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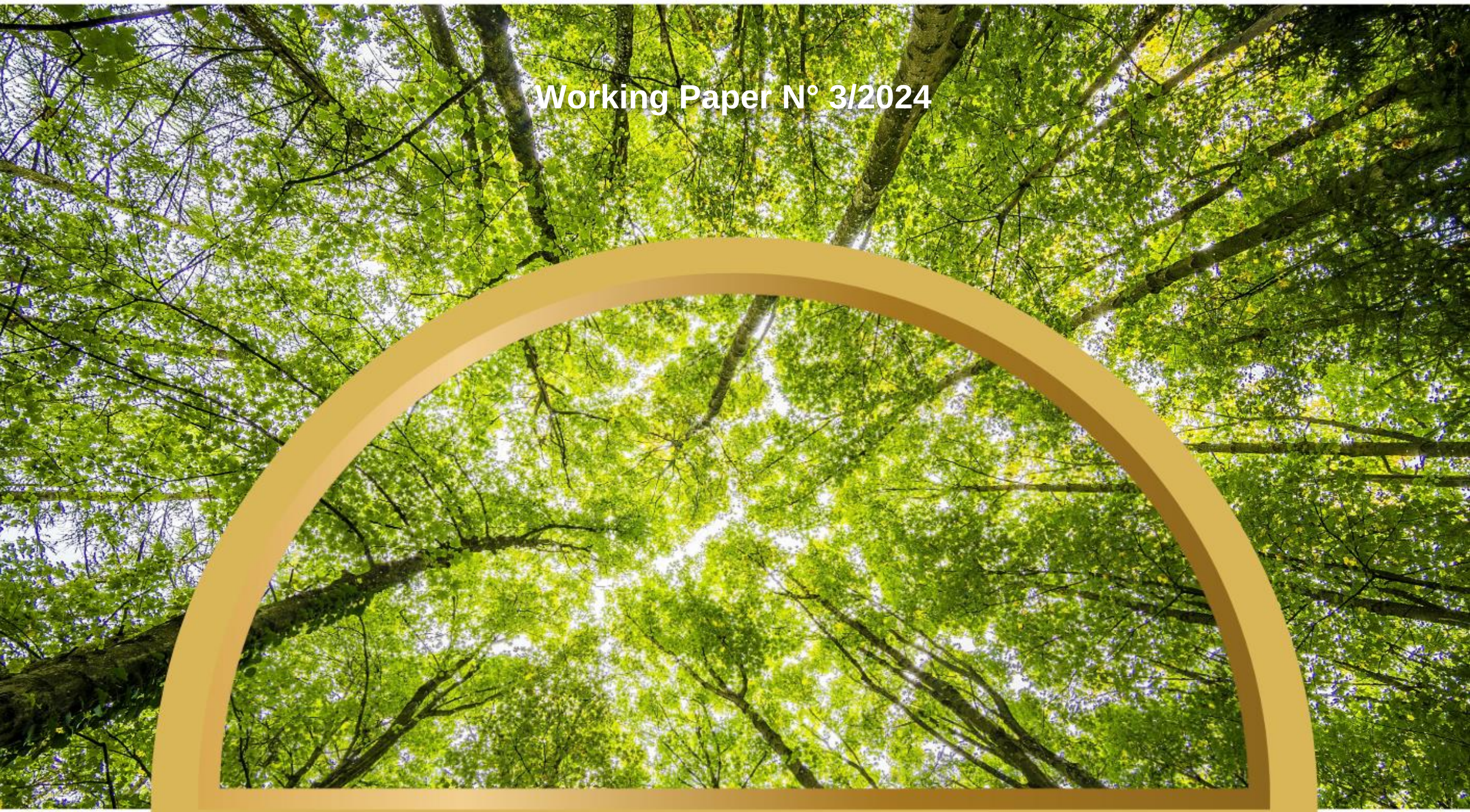

Options for achieving the forest related goals of Bolivia's Nationally Determined Contributions (NDCs): Results from the UCISS-Bolivia model

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Lykke E. Andersen*
Fabiana Argandoñ♦
Diego Calderón⊗
Sergio Choque♣
Álvaro Muñoz♠

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Abstract: This paper presents the Updated Conservation Incentives Spreadsheet for Bolivia (UCISS-Bolivia) tool and uses it to analyze the options and trade-offs involved in achieving the forest related goals of Bolivia's NDCs. UCISS-Bolivia is an Excel-based tool for analyzing the potential effects of different incentives to reduce deforestation. It is based on a spatial econometric model of deforestation in Bolivia during the period 2016-2021, and uses information on forest cover, deforestation rates, geographical conditions, and drivers of deforestation, including agricultural opportunity costs, for more than 120,000 pixels covering the whole country. The model can help answer questions such as: Where in Bolivia does it make most sense to reduce deforestation? What kind of incentives are most effective at reducing deforestation? How much money will it take to reduce deforestation by a given amount? This kind of simulations are helpful for designing the key elements of a Joint Mitigation and Adaptation Mechanism for the Integral and Sustainable Management of Forests.

Keywords: Nationally Determined Contributions, deforestation, conservation, incentives, Bolivia.
JEL classification codes: Q21, Q56.

* Corresponding author: Sustainable Development Solutions Network (SDSN) Bolivia – Universidad Privada Boliviana, La Paz, Bolivia: lykkeandersen@upb.edu.

♦ Sustainable Development Solutions Network (SDSN) Bolivia – Universidad Privada Boliviana, Fabiana.argandona@sdsnbolivia.org.

⊗ Sustainable Development Solutions Network (SDSN) Bolivia – Universidad Privada Boliviana, diegol.calderonacebey@gmail.com.

♣ Sustainable Development Solutions Network (SDSN) Bolivia – Universidad Privada Boliviana, Sergio.Choque@sdsnbolivia.org.

♠ Sustainable Development Solutions Network (SDSN) Bolivia – Universidad Privada Boliviana, Alvaro.Munoz@sdsnbolivia.org.

1. Introduction

Bolivia is blessed with abundant natural resources, including more than 50 million hectares of forest (MapBiomas Bolivia, 2023). Due to the tropical location, combined with extreme altitudinal variation, Bolivia is very rich in biodiversity. Its exact global ranking is difficult to ascertain due to lack of research, but it is usually considered among the top 20 most biodiverse countries in the world (Argandoña, Olmos & Calderón Acebey, 2024).

The forests not only provide habitat for many unique animal and plant species, but also play an important role in stabilizing the local and regional climate. Forest cover acts as a sponge to absorb precipitation and retain humidity, thus moderating hydrological cycles, while also preventing temperature extremes. Unfortunately, forests provide relatively few direct economic benefits for the local population and national economy compared to agricultural land. The insatiable global demand for agricultural commodities means that Bolivian forests are being converted to agricultural land at increasing rates. According to Global Forest Watch, Bolivia lost 491 thousand hectares of humid primary forest in 2023, by far the largest loss ever recorded.[1] According to the same source, Bolivia also has one of the highest per capita rates of deforestation in the World.

As part of the Nationally Determined Contributions (NDCs), updated in 2022, Bolivia has included a series of goals related to the management of forests. Specifically, Goal 11 is to reduce deforestation by 20% by 2030, compared to the average for 2016-2020. Most of this reduction (60%) is conditional on international cooperation (MMAyA-APMT, 2022).

The mechanism through which this is to be achieved is the Joint Mitigation and Adaptation Mechanism for the Integral and Sustainable Management of Forests (JMA), with a special focus on eliminating deforestation in protected areas, controlling illegal deforestation, preventing forest fires, and increasing the economic benefits of forests.

The purpose of the UCISS-Bolivia tool and this paper is to provide quantitative information to support the design of the JMA. The remainder of the paper is organized as follows: Section 2 explains the key equations underlying the UCISS-Bolivia model, while Section 3 presents the spatial econometric model of the drivers of deforestation, which constitutes the basis of the model. Section 4 uses the UCISS-Bolivia model to simulate the effects of different types of interventions to reduce deforestation. The simulations show where it is easiest to reduce deforestation in Bolivia, but it also shows who is likely to suffer from these policies. Finally, Section 5 summarizes the conclusions and policy recommendations.

2. Modeling incentives in UCISS-Bolivia

UCISS-Bolivia (Andersen et al., 2024) is an updated an expanded version of CISS-Bolivia (Andersen et al, 2012), which was developed in 2012 based on the OSIRIS framework of Busch et al. (2009) and Busch et al. (2012). The tool is very data intensive, with detailed information on more than 120,000 pixels covering the whole country. It is built around a country-specific deforestation model (eq. 1), which predicts the

[1] See Global Forest Wathch statistics for Bolivia here: https://www.globalforestwatch.org/dashboards/country/BOL/

probability of deforestation at each site, *i*, in the absence of JMA conservation incentives, based on observable site characteristics:

$$y_i = \exp\left(\beta_0 + X_i{}'\beta_1 + \beta_2 \ln(A_i) + \epsilon\right) \tag{1}$$

Here $y_i = (F_i^o - F_i')/F_i^o$ is percent deforestation at site *i*, where F_i^o is forest cover at site *i* at the start of the 2016-2021 observation period, and F_i' is forest cover at site *i* at the end of the observation period. X_i is a matrix of observable geographic site characteristics related to initial forest cover, access, topography, and other geographic factors explained in detail in the following section. A_i is the net present value of potential net agricultural revenue per hectare at site *i* (see Andersen et al., 2023). Finally, the constant term β_0 captures unobserved components of the expected net benefits of deforesting site *j*.

The predicted probability of deforestation at site *i* in the absence of JMA conservation incentives, $\hat{y}_{i,NOJMA}$, is then given by:

$$\hat{y}_{i,NOJMA} = \exp\left(\hat{\beta}_0 + X_i{}'\hat{\beta}_1 + \hat{\beta}_2 \ln\left(A_i\right)\right) \tag{2}$$

The spatial distribution across the country of $\hat{y}_{i,NOJMA}$ for all cells constitutes the Business-as-Usual (BAU) reference scenario in UCISS-Bolivia, whereas the distribution of y_i constitutes the historical reference scenario. If $\hat{\beta}_2 > 0$, which is the case in Bolivia, then higher potential net agricultural revenues imply higher probability of deforestation, as theory and empirics would suggest (Barbier, 2001).

The purpose of JMA conservation incentives is to raise the relative attractiveness of standing forest compared to agriculture by providing incentives for keeping land as forest. Assuming that one dollar received from conservation initiatives has an equal and opposite impact on the probability of deforestation as one dollar received from agricultural profits, we can deduce the marginal JMA Revenue per hectare, $JMAR_i$, from A_i when simulating the effect of conservation incentives. Thus, if a site chooses to opt into the JMA conservation incentive mechanism, the opportunity costs of maintaining forest would be lower and the probability of deforestation would therefore also be lower. However, there is another effect that works in the opposite direction, which is that an increase in agricultural prices, τ_1, due to the reduction in deforestation and reduction in agricultural supply at the forest frontier caused by the JMA, would make agriculture relatively more attractive.

Thus, if a site opts into JMA, the probability of deforestation is given by equation (3):

$$\hat{y}_{i,JMA,opt\ in} = \exp\left(\hat{\beta}_0 + X_i{}'\hat{\beta}_1 + \hat{\beta}_2 ln((1+\tau_1)A_i - JMAR_i)\right) \tag{3}$$

The increase in national agricultural prices, τ_1, is modeled endogenously in UCISS-Bolivia and depends on an "effective elasticity" parameter, which is functionally equivalent to the price elasticity of exponential demand for frontier agriculture (Busch et al. 2009), but is assumed to also incorporate feedback in the domestic labor and productive capital markets:

$$\tau_1 = \left(\frac{D_{NOJMA}}{D_{JMA}}\right)^e \tag{4}$$

where D_{NOJMA} is the total amount of deforestation in the country without JMA (i.e. the national reference level) and D_{JMA} is the total amount of deforestation in the country with JMA.

The default value chosen for the effective elasticity parameter in UCISS-Bolivia is 1.4, as in the original CISS-Bolivia model (Andersen et al., 2012), but it can easily be changed by the user.

Some sites/municipalities may choose to opt out of JMA because the agricultural net revenues they can gain are higher than the gains from participating in JMA. For these sites/municipalities, the probability of deforestation is given by:

$$\hat{y}_{i,JMA,opt\ out} = \exp\left(\hat{\beta}_0 + X_i'\hat{\beta}_1 + \hat{\beta}_2 ln((1+\tau_1)A_i)\right) \quad (5)$$

The site level participation decision is determined by a comparison of net revenues from opting in and opting out of JMA.

3. A spatial econometric model of the drivers of deforestation

Table 1 describes in detail all the potential variables that correlate with deforestation considered for UCISS-Bolivia. This set of driver variables were evaluated at the pixel level, with the national territory of Bolivia gridded into 120,683 square pixels of 3×3 km.

Following Busch et al. (2012), we estimated the deforestation model in Stata 15 using a Poisson quasi-maximum likelihood estimator (Wooldridge, 2002). A Poisson model tolerates zero values unlike a log-normal distribution, and generates a distribution of predicted values which fits the observed data distribution better than logit or OLS. This distribution is concentrated nearest to zero deforestation and diminishes toward greater levels of deforestation.

Table 1: Potential drivers of deforestation in Bolivia, 2016-2021

Dependent variable	**Unit**	**Source**	**Average value**	**Min – Max**
Deforestation during 2016-2021	Share of forest in 2015	MMAyA-DGGDF-APMT (2024).	0.035	0 – 1
Explanatory variables	**Unit**	**Source**	**Average value**	**Min – Max**
Initial forest cover in 2015	Share of pixel	MMAyA-DGGDF-APMT (2024).	0.484	0 – 1
Distance to roads	km	ABC & IGM (2015).	35.2	0 – 217
Distance to river	km	SNHN (2016).	50.2	0 – 301
Distance to urban center with more than 10,000 inhabitants	km	GeoBolivia (2021).	96.0	1 – 325
Travel time to municipal capital	hours	Weise Andrade (2024)	3.74	0.02 – 30.97
Average slope of pixel	%	MPD (2023).	10.2	0 – 87
Average altitude	m.a.s.l.	MPD (2023).	1244	0 – 5837
Average carbon contents in vegetation	tC/ha	Ruesch, A., & H. K. Gibbs (2008).	88.9	0 – 193

Average carbon contents in soil	tC/ha	FAO/IIASA/ISRIC/ISSCAS/JRC, 2012. Harmonized World Soil Database (version 1.2). FAO, Rome, Italy and IIASA, Laxenburg, Austria.	9.3	0 – 144
Net Primary Productivity	kg C/m2/year	Average Net primary Production of 2001-2005 of grid maps from NTSG (Numerical Terradynamic Simulation Group).	11.7	0 – 60
Historical fire density	Thermal anomalies/ha/year	SIMB (2023).	0.0013	0 – 0.0819
Population density	Inhabitants/ha	INE (2022).	0.094	0 – 1603
Distance to already deforested pixel in 2015	km	Hansen et al. (2013)	29.5	0 – 335
Individual land title	Share of pixel	INRA (2016).	0.268	0 – 1
Communal land title	Share of pixel	INRA (2016).	0.158	0 – 1
Unclear land title	Share of pixel	INRA (2016).	0.359	0 – 1
Protected area	Dummy if present within pixel	FAN (2023).	0.298	0 – 1
Municipal Sustainable Development Index	Index	Andersen, Canelas, Gonzales & Peñaranda (2020).	50.5	35.7 – 80.2
Tourism Potential Index	$/ha	Andersen, Medinaceli, Pacheco, et al. (2023).	1293	1 – 16,689
Net present value of Net agricultural value	$/ha	Andersen, Argandoña, Choque Sunagua, et al. (2023).	1293	1 – 16,689

A necessary condition for deforestation to potentially take place is that there was at least some forest present in the pixel at the beginning of the period. Therefore, all the pixels with no forest cover at all in 2015 were excluded from the regression analysis. This left 78,618 pixels with positive forest cover in 2015, which were used to estimate the deforestation model (see Table 2). With over 70,000 observations and only 20 potential explanatory variables, there was no risk of overfitting, so we initially included all potential explanatory variables, but subsequently excluded those that were not found to be statistically significant at the 5% level.

Table 2: Poisson Deforestation Model for Bolivia, 2016-2021 (6 years)

Dependent variable	Number of observations	Pseudo R^2
Deforestation during 2016 – 2021 (% of initial forest cover in 2015)	78,618	0.1662
Explanatory variables	**Coefficient**	**Z-value**
Initial forest cover in 2015	-2.5148	-64.97
Travel time to municipal capital	-0.0554	-9.92
ln(Distance to road)	-0.0629	-6.80
ln(Distance to city of more than 10,000 inhabitants)	-0.1033	-7.26
ln(Distance to river)	-0.7854	-27.50
ln(Distance to river)^2	0.1518	32.27
Average slope of pixel	-0.0037	-3.80
Carbon contents in vegetation	0.0027	14.03
Carbon contents in soil	-0.0056	-8.48
Net Primary Productivity	0.0094	6.41
ln(Historical fire density)	31.8097	11.07
ln(Distance to already deforested pixel)	-0.0696	-22.62
Individual land title share	0.1892	6.83
Communal land title share	0.2389	7.85
Protected Area share	-0.2658	-8.61
Sustainable Development Index	0.0232	9.28
Tourism Potential Index	-0.0196	-13.48
Natural logarithm of net present value of net agricultural value	0.1105	12.11
Constant	-1.8318	-12.55

By far the most important explanatory variable in the estimated model is initial forest cover. The negative coefficient indicates that deforestation rates during 2016-2021 were higher in pixels with lower initial forest cover. This makes sense, as fragmented forest is easier to deforest than intact, dense forest, but it also implies that deforestation tends to accelerate over time. This acceleration effect is reinforced by the second and third most important explanatory variables: historical fire density (which increases the probability of deforestation), and distance to an already cleared pixel (the closer the higher the probability of deforestation).

As expected, deforestation rates were higher on flat areas close to roads, rivers and urban centers. A non-linear relationship for distance to a river was included in the model, since deforestation is illegal within 50 meters of a river, so low deforestation might be expected very close to a river, but also far away. However, the pixel resolution is not high enough to capture the first 50 meters within reach of a river, and the model actually shows the highest deforestation rates closest to a river, and decreasing until more than 30 kilometers from the river.

Deforestation is less likely in Protected Areas, as would be expected. However, in contrast to the original OSIRIS/CISS models (Andersen et al., 2012), communal land titles are now associated with higher deforestation rates, and indeed even higher rates than private land titles. This is worrying, because in most other studies, Indigenous Peoples' Territories (which constitute an important share of communally owned land) have been found to be associated with less deforestation (see Busch and Ferretti-Gallon (2023) for a recent meta-analysis).

Importantly, deforestation rates were significantly higher in areas with higher agricultural value. This is central for the functioning of the model, as the impacts of conservation incentives are simulated through this particular variable. For example, as overall deforestation is reduced, the price of agricultural output at the frontier increases, which causes an increase in agricultural value and thus an increase in the probability of deforestation.

The explanatory power of the regression model is $R^2 = 0.1662$, indicating that there is still a lot of unexplained variation in deforestation rates, even after controlling for so many factors. However, if we aggregate the results to the municipal level (339 municipalities), the correlation between measured and modeled deforestation is 0.83, which is quite high. Thus, the model is better at predicting how much deforestation will occur in a municipality than predicting exactly where within a municipality that deforestation will occur.

4. Applications

This section applies the UCISS-Bolivia tool to questions that are important for the design and implementation of incentives to reduce deforestation in Bolivia.

The tool includes both positive incentives (payments to support activities compatible with standing forest, such as tourism, forest products, research, biodiversity protection, etc.) as well as negative incentives (summarized as a tax on deforestation). The positive incentives can be directed towards areas that are particularly important in terms of biodiversity, carbon sequestration, poverty alleviation or tourism potential, depending on the priorities of the stakeholders involved.

One overarching principle that needs to guide the design of policies is to "do no harm". At least on average, and for most of the population, and especially for the poorest segments of the population, we need to ensure that the combination of positive and negative incentives leaves them better off. Otherwise, the proposed policies will have little chance of obtaining political support and getting implemented.

Another important principle is simplicity and transparency. The rules and rewards need to be as simple as possible. Not only to reduce transaction costs, but also to be understood and considered fair by the affected population, and to reduce the risk of corruption and rent-seeking.

Finally, as the benefits of forests reach way beyond national borders, we need to recognize the principle of shared responsibility for protecting these forests.

In this sense, the first question to be explored is: Does it make sense to reduce deforestation in Bolivia, and if so, where?

4.1 Does it make sense to reduce deforestation in Bolivia, and if so, where?

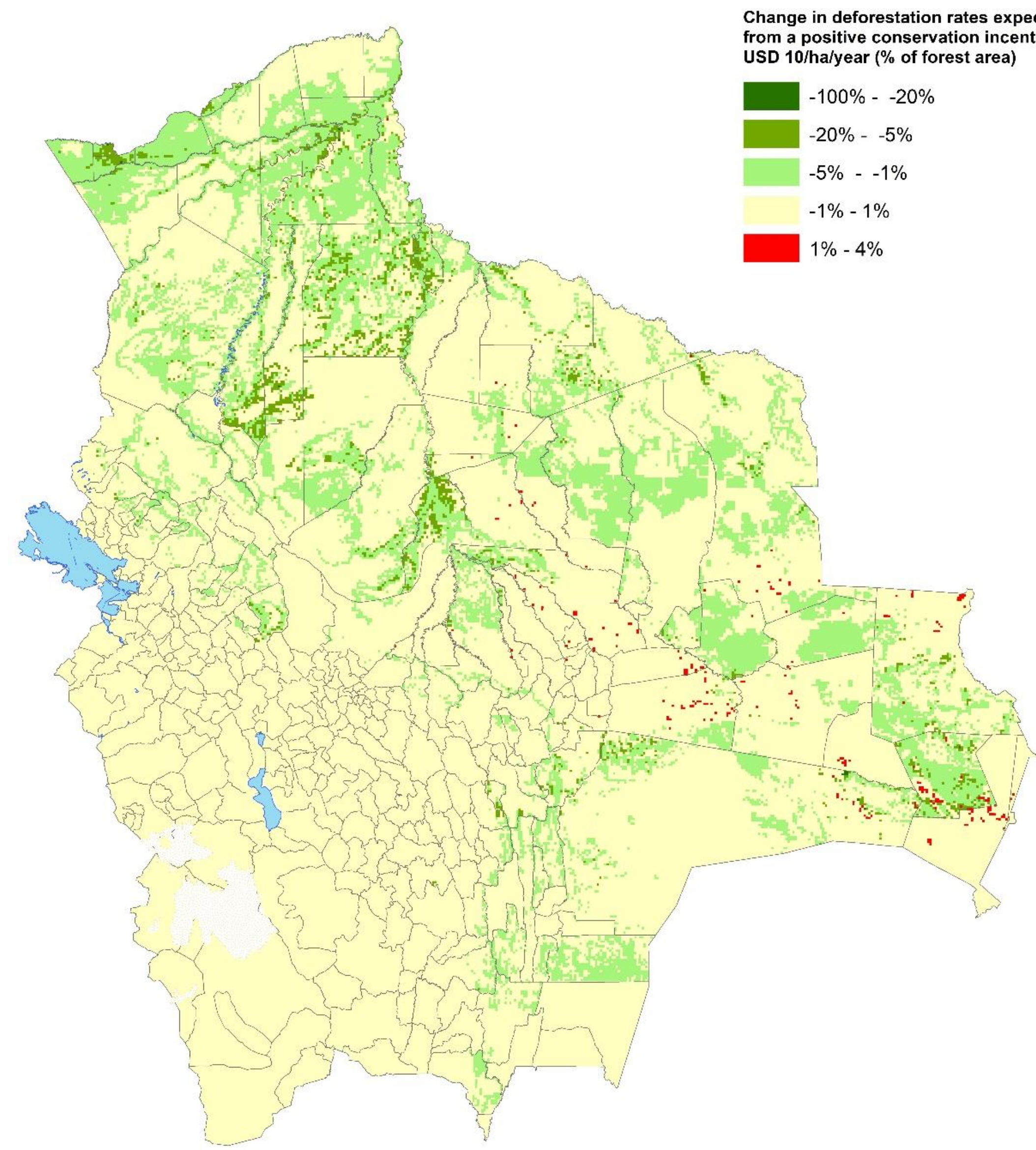
On average, agricultural land in Bolivia is much more profitable than forested land. In 2022, for example, Bolivia exported about USD 3 billion worth of agro-industrial products (INE, 2023) from a total area of agropastoral land of about 11 million hectares (MapBiomas Bolivia, 2023), implying average agropastoral export revenues of USD 273/ha/year. In contrast, the exports of products derived from forests (mainly Brazil nuts and wood products), amounted to only USD 300 million from a total forest area of about 56 million hectares, implying average forest export revenues of about USD 5/ha. Of course, there are additional benefits from both forests and agricultural land (for example for local consumption) as well as costs (for example diesel imports), but the fact is that the profits from agricultural tend to be at least an order of magnitude higher than the profits from forests, which, of course, provides a strong incentive to clear forest.

However, there are big differences in the ratio of agro/forest benefits from place to place. While on average the ratio is very much in favor of agro, in some places - for example on steep slopes or remote locations - the potential agro revenues are so low, that the ratio is in favor of maintaining forests. The ratio can also be changed by including other benefits and costs in the calculations of the land owner. For example, if fuel subsidies were eliminated, it would make agriculture less attractive. Or if biodiversity protection were to be rewarded, it would make standing forest more attractive.

UCISS-Bolivia is designed to allow us to simulate how the optimal land use decision change in each pixel in response to changes in incentives. With small changes in incentives (for example the introduction of a conservation payment of USD 10/ha/year for people who promise to maintain their forest areas), only the pixels that are close to a ratio of 1 between agropastoral activities and forests will change their decisions. For large changes in incentives (for example the introduction of a USD 1000/ha tax on deforestation), the optimal decision would change in more areas.

One of the goals of Bolivia's Nationally Determined Contributions (NDC) is to reduce deforestation by 20% by 2030 (MMAyA-APMT, 2022). This goal can be achieved in many different ways. Map No. 1 shows where the 20% reduction would take place if a positive conservation incentive of USD 10/ha/year were offered to people with forest, who promised to maintain the area forested during the period of the simulation (6 years). To achieve a 20% reduction in deforestation through this incentive, the government would have to spend about USD 2.34 billion in conservation payments over 6 years. It is important to note that with a 20% reduction in deforestation, the prices of agricultural products would increase (by about 37% if we use the default elasticity of 1.4), which means that while some regions will opt for conservation, deforestation will actually increase in other areas, as farmers are encouraged by higher prices of their production.

Map No. 1: Change in deforestation rates expected from a positive conservation incentive of USD 10/ha/year (% of forest area)



Source: Simulation results from UCISS-Bolivia (Fund Size: USD 2.34 billion; Conservation Incentive: $60/ha/6yrs; equal weights to biodiversity, poverty, carbon, and tourism priorities).

Table 1 summarizes the results of the same positive conservation incentive in numerical terms, per state. The positive conservation incentive would be most effective in Pando (93% reduction in deforestation) and Beni (39% reduction). In Santa Cruz, the reduction would only be of 11%, but this net effect hides substantial differences within the state, as shown in Map 1, and an absolute terms Santa Cruz would still be the state with the largest reductions in deforestation if a conservation incentive were to be implemented.

Table 1: Change in deforestation expected from a positive conservation incentive of USD 10/ha/year

State	Starting forest area, 2015 (ha)	Change in deforestation due to conservation incentives (ha)	Change in deforestation due to conservation incentives (%)
Chuquisaca	1,997,621	-12,352	-27%
La Paz	5,954,105	-36,008	-30%
Cochabamba	2,050,390	-3,454	-4%
Oruro	0	0	0%
Potosi	871	+3	+3%
Tarija	2,292,510	-1,435	-3%
Santa Cruz	24,666,496	-122,656	-11%
Beni	8,773,955	-96,034	-39%
Pando	5,828,961	-67,438	-93%
Total	**51,564,907**	**-339,374**	**-20%**

Source: Simulation results from UCISS-Bolivia (Fund Size: USD 2.34 billion; Conservation Incentive: $60/ha/6yrs; equal weights to biodiversity, poverty, carbon, and tourism priorities).

The municipality with the biggest reduction in deforestation would be San Ignacio de Velasco (20,552 hectares less of deforestation over 6 years) followed by Ixiamas (-19,341 ha), Charagua (-17,927 ha), Carmen Rivero Torres (-15,364 ha), Riberalta (-15,285 ha), and Urubichá (-14,456 ha).

The municipalities that would see the biggest increases in net deforestation due to the same incentive, would be Puerto Villarroel (+623 ha) and Villamontes (+608 ha), but these are fortunately very modest increases.

Since it is entirely voluntary to participate in the conservation incentive scheme, the rural population generally ends up with a net benefit from this mechanism. The ones who lose are the central government (which has to spend USD 2.34 billion on conservation payments) and the urban population (who has to pay about 37% more for their food).

4.2 The principle of shared responsibility

To make the mechanism attractive for the central government, most of the conservation incentives would have to be financed externally, recognizing shared responsibility for protecting the world's biodiversity and mitigating climate risks. In the above case, an international results-based compensation of around USD 6,700 per hectare of reduced deforestation would cover the USD 2.34 billion needed to pay the conservation incentives of $10/ha/year for the forested areas interested in enrolling in six years of conservation.

However, the increased food costs for the urban population (more than 70% of the population) would still not be covered, so additional funds would be needed to comply with the principle of "do no harm". The estimate in Andersen, Gonzales and Malky (2022) of a minimum fair payment of USD 9,000 per hectare of reduced deforestation seems to be necessary to reach the point of not doing harm.

This magnitude of international financing is what would be needed to make it feasible to even try to reverse the trend of increasing deforestation in Bolivia. Without serious, results-based international financing, basic economic incentives are likely to win over wishful thinking and politically correct promises. It is also essential to coordinate between tropical forest countries, because otherwise deforestation reductions in one country may increase the pressure on forests in other countries, resulting in a very high degree of leakage. In this sense, Brazil's recent proposal at the COP 28 in Dubai of an alliance of tropical countries and a USD 250 billion "Tropical Forests Forever" Fund is crucial (Mongabay, 2023).

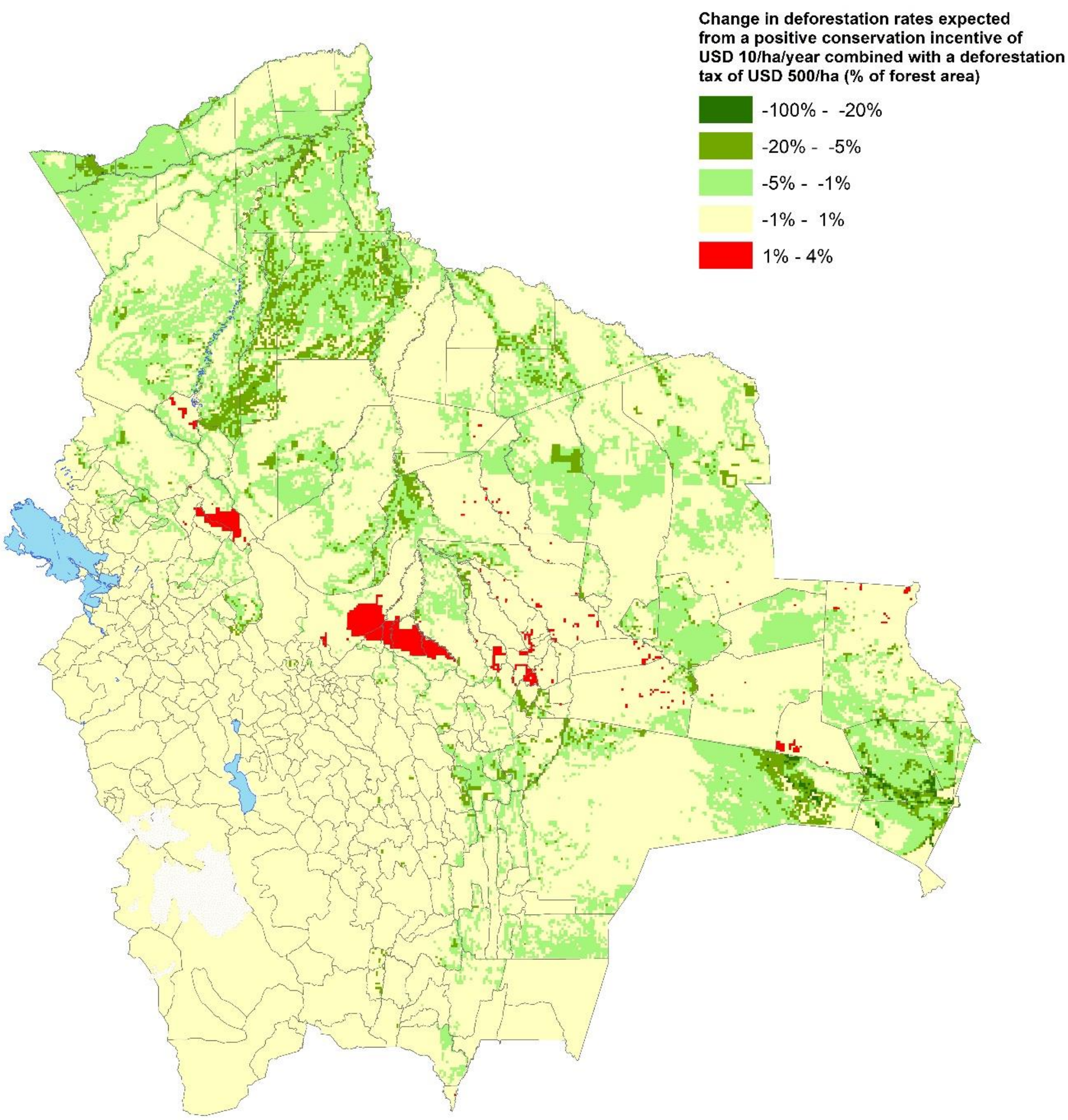
4.3 Combining positive and negative incentives

One option to raise local revenues for conservation would be to implement a tax on deforestation (a payment for deforestation permits or a fine on illegal deforestation). This would not only dramatically change the land use decision in favor of forests, but it would also raise revenues to finance the conservation payments.

If we combine the above-mentioned conservation incentives of USD 10/ha/year with a one-time deforestation cost of USD 500/ha, we could potentially reduce deforestation by 28.7%. If this is reasonably rewarded by international compensation for reduced deforestation (USD 9,000/ha), it would imply total revenues to the central government of around USD 764 million per year, which would be enough to cover conservation payments, as well as some support to the urban population to cover increased food prices.

Map No. 2 shows how deforestation would change in Bolivia with the combination of a positive incentive of USD 10/ha/year for forest areas dedicated to conservation, and a negative incentive in the form of a one-time payment of USD 500/ha for a deforestation permit.

Map No. 2: Change in deforestation rates expected from a positive conservation incentive of USD 10/ha/year combined with a deforestation tax of USD 500/ha (% of forest area)



Source: Simulation results from UCISS-Bolivia (Fund Size: USD 2.34 billion; Conservation Incentive: $60/ha/6yrs; Deforestation tax: $500/ha; equal weights to biodiversity, poverty, carbon, and tourism priorities).

Table 2: Change in deforestation expected from a positive conservation incentive of USD 10/ha/year combined with deforestation tax of USD 500/ha

State	Starting forest area, 2015 (ha)	Change in deforestation due to conservation incentives and tax(ha)	Change in deforestation due to conservation incentives and tax (%)
Chuquisaca	1,997,621	-15,018	-33%
La Paz	5,954,105	-39,434	-33%
Cochabamba	2,050,390	-2,012	-2%
Oruro	0	0	0%
Potosi	871	0	0%
Tarija	2,292,510	-1,256	-3%
Santa Cruz	24,666,496	-242,261	-23%
Beni	8,773,955	-117,832	-47%
Pando	5,828,961	-69,510	-95%
Total	**51,564,907**	**- 487,323**	**-29%**

Source: Simulation results from UCISS-Bolivia (Fund Size: USD 2.34 billion; Conservation Incentive: $60/ha/6yrs; Deforestation tax: USD 500/ha; equal weights to biodiversity, poverty, carbon, and tourism priorities).

Almost half a million hectares of forest would be saved (over the 6-year period of the simulation), mostly in Santa Cruz, Beni and Pando. The municipality that would be encouraged to change most would be Charagua (50,568 hectares less of deforestation), followed by San Ignacio de Velasco (-35,817 ha) and Urubichá (-30,686 ha). Due to the significantly higher food prices (60% increase), areas with high agricultural potential would choose to increase production and pay the deforestation tax. The municipalities with the highest increases in deforestation in this scenario would be Puerto Villarroel (+919 ha), Villamontes (+565 ha), and Chimoré (+556 ha).

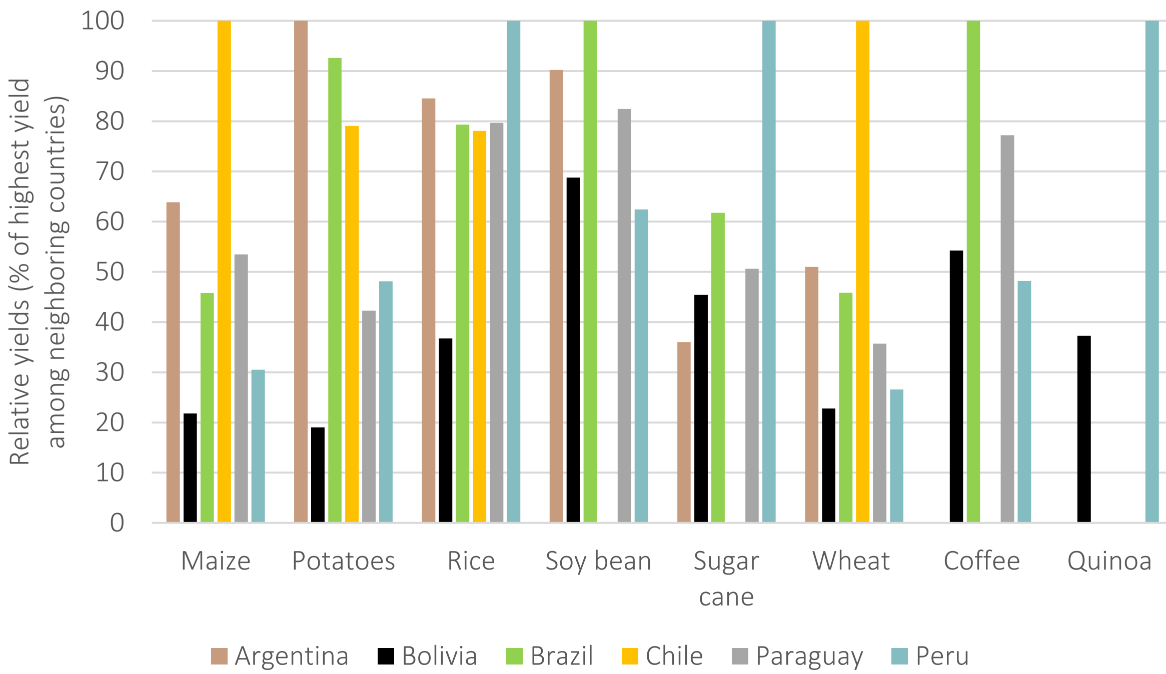
With this combination of positive and negative incentives, deforestation would be reduced by 28.7%, carbon emissions by 33.4% and biodiversity loss by 28.7%. With international compensation for reduced deforestation, the central government would receive sufficient revenues to pay conservation incentives and recover some of the fossil fuel subsidies for the agricultural sector. However, there is still the problem of higher food prices (+60%), which would likely mean political suicide.

4.4 Preventing food price inflation

The only way to prevent food prices from increasing when reducing deforestation, is to simultaneously increase yields.[2] There is ample room for yield improvement in Bolivia, as yields for most crops are generally much lower than in neighboring countries (see Figure 1). Yields in Bolivia are particularly low for Maize, Potatoes and Wheat with yields that are only a fifth of the best performing neighbor. A much smaller gap is found for soy beans, where Bolivian yields are 69% of the best performing neighbor.

[2] Assuming that other countries will also try to reduce deforestation, which is a reasonable assumption given that most countries have much higher ambitions than Bolivia. At the COP26 in Glasgow in 2021, 144 world leaders (not including Bolivia) promised to work together to end deforestation by 2030 (https://webarchive.nationalarchives.gov.uk/ukgwa/20230418175226/https://ukcop26.org/glasgow-leaders-declaration-on-forests-and-land-use/).

Figure 1: Average yields of Bolivia's most common agricultural crops, compared to neighboring countries, 2016-2022 (% of highest yield among neighboring countries).



Source: FAOSTAT (https://www.fao.org/faostat/en/#data/QCL).

The combination of a tax on deforestation and a conservation payment will automatically encourage increased efficiency in the use of agricultural land. By avoiding deforestation on the most marginal land, average yields are expected to increase, but not enough to avoid a reduction in overall food production. It will still be necessary to provide technological support and agricultural extension services to help farmers get more nutritional value out of each hectare of land. Given the increasing risk of extreme weather events, farmers will also need help to access more climate resilient varieties. Thus, part of the government revenues from reduced deforestation will need to be directed towards agricultural research and extension work.

4.5 Securing long-term sustainability

Relying on external compensation for reduced deforestation is not a sustainable strategy for the long run. It can help facilitate a transition towards a zero-deforestation future, but it cannot be relied upon to pay for forest conservation forever.

Thus, the external funds received during the transition phase cannot all be used for consumption. A substantial share needs to be invested in solutions that bring long term revenue from standing forest. The most obvious sustainable income from forest is wood, and Bolivia has the potential to earn more than USD 10 billion per year from sustainably harvested wood (Andersen, Argandoña, Choque Sunagua, Malky, et al., 2023). Another option worth considering is tourism. Experiential tourism is on the rise worldwide[3] and Bolivia has exceptional potential in this area. Costa Rica has been very successful in attracting scientists and

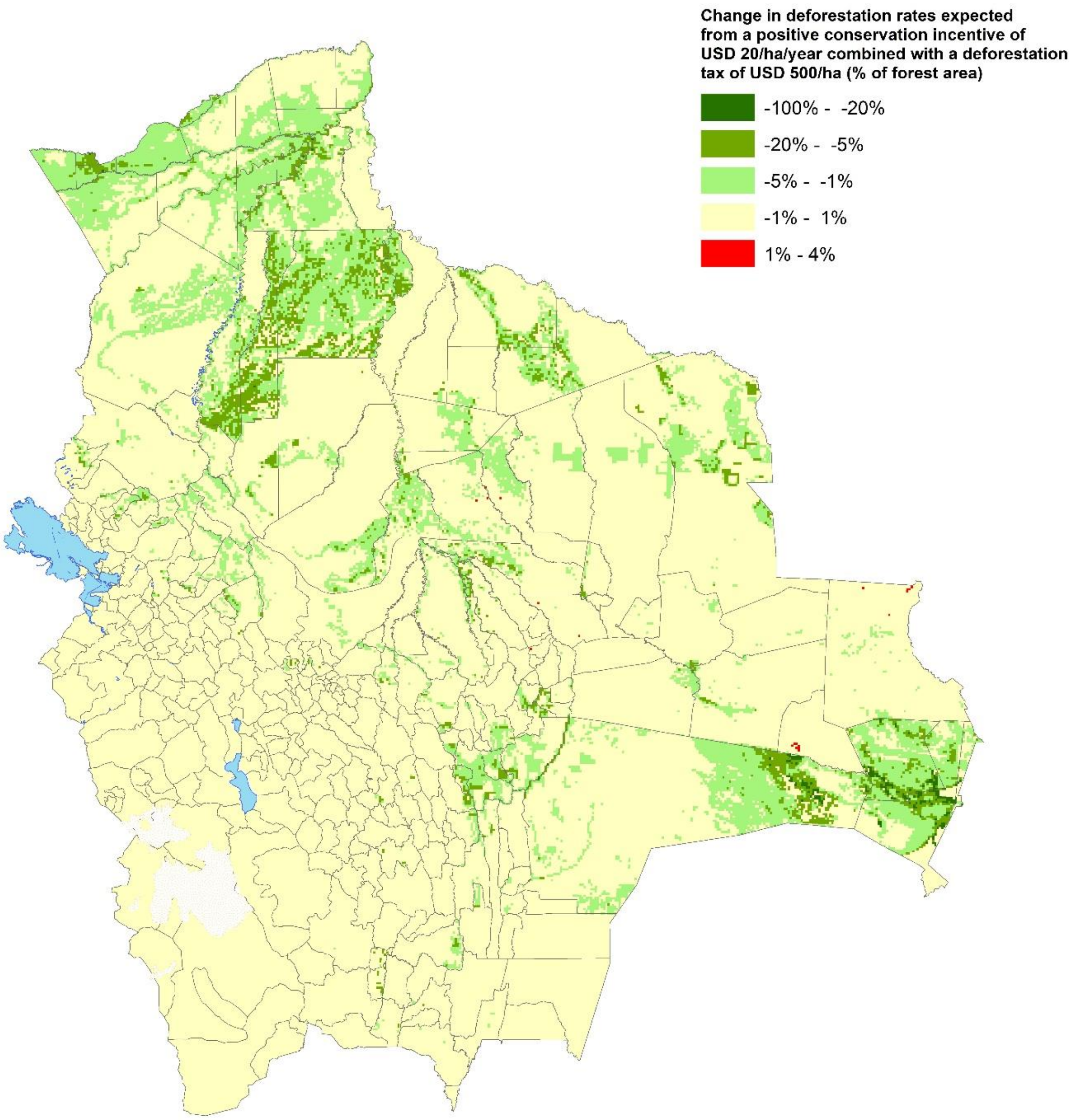
[3] See https://mabrian.com/blog/evolving-traveller-behaviour-the-rise-of-experiential-travelling/.

wealthy tourists in support of biodiversity conservation, and this could be a successful strategy for Bolivia as well. It would require a very concerted effort involving national and local governments, as well as private companies and academia. But it is potentially a promising solution for long term sustainability.

Considering transaction costs as well as long-term sustainability, it may be worth increasing conservation payments per hectare, and thus lowering the number of sites participating. In addition, priority can be given to locations with high tourism potential and high biodiversity value, so as to encourage complementary investments from institutions and individuals interested in sustainability, and reach a new low-deforestation equilibrium faster.

Map 3 shows a scenario which achieves the target of 20% reduction in deforestation with as few disruptions and negative side-effects as possible. It includes a modest deforestation tax of USD 500/ha to discourage deforestation in the least productive areas. To compensate farmers for this unpopular policy, a positive conservation payment of USD 20/ha/year is offered for forest enrolled in a simple conservation program. A fund of USD 1.37 billion will be needed to cover the costs of this program for 6 years. Since the fund is not big enough to pay everybody interested in participating, priority will be given to rural locations with high tourism potential (50%), high biodiversity (30%), high carbon contents (10%), and high poverty (10%). Transaction costs of USD 10/ha have been included in this simulation, as there will necessarily be administrative costs involved in choosing participants, signing contracts with them, transfer funds, and verify that they comply with the conditions of the contract.

Map No. 3: Change in deforestation rates expected from a positive conservation incentive of USD 20/ha/year (giving 50% priority to sites with high tourism potential) combined with a deforestation tax of USD 500/ha (% of forest area)

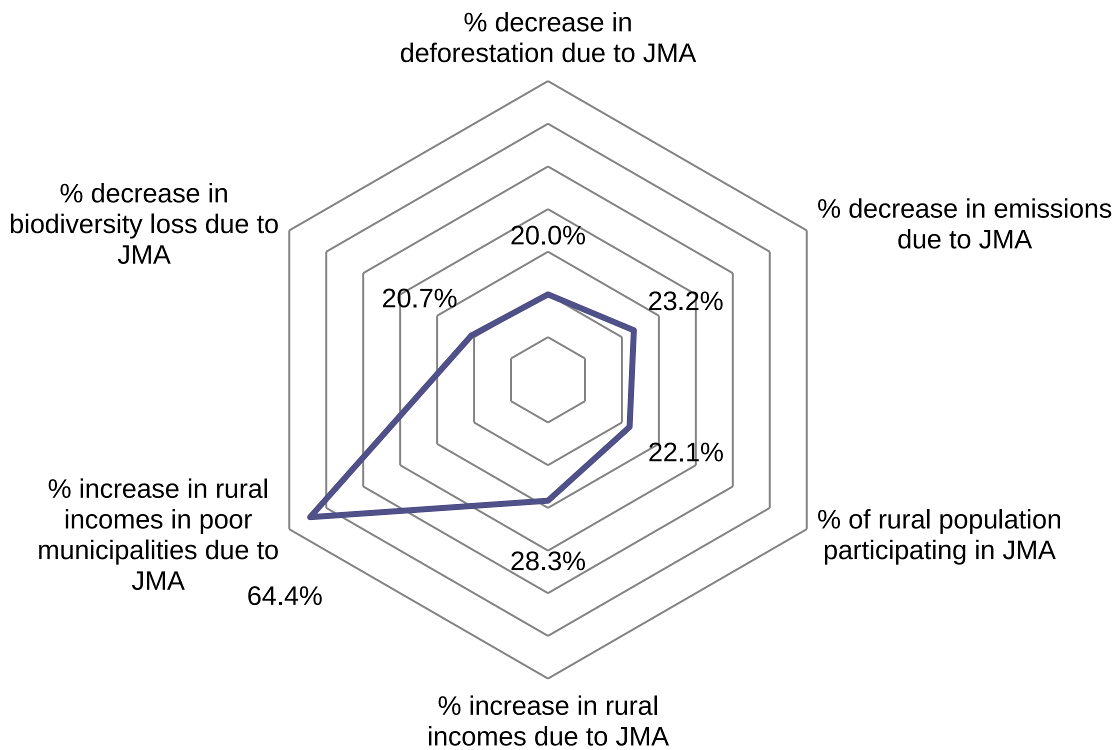


Source: Simulation results from UCISS-Bolivia (Fund Size: USD 1.37 billion; Conservation Incentive: $120/ha/6yrs; Weights: biodiversity (30%), poverty (10%), carbon (10%), and tourism potential (50%); Transaction costs: $10/ha; Deforestation tax: $500/ha.

With this combination of incentives, a 20% reduction in deforestation, as well as a 23% reduction in carbon emissions and a 21% reduction in biodiversity loss, can be achieved. 22% of the rural population of the country would receive positive conservation incentives of $20/ha/year for all their forested areas, by agreeing not to deforest any of it for an agreed number of years. This will cause an average increase in rural incomes of 28% across the country, but, importantly, in the municipalities with below average Sustainable

Development Index values in 2020, the rural population will see a 64% increase in incomes due to the conservation incentive (see Figure 2). Thus, this combination of incentives is strongly pro-poor as well as pro-forest. The problem of increased food prices for the urban population remains a problem, however, and it is crucial to help farmers increase agricultural production without causing deforestation.

Figure 2: Impacts of a positive conservation incentive of USD 20/ha/year (giving 50% priority to sites with high tourism potential) combined with a deforestation tax of USD 500/ha



Source: Simulation results from UCISS-Bolivia (Fund Size: USD 1.37 billion; Conservation Incentive: $120/ha/6yrs; Weights: biodiversity (30%), poverty (10%), carbon (10%), and tourism potential (50%); Transaction costs: $10/ha; Deforestation tax: $500/ha.

5. Conclusions and recommendations

The balance of economic incentives is currently strongly in favor of converting forest to agricultural land in Bolivia. But with relatively minor changes in incentives, decision makers can be convinced to maintain their forest standing. Especially the combination of a small positive incentive and a small negative incentive is theoretically powerful and could reduce deforestation by the target amount in the NDCs of 20%. However, it is costly for the central government and costly for consumers, so international support will be needed for this to be politically feasible. A minimum compensation of about USD 9000 per hectare of reduced deforestation seems to be necessary to convince both the central government and a sufficient share of local decision makers to favor conservation instead of deforestation.

If such a compensation is sustained for at least a decade it may be sufficient to make the investments necessary to sustain a zero-deforestation economy. Without such compensation, it is very unlikely that the trend of deforestation can be reverted before having deforested at least half of the remaining forests.

The details of the Joint Mitigation and Adaptation Mechanism for the Integral and Sustainable Management of Forests remains to be determined, but the results of the UCISS-Bolivia simulations suggest the following:

1. International collaboration is absolutely necessary, and it should be in the order of USD 9000 per hectare of reduced deforestation in order to prevent unacceptable harm to poor people in Bolivia.
2. A combination of a small positive conservation incentive (USD 20/ha/year) and a small tax on deforestation (USD 500/ha) will cause enough farmers to change their land use decisions to reduce annual deforestation by 20%.
3. Significant investment needs to be directed towards improving agricultural yields in order to avoid an unacceptable increase in food prices.
4. If conservation incentives are directed toward areas with high tourism potential and high levels of biodiversity, it may stimulate complementary investments that could help secure that the reductions in deforestation are permanent.
5. Investments in a certified sustainable forestry sector is also important in order to generate permanent incomes from standing forest.
6. It is important that similar mechanisms are implemented simultaneously in all tropical forest countries. Otherwise, early success in one country will cause increased deforestation pressures in other countries, and they will have difficulties reaching their NDC targets despite their best efforts.

References

ABC – Administradora Boliviana de Carreteras, IGM – Instituto Geográfico Militar (2015). Caminos y Vías férreas. Data available on: http://geo.gob.bo/download/?w=igm&l=CAMINOS_Y_VIA_FERREA
Andersen, L., Medinaceli, A., Pacheco, E., García, L., Choque, S., Paz, F., Ramos, I. (2023). Índice Municipal de Potencial Turístico. Universidad Privada Boliviana, SDSN Bolivia. Available at: https://impt.sdsnbolivia.org/#/

Andersen, L. E., Argandoña, F., Calderón, D., Choque, S., Muñoz, A. (2024). Updated Conservation Incentives Spread Sheet – Bolivia (UCISS-Bolivia), version 2024-3, <http://www.sdsnbolivia.org/uciss>, accessed16 July 2024.

Andersen, L. E., Argandoña, F., Choque Sunagua, S., Malky, A., Quispe Gemio, G. & Ávila, J. (2023). "Forestry concessions experience lower rates of forest loss than Protected Areas in Bolivia." Blog SDSN Bolivia, 21 November. Available at: https://sdsnbolivia.org/en/forestry-concessions-experience-lower-rates-of-forest-loss-than-protected-areas-in-bolivia/

Andersen, L. E., Argandoña, F., Choque Sunagua, S., Calderón Acebey, D., Inkinen, V. & Malky, A. (2023). Map of Agricultural Potential in Bolivia. La Paz, Bolivia: Universidad Privada Boliviana – SDSN Bolivia. Working Paper No. 5/2023, October. Available at: https://sdsnbolivia.org/working-paper-n-5-2023-map-of-agricultural-potential-in-bolivia/

Andersen, L. E., Gonzales, L. E. & Malky, F. (2022). Bolivia's Net Zero path: Investment needs, challenges, and opportunities. Frontiers in Climate, Sec. Climate and Economics, Vol. 4, https://doi.org/10.3389/fclim.2022.1026344

Andersen, L. E., Canelas, S., Gonzales, A., Peñaranda, L. (2020) Atlas municipal de los Objetivos de Desarrollo Sostenible en Bolivia 2020. La Paz, Bolivia: Universidad Privada Boliviana - SDSN Bolivia. Available at: https://sdsnbolivia.org/atlas/

Andersen, L. E., J. Busch, E. Curran, J. C. Ledezma & J. Mayorga (2012). Open Source Impacts of REDD+ Incentives Spreadsheet – Bolivia (OSIRIS-Bolivia). Version 2.0, <http://www.conservation.org/osiris>, Downloaded 1 March 2012.

Argandoña, F., Olmos, C. & Calderón Acebey, D. L. (2024). How much is known about Bolivia's biodiversity? SDSN Blog post, April 10th. La Paz, Bolivia: Universidad Privada Boliviana - SDSN Bolivia. Available at: https://sdsnbolivia.org/en/how-much-is-known-about-bolivias-biodiversity/

Barbier, E. B. (2001) "The Economics of Tropical Deforestation and Land Use: An Introduction to the Special Issue" *Land Economics* **77**(2): 155-171

Busch, J. & Ferretti-Gallon, K. (2023). What drives and stops deforestation, reforestation, and forest degradation? An updated meta-analysis. Review of Environmental Economics and Policy, 17(2). https://doi.org/10.1086/725051.

Busch, J., B. Strassburg, A. Cattaneo, R. Lubowski, A. Bruner, R. Rice, A. Creed, R. Ashton & F. Boltz (2009) "Comparing climate and cost impacts of reference levels for reducing emissions from deforestation." *Environmental Research Letters*, 4:044006 (11 pp.) doi:10.1088/1748-9326/4/4/044006.

Busch, J., R. Lubowski, F. Godoy, D. Juhn, K. Austin, J. Hewson, M. Steininger, M. Farid & F. Boltz (2012) "Structuring economic incentives to reduce emissions from deforestation in Indonesia." *PNAS,* **109** (4) 1062-1067; published ahead of print January 9, 2012, doi:10.1073/pnas.1109034109

Fundación Amigos de la Naturaleza FAN (2023). Mapa de Áreas Protegidas Subnacionales. Data available from: https://plataforma.bolivia.mapbiomas.org/

GeoBolivia (2021). Comunidades INE 2012. Available at: https://geo.gob.bo/geoserver/fondos/wfs?SERVICE=WFS&REQUEST=GetFeature&VERSION=1.0.0&TYPENAME=fondos%3Acomunidades_2012&OUTPUTFORMAT=SHAPE-ZIP

INE (2022). Población y hechos vitales – Proyecciones de población. La Paz, Bolivia: Instituto Nacional de Estadísticas. Available at: https://www.ine.gob.bo/index.php/censos-y-proyecciones-de-poblacion-sociales/

INE (2023). Exportaciones – Cuadros Estadísticos. La Paz, Bolivia: Instituto Nacional de Estadísticas. Available at: https://www.ine.gob.bo/index.php/estadisticas-economicas/comercio-exterior/cuadros-estadisticos-exportaciones/

INRA (2016). "Parcelas y predios titulados por el instituto Nacional de Reforma Agraria." Available at: https://geo.gob.bo/geonetwork/srv/spa/catalog.search#/metadata/f5c31a96-c4f0-4140-ba47-2cfbd931075a

MapBiomas Bolivia (2023). Colección 1 de la Serie Anual de Mapas de Cobertura y Uso del Suelo de Bolivia. Data available from: https://bolivia.mapbiomas.org.

MMAyA-DGGDF-APMT (2024) Nivel de Referencia de Emisiones Forestales por la Deforestación del Estado Plurnacional de Bolivia. Versión 3.0 del 8 de enero 2024.

MMAyA-APMT (2022). Contribución Nacionalmente Determinada (CND) del Estado Plurinacional de Bolivia. Actualización de las CND para el periodo 2021-2030 en el marco del Acuerdo de París. La Paz: Ministerio de Medio Ambiente y Agua – Autoridad Plurinacional de la Madre Tierra. Obtenido de https://unfccc.int/sites/default/files/NDC/2022-06/CND%20Bolivia%202021-2030.pdf

Mongabay (2023). "Brazil proposes $250 billion "Tropical Forests Forever" fund for rainforests." 3 December. Available here: https://news.mongabay.com/2023/12/brazil-proposes-250-billion-tropical-forests-forever-fund-for-rainforests/#:~:text=During%20a%20panel%20at%20the,restore%20the%20world's%20tropical%20forests.

MPD - Ministerio de Planificación del Desarrollo (2023). INFO-SPIE, Fisiografía, Modelo de Elevación. Available at: http://si-spie.planificacion.gob.bo/

Ruesch, A., & H. K. Gibbs (2008). New IPCC Tier-1 Global Biomass Carbon Map For the Year 2000. Available online from the Carbon Dioxide Information Analysis Center (URL: http://cdiac.ornl.gov), Oak Ridge National Laboratory, Oak Ridge, Tennessee.

SNHN – Servicio Naval de Hidrografía Naval. (2016). Rios Principales & Rios Secundarios de Bolivia. Data available on: http://geo.gob.bo/download/?w=igm&l=RIOS_SECUNDARIOS, http://geo.gob.bo/download/?w=igm&l=RIOS_PRINCIPALES

SIMB - Sistema de Información y Monitoreo de Bosques (2023). Focos de calor (Shapefile). Dirección General de Gestión y Desarrollo Forestal (DGGDF). Ministerio de Medio Ambiente y Agua (MMAyA). Data available from: https://simb.siarh.gob.bo/simb/map_heat_source

Weise Andrade, G. E. (2024). Estimación de tiempos de viaje en Bolivia con datos geoespaciales. SDSN Bolivia, Documento de Trabajo N° 1/2024. Available at: https://sdsnbolivia.org/documento-de-trabajo-n-1-2024-estimacion-de-tiempos-de-viaje-en-bolivia-con-datos-geoespaciales/

Wooldridge, J. M. (2002). *Econometric Analysis of Cross-Section and Panel Data.* MIT Press: Cambridge, MA.

ata. MIT Press: Cambridge, MA.