceli Monrroy and Velásquez Bilbao La Vieja (2022); an efficient strategy to reduce the subsidy and avoid social conflicts should consider: (i) a gradual elimination, (ii) open dialogue and communication processes between economic policy makers and civil society, (iii) the establishment of support programs–direct money transfers–serve to mitigate the increase in prices in the most vulnerable sectors and, (iv) transparency in the use of fiscal resources released thanks to the elimination of said subsidies.

Of these recommendations, the most important is probably associated with the establishment of support programs. Since Bolivia is a lower-middle income country, with substantial levels of poverty, the policy of eliminating the subsidy must necessarily be accompanied by mitigation impact measurements, that must focus on the medium and low-income households. Thus, although the policy must be applied uniformly to all sectors, it will be necessary to eliminate its impact on the most vulnerable sectors, at least during the first years, through direct transfers that gradually compensate for losses due to removal of the subsidy.

Another element to consider is that the subsidy currently benefits sectors that have a direct link to deforestation and environmental pollution, such as agricultural production and mining, these sectors have access to subsidized diesel. Diesel imports in Bolivia represent more than USD 1.5 billion, which is equivalent to 70% of the total value of imported fuels. More than 35% of diesel consumption is in the Department of Santa Cruz (IBCE, 2015), where agribusiness is concentrated, and where 86% of deforestation occurs (Colque, 2022).

Total financing needs for Bolivia's Net Zero path

To reach Net Zero by 2050, Bolivia has to reduce its BAU emissions by 6.5 billion tCO_2eq between 2022 and 2050. Most of the reductions can be done relatively cheaply ($20/$tCO_2$) by dramatically reducing deforestation. If Bolivia follows its latest NDC and the linear path to Zero Deforestation by 2050, it can reduce emissions by 3.1 billion tCO_2. If it goes for more aggressive reductions with a goal of Zero Deforestation by 2030, it can potentially reduce emissions by 5.6 billion tCO_2 compared to Business-As-Usual. In the first case, the costs would be around USD 61 billion, and in the latter USD 112 billion.

Letting forest grow back naturally is expected to have a similar cost per tCO_2, and we could potentially pay farmers to let about four million hectares of their most marginal deforested land grow back into forest, while intensifying agricultural production on their remaining land. Over 28 years, this could absorb 1.5 billion tCO_2 at a total cost of USD 30 billion.

As we saw in Section Main sources of greenhouse gas emissions in Bolivia, 2021–2050, electricity is not a major source of emissions, but some emissions could potentially be avoided if Bolivia invested more in renewable energy instead of natural gas-powered plants. The initial investment costs tend to be higher, and there is a limit to how much solar and wind energy can be included in the system, but well-situated hydroelectric plants are an attractive option. If emissions from natural gas-based electricity is halved between now and 2050, another 325 million tCO_2 can be reduced, and the cost per tCO_2 is probably only slightly higher than for reduced deforestation, so that would only cost about one billion dollars.

Emissions from the transport sector are currently difficult to reduce significantly, but in the 2040s the global technology has probably evolved sufficiently to make it feasible. To obtain a rough idea of the magnitudes, we use the calculations of Gonzales et al. (2022) and assume that transport emissions can be reduced by 25% at a cost of $50/$tCO_2$. This would provide another 188 million tCO_2 of reduction at a cost of USD 9.4 billion.

It is clear from the above calculations that the slow reduction in deforestation is not enough to reach Net Zero by 2050. It would be necessary to go for the more aggressive deforestation reductions aiming for close to zero deforestation after 2030, four million hectares of regenerating forest, and some reductions from electricity generation and transport. With about USD 150 billion, it should be possible to reach Net Zero without hurting the Bolivian population and causing social unrest.

Most of these funds should be used to promote alternative and more sustainable economic opportunities for the population, such as resilient and diverse agro-forestry activities, zero-deforestation beef production, nature-based tourism, high value-added wood products, scientific research, etc. At the same time, deforestation should be prohibited in protected areas and it should become more expensive to obtain deforestation permits outside protected areas. Enforcing

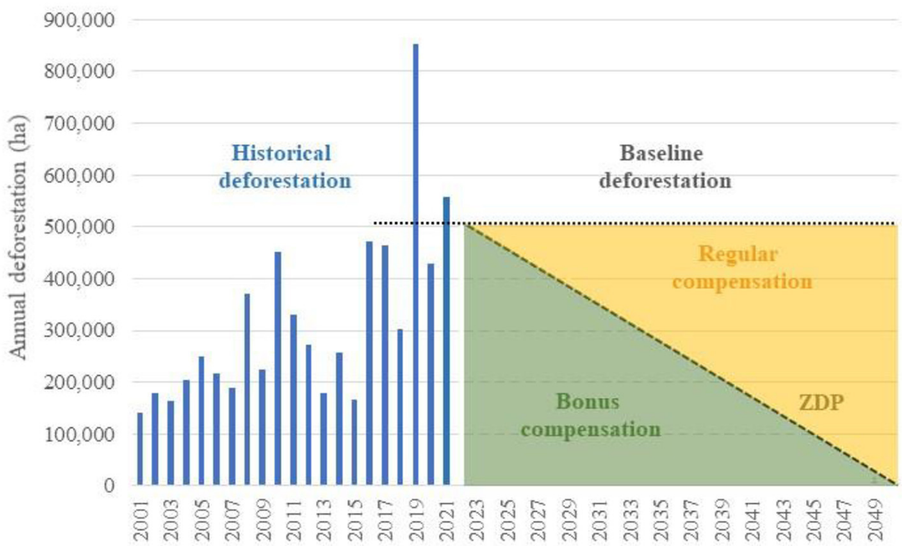

FIGURE 5
Historical deforestation, NDC commitment, and Zero deforestation by 2050 (Scenario 1). Source: Authors' elaboration.

this will entail some up-front investment, but in general the system should be able to finance itself through deforestation permits and fines. It is also necessary to change and strengthen the system of property rights, so that deforestation no longer functions as a way of claiming land. In addition, the government needs to change laws so that public money and pension funds can only be invested in agriculture that is deforestation-free.

Financing options

In the previous section we calculated that Bolivia would need to invest a total of USD 150 billion between 2022 and 2050 to facilitate the Net Zero transition. This corresponds to 7.8% of Bolivia's projected GDP during the period, and this investment would be on top of all the other investments it needs to make to cover basic needs like water, sanitation, electricity, education, public infrastructure, safety, etc.

The United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol, and the Paris Agreement all call for financial assistance from rich countries to poor countries to adapt to and mitigate climate change. In this section we will discuss different options Bolivia has for financing the huge investments needed.

The options can be divided into three types: (i) Global climate funds, (ii) carbon markets, and (iii) REDD+ mechanisms. The advantages and disadvantages of each will be discussed in detail below, after which we will propose a better option.

Global climate funds

The biggest climate fund in the world is the Green Climate Fund (GCF)[10] established at the COP16 in 2010 to provide climate finance for developing countries. The Global Environment Facility (GEF) operates the GCF, together with three smaller funds: The Special Climate Change Fund (SCCF), the Least Developed Countries Fund (LDCF), and the Adaptation Fund (AF).

The latest performance review of the Green Climate Fund was published in June of 2019 (Green Climate Fund/Independent Evaluation Unit, 2019). By that time, the GCF had committed just over USD 5.3 billion to 102 climate projects and programs in many different developing countries, but mostly in Africa. The funding was expected to be leveraged with co-financing of USD 12.6 billion, reaching a total of USD 17.9 billion of investments. The expected reduction of greenhouse gas emissions from all these projects was about 1.5 billion tons of CO_2-equivalent, implying an average cost of about 12 USD/tCO_2eq.

Although the GCF had received pledges of USD 10.3 billion from donor countries, it is clear that the level of funding is woefully inadequate. The Fund does not even have enough to finance Bolivia's climate investment needs, and much less the needs of all 152 developing countries.

Apart from inadequate levels of funding, the performance review highlighted several problems, of which the following are particularly discouraging. First, the GCF's policies and

10 https://www.greenclimate.fund/

procedures are burdensome and inflexible (one-size-fits-all), implying that the GCF has gained a reputation as slow, nontransparent and unpredictable. Both accreditation and project cycle are heavy, compliance-driven processes, and this has become a bottleneck since compliance requirements accumulate and continue into the project cycle. Second, financing is highly concentrated in energy projects, while forestry, land use and ecosystems are underrepresented. Third, about 82% of all funding is channeled through international development institutions rather than being disbursed directly to the beneficiaries, thus adding an extra layer of bureaucracy and administrative costs. Fourth, current procedures are insufficient to report credibly on the impacts of GCF financed projects on climate change mitigation and adaptation (Green Climate Fund/Independent Evaluation Unit, 2019, Executive Summary).

Of the 207 GCF projects approved by the time of writing, not a single one involves Bolivia.[11]

Carbon markets

The goal of carbon markets is to internalize the negative externalities of carbon emissions in economic decisions across the world. However, unlike markets for goods and services, a carbon market does not appear spontaneously–it has to be artificially created by policy makers. One way to create such a market is to determine the maximum amount of CO_2 that can be emitted each year and distribute that number of emission permits to all economic actors across the world, and then allow actors to trade permits between them, depending on how valuable a permit is to each actor. A permit is only valuable if there is a system of control to secure that you do not emit carbon without a permit. Thus, a functioning carbon market necessarily needs a system of enforcement behind it.

Currently, there is no global carbon market-only regional or national markets. The European Union operates the biggest Emissions Trading Scheme (ETS) in the world, selling about 760 billion Euros worth of emission permits in 2021.[12] The price has exceeded 80 Euros per ton CO_2 for most of 2022 so far.[13] New Zealand has also implemented an ETS to help control their carbon emissions, and the price by mid-2022 was around 50 USD/tCO_2.[14] United States, despite being one of the world's largest greenhouse gas emitters, does not have an ETS. However, the state of California pioneered a cap-and-trade system in 2013, and after years of wildly fluctuating prices, they implemented a floor price and has managed to maintain a relatively stable price around 30 USD/tCO_2 so far during 2022.[15] In 2021, China implemented an ETS for its energy sector, with a price averaging about 7 USD/tCO_2 over the year.[16]

The abovementioned schemes constitute compliance markets where firms and countries are obliged to participate. There are also voluntary carbon markets where people can buy and sell voluntary offsets, but it is a tiny market compared to compliance markets, and the prices are generally low. For example, aviation and tech-industry offsets are selling for a few dollars per tCO_2, while nature-based offsets sell around 10 USD/tCO_2.[17]

The main problem with carbon markets is their fragility. The price is determined by political decisions, which any day might be rejected by the population if perceived as too damaging or unfair. If carbon markets are fragmented and only cover a small fraction of global emissions, they may also be considered ineffective, which means they would gradually loose support. Thus, the risk of a collapse of the carbon price is high, and a poor country would be ill advised to build a development strategy that relies on carbon markets and high carbon prices.

REDD+ mechanisms

Bolivia has tremendous potential for Reducing Emissions from Deforestation and Degradation (REDD+) because of three concurrent factors: (i) large amounts of forest, (ii) high deforestation rates, and (iii) low value of agricultural land. However, Bolivia has been reluctant to engage in REDD+ mechanisms for several reasons. First, forests are so much more than carbon, and the excessive focus on CO_2 emissions can create perverse incentives. Second, while tracking the absence of an invisible gas (reduced CO_2 emissions) is theoretically possible, it is difficult for the actual population living in the forest to understand. Third, if REDD+ is applied at the local level as a mechanism to reduce deforestation, then, by definition, it could only benefit communities that were expected to deforest, while communities already living in harmony with nature would not qualify. Fourth, a lot of the money go to consultants to calculate and certify the emissions reductions, rather than to the people living in the forest.

Nevertheless, REDD+ mechanisms have been implemented successfully in other parts of the region. For example, the Amazon Fund in Brazil received around USD 800 million during 2009–2014 (Marcovitch and Cuzziol, 2014). However, it is likely that, as a result of this, part of the deforestation in

11 https://www.greenclimate.fund/projects#overview

12 https://www.refinitiv.com/perspectives/market-insights/carbon-trading-exponential-growth-on-record-high/

13 https://carboncredits.com/carbon-prices-today/

14 https://environment.govt.nz/what-government-is-doing/areas-of-work/climate-change/ets/about-nz-ets/

15 https://carboncredits.com/carbon-prices-today/

16 https://chinadialogue.net/en/climate/the-first-year-of-chinas-national-carbon-market-reviewed/

17 https://carboncredits.com/carbon-prices-today/

the Brazilian Amazon was displaced to other parts of Brazil and to Bolivia, thus involving a high degree of leakage (Alix-Garcia and Gibbs, 2017; le Polain de Waroux et al., 2017; Garrett et al., 2018).

The LEAF coalition (lowering emissions by accelerating forest finance)

The goal of the LEAF Coalition[18] is to halt deforestation by financing large scale tropical forest protection. It is a new initiative first launched in 2021, with an initial fund of USD one billion provided by the governments of Norway, United Kingdom and United States, as well as a group of very large companies, like Amazon, Unilever, Nestlé, and Walmart.

LEAF guarantees a minimum price of USD 10 per ton of certified[19] emissions reductions from enrolled jurisdictions, although due to uncertainty and risk of leakage and/or reversal, the payment received may be closer to USD 5 per tCO_2.

Bolivia, deviating from a decade-long policy of not participating in REDD+ schemes, applied for enrollment in LEAF in July of 2021, with a three-step plan of increasing ambitions. During the first 5 years (2022–2027) all the country's protected areas (more than 25% of the national territory and 22 million hectares of forest) would be enrolled in the mechanism. Average annual CO_2 emissions from these protected areas during the reference period (2016–2020) were calculated at 28 million tCO_2/year. Thus, if Bolivia halted all deforestation in protected areas for 5 years, LEAF would have had to pay Bolivia USD 1.4 billion, which was more than the total size of the fund. During the second crediting period (2027–2030), the plan was to add all indigenous territories and communally owned lands, plus the entire departments of Beni, La Paz and Pando. The Phase 2 area would then include a total of 41 million hectares of forest. Finally, from the 1st of January 2031, the mechanism would cover the entire country, which was expected to have about 54 million hectares of standing forest at the time.

However, Bolivia's proposal was rejected on a technicality (protected areas were not considered a valid jurisdiction, despite being of particularly high conservation value). Still, Bolivia is planning to submit a new proposal to LEAF in 2022.

18 https://leafcoalition.org/

19 They follow the ART (Architecture for REDD+ Transactions) TREES (The REDD+ Environmental Excellence Standard) standard for the quantification, monitoring, reporting and verification of Greenhouse Gas (GHG) emission reductions and removals from REDD+ activities (https://www.artredd.org/trees/).

Authors' proposal for a simple performance-based mechanism to reduce emissions from deforestation in Bolivia

We propose a much simpler mechanism that achieves the same objectives, with very little bureaucracy involved. It is based on the following three principles:

1) Keep it simple and focus on things that can be observed
2) Reward consistently good behavior
3) Share costs and benefits fairly

To keep it simple, we propose to focus on deforestation rather than CO_2 emissions. Deforestation is very visible and relatively easy to measure. There are global initiatives doing that already in a standardized, timely, impartial manner for all countries (e.g., Global Forest Watch), and this service can be used as a basis for a national monitoring system linking real-time satellite information with enforcement on the ground.

Focusing on deforestation rather than CO_2-emissions also acknowledges that forests are much more than just carbon. Indeed, the costs of carbon emitted from deforestation may prove to be relatively small compared to other impacts of deforestation, such as (i) the destruction of habitat for countless species and communities, (ii) the increased risk of local floods and droughts as forests are not able to absorb heavy precipitation and channel it into the soils, (iii) the increased risk of the entire Amazon reaching a tipping point and changing into savanna, which would change the hydrological cycle of the entire continent.

Finally, focusing on deforestation rather than CO_2-emissions avoids spending a lot of resources on highly paid consultants thus freeing up funds to invest in real initiatives and people on the ground. When implementing the scheme at the national level, variations in carbon contents between plots will cancel each other out and reduces administrative costs dramatically.

To reward consistently good behavior, we propose that Bolivia should be paid regular compensation for reducing deforestation below an agreed baseline (such as the average for 2016–2020, which was 503,504 ha/year according to Global Forest Watch), and a bonus compensation for reducing deforestation below the Diagonal 2050 Zero Deforestation Path (ZDP) (see Figure 5). The payment per hectare of avoided deforestation should be modest in the beginning, but should increase every year if targets are consistently met.

Sharing costs and benefits fairly is vital to secure the acceptance and sustainability of any mechanism to reduce emissions. Bolivia, in its latest NDC, has promised that about half of its contributions to reducing emissions would be national, while the other half would require international support.

Thus, the authors believe that a fair way to share the costs and benefits of reduced deforestation in Bolivia would be the following:

1) All the deforestation reductions below the baseline scenario (BAU), but above the 2050 Zero Deforestation Path (ZDP), would be compensated by half of the Minimum Fair Payment. The Minimum Fair Payment could either be fixed at \$9,000/ha ($\sim$\$20/tCO_2) or it could be linked to one of the major carbon markets in the world.
2) Deforestation reductions below the ZDP would be compensated by the full Minimum Fair Payment (which would be at least \$9,000/ha, but could be higher if linked to an important carbon market).
3) To encourage consistently good behavior, the payment per hectare of reduced deforestation could be increased by 10% every year deforestation is below the ZDP line, while the price would return to the initial Minimum Fair Payment if targets are not met.
4) Emissions reductions between BAU and ZDP would be shared equally between Bolivia and the financing country/institution, recognizing joint responsibility, and avoiding that developed countries can simply buy offsets in developing countries. This means that most of the emissions reductions achieved through a bilateral agreement would be shared 50/50. However, if emissions are systematically lower than the ZDP, the financing partner can receive full credits for these reductions, as Bolivia has already reduced its emissions to the Net Zero Path.
5) Even with an attractive long-term agreement, the first steps will be very hard, and a \$1 billion advance payment when signing the agreement might be useful to get the scheme off the ground.

With such a system of incentives, and a very determined government, it is at least theoretically possible to not only generate better alternative economic opportunities for the rural population, but also to obtain enough funds to invest in clean energy and transportation solutions so as to reach true Net Zero by 2050.

With a nation-wide mechanism covering all of Bolivia, there is no risk of deforestation leakage within the national borders. However, unless similar mechanisms are implemented simultaneously in other countries, there is a risk of international leakage. For example, when a moratorium on soybean production in the Brazilian Amazon was implemented, soybean production clearly moved to other parts of Brazil and Bolivia instead (Alix-Garcia and Gibbs, 2017; le Polain de Waroux et al., 2017; Garrett et al., 2018). It is therefore important to join collaborative efforts between the countries of the region to reduce the risk of leakage.

Concluding remarks

Bolivia's per capita CO_2 emissions are currently among the highest in the world, exceeding 25 tCO_2eq/person/year. This is mainly due to high levels of deforestation caused by the expansion of the agricultural frontier for industrial scale farming. The government encourages this process, because it brings various benefits to the country. First, subsistence farmers moving from a tiny plot in the arid Bolivian highlands to a decent-sized plot on the agricultural frontier can pull themselves out of poverty by inserting themselves into the agro-industrial complex. Thus, it is good for poverty reduction and social mobility. Second, the agro-industrial complex produces millions of tons of soybeans for export, which brings in about a billion dollars per year in export revenues. The agricultural frontier also attracts foreign investors, especially from neighboring Brazil, who find the cheap land, subsidized fuel, and lack of environmental restrictions very attractive. This helps bring new agricultural technology to the country, which is important as soybean yields in Brazil are about 50% higher than in Bolivia.

However, the expansion of the agricultural frontier is not an orderly process, and farmers scramble to clear forest so as to establish land claims and titles, with the expectation of future gains in value. This means that a lot of forest is cleared for land-grabbing and land-speculation purposes rather than productive purposes, with devastating consequences for the environment.

In this context, the agricultural sector necessarily must be the main ally of any strategy to reduce deforestation in Bolivia. The sector needs to receive the right incentives to venture into sustainable development models, mainly in what refers to the production of soybeans and meat. A program to promote technologies and good practices, offering rewards to those who manage to improve their production levels, without expanding their production area, could be attractive to producers. The rewards could come from the financial sector, or from the efforts that the government can make to identify specialized markets for deforestation-free Bolivian products.

Another important cause of unnecessary emissions is artificially low prices of fossil fuels both for the transport sector and for electricity generation. The prices of gasoline and diesel have been fixed by supreme decree since 2005, which has been great for economic stability and low inflation. However, with real fuel costs being several times higher than the decreed prices, the government is finding it increasingly expensive to finance the subsidy. Medinaceli Monrroy and Velásquez Bilbao La Vieja (2022) calculated that the direct costs of the subsidy amount to about 3% of GDP, a large part of which goes to the agro-industrial sector in the Bolivian lowlands, making agricultural expansion even more attractive. The government has previously tried to eliminate the subsidy, but that almost caused a revolution, and they quickly had to walk it back. It is clear that the reduction of the subsidy has to be done much more strategically securing that the population gets something in return for giving up their acquired right to cheap fuel.

This paper has estimated that the magnitude of the investments needed to change course from the current high-emission trajectory to a path toward Net Zero by 2050 is about $150 billion or 7.8% of Bolivia's GDP between 2022 and 2050. Following the principles of shared responsibility laid out in the United Nations Framework Convention on Climate Change, part of the costs should be borne by Bolivia, but the majority should come from rich countries which benefit from the protection of global common goods, such as the Amazon rainforest and the atmosphere.

We have laid out a simple, easily verifiable, performance-based mechanism that shares the costs and benefits of reduced deforestation fairly. The mechanism recommends focusing directly on deforestation, which is highly visible and easily measurable, rather than trying to measure reductions in an invisible gas below a theoretical baseline. The mechanism recommends that deforestation reductions below the baseline but above the 2050 Zero Deforestation Path (ZDP) should be rewarded with half the Minimum Fair Payment per hectare of reduced deforestation, while reductions below the ZDP should be rewarded with the full Minimum Fair Payment, which we have tentatively set at USD 9,000/ha to cover typical opportunity costs. This would be equivalent to an average of $20 per tCO_2 of reduced emissions, which is not only attractive compared to most other options for dramatically reducing emissions, but also comes with significant co-benefits in terms of protection of indigenous people and biodiversity in the Amazon. In addition, since the mechanism is country-wide, there is no risk of leakage to other parts of the country, and since it is long-term (until 2050), a high level of permanence is secured.

If Bolivia's government and one or more international partners were to agree on committing to such a mechanism, it could potentially drastically reduce deforestation and bring in more than USD 150 billion in compensation between now and 2050.

Despite these reductions being of high quality and relatively cheap compared to other options, it is not clear where financing would come from. The Global Climate Fund has not managed to secure even 10% of that amount so far for all developing countries together, and the LEAF Coalition, while including some of the biggest multinational companies in the world, have not even secured 1% of the funds necessary just for Bolivia.

A business obliged by law or customer demand to reduce emissions might be interested, given that the Bolivian emissions reductions are relatively cheap, easily verifiable, and come with immense co-benefits in terms of saving biodiversity and protecting indigenous communities. Many international companies have committed to Net Zero, including the Danish shipping giant Maersk, which currently emits about 0.1% of global greenhouse gas emissions, or about 35 million tCO_2 per year.[20] However, even such a huge, global, emissions-intensive company only emits a fraction of the emissions of Bolivia, so we would need to find several such companies to sponsor Bolivia's emissions reductions.

To make sure that poor people are not hurt by the mechanism, most of the funds should be used to promote alternative and more sustainable economic opportunities for Bolivians, including resilient and diverse agro-forestry activities, zero-deforestation beef production, nature-based tourism, high value-added wood products, scientific research, etc. These alternative opportunities should include women as much as possible, so as to provide more gender equal opportunities than the traditional activities at the agricultural frontier.

While Bolivia's 2025 Agenda and the most recent Social and Economic Development Plan actively promote the expansion of the agricultural frontier, Bolivia's upcoming 200th anniversary is a unique opportunity to change course and chart a more sustainable path forward.

While all CO_2 molecules are identical, there are vast differences in impacts between burning forest and burning fossil fuels. When burning forests, you are burning hundreds of millions of living organisms, whereas when you burn fossil fuels you are burning organisms that have already been dead for hundreds of millions of years. Due to the immediate negative effects of deforestation, and the short- and long-term adverse effects on both the local, regional and global climate, it is essential that actions to reduce deforestation be prioritized in the short term.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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20 https://www.maersk.com/sustainability/our-priorities/the-environment/climate-chang

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2022.1026344/full#supplementary-material

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