To reduce deforestation in the Argentinean Chaco, strengthen current policies and introduce complementary strategies.

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Introduction

Increases in demand for food, fiber, and energy in developed and emerging countries are being met through the expansion and intensification of agriculture in tropical and subtropical regions of developing countries (Pendrill et al 2022). Since the beginning of the 21st century, the Gran Chaco in South America has been one of the regions of the world where agriculture and livestock production have expanded the most, making this region a global deforestation hotspot (Curtis et al. 2018; Hansen et al. 2013). In this region, dry forests are replaced by annual crops and pastures to feed cattle. Currently, nearly 25% of its natural ecosystems have been converted, a large fraction of it in the Argentine Dry Chaco (Baumann et al. 2022). Although agricultural exports are creating important revenues for commodity-exporting countries, agricultural expansion also triggers huge ecological and social problems (Lewis et al. 2015). For example, the conversion and degradation of the forests in the Chaco is associated with major greenhouse gas emissions, biodiversity losses, and soil degradation, which may undermine agriculture (Baldassini et al. 2020; Baumann et al. 2017; Semper-Pascual et al. 2018). Moreover, deforestation deprives forest-dependent communities (e.g. indigenous and local peoples) of their resource base, and the privatization of land that is often associated with agricultural expansion leads to rising inequalities and social unrest (Aguiar et al. 2016).

In 2007, Argentina enacted National Law No. 26,331 on " Minimum environmental protection standards for the Environmental Protection of Native Forests" (known as the "Forest Law") with the objective of protecting native forests at the national level (Aguiar et al. 2018; Alcañiz & Gutierrez 2020). The Minimum Environmental Protection Standards laws were introduced in Argentina as part of the constitutional reform in 1994. Their aim is to address the challenge of harmonizing the delegation of responsibilities between different jurisdictions in the country, which is decentralized and operates under a federal system. The constitutional reform recognizes the provinces' original ownership of the natural resources within their territories. However, to establish minimum criteria for environmental protection across the country, the Minimum Environmental Protection Standards laws were enacted. By establishing a shared framework for environmental management, the Minimum Environmental Protection Standards laws help to ensure consistent and effective environmental protection across the country. They also provide a foundation for collaboration and coordination among different levels of government, which is essential for addressing environmental challenges in a federal system like Argentina's.

This Forest Law has two main instruments. On the one hand, a forest zoning scheme (hereinafter, the "OTBN"), which seeks to zone the area of native forests existing in each jurisdiction according to their conservation value-based sustainability criteria. According to the law, the native forests should be classified according to their conservation value into three categories (hereafter conservation categories): Category I encompasses forests with high conservation value where any kind of transformation is forbidden; Category II includes forests with intermediate conservation value where transformation is not allowed but certain sustainable activities are permitted, such as tourism, harvest of non-timber products, scientific research and cattle ranching; Category III corresponds to forests with low conservation value where total transformation is allowed with a previous environmental impact assessment.

On the other hand, a national compensation fund (hereinafter, the Fund), which aims to compensate the jurisdictions and landowners that conserve native forests for the environmental services they provide. The Forest Law stipulates financial compensation for each participating province based on the amount of land in each conservation category. The funds allocated to each province have two targets: 70 percent of the money must be used to pay landholders that preserve or sustainably manage native forests. The remaining 30 percent is assigned to the provincial

government office in charge of implementing the Law for institutional building, such as hiring personnel, buying vehicles, and monitoring compliance in the field (Alcañiz & Gutiérrez, 2020). The funds for landholders voluntary, and participants first must enroll at least a portion of a cadastral parcel, or several parcels of land, for a one-year period for the collection of baseline biodiversity information. After this initial period, a landowner can submit a plan for a longer-term project that specifies the proposed land use and activities to be carried out to maintain or enhance the ecosystems services provided. The contract length for this second phase of enrollment is at the discretion of the landowner. Payments are conditional on landowners providing and implementing these plans (Núñez Regueiro et al. 2019; Alcañiz & Gutiérrez, 2020).

In the following, we assess the status of the Forest Law 15 years after its enactment, describe its main challenges, and the opportunities of complementary strategies that have proven to effective in reducing deforestation in other deforestation frontiers. For this, we summarize insights from previous reviews (Aguiar et al. 2018; Di Pangracio et al. 2020) and studies that were published after these reviews.

Status and challenges of the Forest Law

1. The Forest Law is the main forest policy instrument to protect native forests in Argentina. It is the only law of minimum environmental protection standards that currently has funding. It was important to make visible socio-environmental conflicts derived from the expansion of the agricultural frontier in different forest regions of the country. 15 years after its enactment, the Law presents a series of limitations and challenges that require attention. In this context, during recent years, the National Forest Agency in collaboration with various institutions of the National Science and Technology System have produced valuable information to improve the implementation and monitoring of compliance with the Forest Law.

2. After the application of the Forest Law, forest loss was reduced in most of the provinces in the Chaco region. However, it is not possible to attribute this decrease solely to the application of the Forest Law, as reductions in international prices of agricultural products were also observed and lands with higher agricultural potential have already been converted. Numerous studies have analyzed the effectiveness of the Forest Law in reducing deforestation. Some suggest that the Forest Law was effective (Nolte et al. 2017), while others do not (Camba Sans et al. 2018; Vallejos et al. 2021; Volante & Seghezzo 2018), which has led to a debate on how to evaluate the effectiveness of the Forest Law (Nolte et al. 2018).

Even though deforestation rates have been reduced in many of the provinces, forest conversion continues to occur in areas classified under the red and yellow categories, where forest conversion is prohibited. Illegal deforestation has been attributed in part to the power of producers and their connection to provincial politicians (Blum et al. 2022). Therefore, this lack of effectiveness of the Forest Law is due to institutional weakness associated with the power of large producers to influence its design and implementation (Fernández Milmanda & Garay, 2019; Figueroa & Gutiérez, 2018; Gutiérrez et al. 2017; Seghezzo et al. 2011).

3. Since its implementation, the funding for the Forest Law has been much lower than what is indicated by the Law (Aguiar et al. 2018; Di Pangracio & Cáceres 2020). In the 2022 budget, only 3% of the total amount required by the Forest Law was assigned. However, over the last 15 years, a portion of these funds have been channeled toward strengthening or creating provincial forest departments, which is crucial for proper implementation (Alcañiz & Gutiérrez, 2020). Moreover, due to many cases of under-executed budgets, the provincial authorities have improved how they are required to account for the funds. Finally, following the reduction in deforestation rates after the

implementation of the Forest Law, Argentina was able to access international funding, which is currently being used to improve its implementation through various strategies.

4. The economic incentives to reduce deforestation have limitations. Firstly, the Compensation Fund amounts are low and do not provide a significant source of income to cover the opportunity cost of any economic activity (i.e. agriculture, livestock, or forestry). Furthermore, it is difficult to access the fund, and the funds often arrive late and devalued, and can only be used for improvements to the property (Fernández Milmanda & Garay, 2019). As for their effectiveness in reducing deforestation, the funds are usually allocated to conserve areas where the probability of conversion is null or low, thus presenting low additionality. Moreover, lands with high conversion probability participate in the compensation fund for short periods. This process of adverse selection compromises the long-term effectiveness of the compensation fund as an instrument to reduce deforestation (Núñez-Regueiro et al., 2019; Núñez-Regueiro et al., 2020).

Secondly, non-compliance with the Forest Law is resolved through payment of a fine that is low and, in many cases, not even paid (Milmanda & Garay, 2019). Therefore, this economic incentive is also not effective in changing the behavior of landowners. From the perspective of civil law, this fine is considered a misdemeanor. However, the Forest Law also allowed environmental damages related to forest loss or degradation to be considered also as penal damages. The "Karlen Case" in the northeastern province of Salta is an example of the application of this legal procedure. It was an emblematic case since the provincial court of Salta sentenced a landowner to six months of conditional imprisonment for the crime of judicial disobedience for not complying with the closure of his property after clearing forests without authorization. This case sets a precedent that could promote debate regarding criminal environmental offenses in Argentina. In this regard, there is a proposal promoted by Greenpeace some years ago to convert environmental offenses into criminal offenses, which has not been discussed in the National Congress. Although there has been progress worldwide in the development of environmental jurisprudence and the creation of specific courts to address these issues, there are still many challenges ahead (Pring & Pring, 2015). In this context, it is interesting to evaluate how Latin American countries with similar characteristics to Argentina have progressed in this issue. Chile presents an interesting example, as it not only has modern jurisprudence on environmental issues but also has specific courts to address these problems (Minaverry, 2015; Sbdar, 2017). And Brazil has an environmental crime act that can also be useful to define the civil, penal, and administrative sanctions for conducts and activities that harm the environment (Brancalion et al 2016).

5. There has been a notable disparity in the implementation of the Forest Law across provinces, particularly in the application of sustainability criteria for the OTBN. This is evidenced by the fact that forests with similar socioecological conditions have been classified differently in neighboring provinces, resulting in numerous inconsistencies in national zoning (García Collazo et al., 2013). Moreover, some provinces have allowed recategorizations of forests even after the approval of the OTBN by the national authority (Aguiar et al., 2018; Fernández Milmanda and Garay, 2019; Figueroa, 2017). In addition to differences in the implementation of the OTBN, there are also significant variations in how provinces implement the Compensation Fund, monitor compliance with the law, and collect fines from violators (Alcaniz and Gutiérrez, 2020; Fernández Milmanda and Garay, 2019; Figueroa, 2017). The complex articulation between the national and provincial levels of government is to the federal nature of Argentina and particularly due to environmental governance under minimum environmental protection standards laws. While the Federal Council of the Environment (COFEMA) is a political body that could resolve some of these issues, its decision-making authority is still limited.

6. The Forest Law does not specify which productive activities are considered sustainable or the criteria they must meet to be classified as such. As a result, it has not been clear which activities are allowed in forest areas classified as yellow in the OTBN (Class 2). One of the activities that has expanded the most in these areas are silvopastoral systems, which involve the removal of a fraction of the shrub and tree stratum and the planting of pasture to feed livestock. However, in many cases the woody component is very low, and therefore, they are a form of illegal deforestation (Blum et al. 2022). In recent years, the National Agricultural Technology Institute (INTA) has developed and promoted Integrated Forest Management with Livestock as a proposal for sustainable livestock production and forest extraction (Navall et al. 2021). However, the adoption and correct implementation are still limited (Tschopp et al. 2020; Tschopp et al. 2022), but its potential to balance meat production and carbon sequestration is promising (Fernández et al. 2020). Moreover, due to the technology and infrastructure to develop these management systems, their adoption by smallholders is challenging. Hence, it is necessary to advance in the adoption and correct implementation of these management schemes and also to generate productive alternatives that can be adopted by family farmers.

Overall, the previous findings suggest that there are many areas where the design and implementation of the Forest Law need to be strengthened. Some of these are technical, but most of them are institutional and political. In addition to tackling these challenges, it is necessary to explore complementary mechanisms to the Forest Law that can reduce deforestation, whether through public policies or voluntary private initiatives that affect the behavior of rural producers. Based on a literature review, we briefly describe some strategies that have been effective in reducing deforestation in other deforestation frontiers (Börner et al. 2020; Pacheco et al. 2021). In the following, we describe some of the that are promising for the Argentine Chaco.

Complementary strategies for halting deforestation

1. Expansion of protected areas. The proportion of protected area in the Dry and Humid Chaco is 4.78% and 1.3% of the total area of these ecoregions, respectively (Nanni et al. 2020; Nori et al. 2016). Therefore, the Chaco region is well below the targets set by international agreements, such as the Aichi Target, which aimed for 17% of each ecoregion's land area to be under some form of conservation by 2020. The recently established Global Biodiversity Framework (GBF), which replaces the Aichi Target and similar agreements, sets an even more ambitious target, requiring 30% of each terrestrial ecoregion to be protected by 2030 (Díaz et al. 2020). In this context, it is crucial to expand protected areas in the Argentine Chaco to meet international agreements and ensure biodiversity conservation. However, in addition to the low current coverage of protected areas, many of the existing protected areas are located in areas with low agricultural opportunity costs, meaning they are situated in zones with low agricultural suitability. Furthermore, the recent expansion of protected areas has been guided by opportunistic rather than spatial prioritization criteria (Baldi et al. 2019; Marinaro et al. 2012). Moreover, existing protected areas are isolated with little connectivity between them.

Globally, there is evidence that protected areas are an effective strategy for reducing deforestation (e.g., Wolf et al. 2021). Given the low proportion of protected areas in the Argentine Chaco, there is a significant opportunity to expand protected areas and improve their connectivity. It is also important to expand natural and semi-natural areas in agricultural landscapes outside of protected areas. Recent studies indicate that between 30% and 50% of these areas are needed in forested landscapes to provide adequate ecosystem services and ensure habitat thresholds that increase the viability of wild species (Arroyo-Rodríguez et al. 2020; Garibaldi et al. 2021). In Brazil, the law on the protection of native vegetation establishes that a minimum fraction of the properties

must be protected as legal reserves (e.g., 80% in the Amazon and 35% in the Cerrado). Advancing these types of strategies would surely contribute to increasing the sustainability of agricultural landscapes (Arroyo-Rodríguez et al. 2020; Garibaldi et al. 2021).

Expanding conservation areas presents some challenges and barriers. Currently, there are no studies that present different scenarios of protected area expansion based on ecological, economic, and social criteria. Moreover, the feasibility of this expansion is unknown, as it is unclear how much land is privately owned and how much is public. Regarding the conservation and/or restoration of natural and seminatural areas in agroecosystems, landowners may not have the economic or productive incentives to conserve and/or restore forests within their properties. Finally, the expansion of protected areas must bring benefits to the local population, rather than being at the expense of their well-being and through exclusion and/or displacement, as is the case in many regions of the world (Ghoddousi et al. 2022; Sandbrook et al. 2023).

2. Land titling to indigenous and local communities. This is one of the most effective global strategies for reducing deforestation (Sze et al. 2022). Local evidence from Brazil (Nolte et al. 2013), Peru (Blackman et al. 2017), and recently from the Chaco Seco region in Argentina, Bolivia, and Paraguay (Camino et al. 2023), also supports this approach. The latter study highlights that secure land tenure for indigenous communities is important for reducing deforestation in the Chaco. The Chaco region is home to numerous indigenous and local communities that rely on the forest for subsistence through hunting, gathering, logging, and livestock raising. While they may contribute to forest degradation in some areas near their settlements, their means of livelihood do not involve forest conversion.

The extent of indigenous and local communities land tenure in the Chaco region is still uncertain, similar to the previous strategy. Many indigenous communities have a semi-nomadic way of life, making it challenging to demarcate their territories accurately. Moreover, for those who have a more sedentary way of life, their lands often lack well-defined boundaries such as fences, which results in insecure land tenure. Additionally, many of these lands are used communally, adding to the complexity of land titling. Land titling in this context necessitates extensive surveying and systematization efforts. The National Institute of Indigenous Affairs has taken some initiatives to advance land titling, but the current status of the surveying is imprecise. Recent studies suggest that the surveying is incomplete (Camino et al. 2023). Advancing the surveying process presents both technical and political challenges. Furthermore, land titling requires significant political decisions and coordination from national and provincial governments. It would be interesting to explore and learn from the agrarian reform initiatives in other regions of Latin America, particularly Colombia, where significant strides have been made toward land titling for indigenous and local peoples in the past 30 years (Peña et al. 2017).

In parallel, the "Native Forest and Community" project funded by the World Bank is being implemented in some areas of the Argentinean Chaco. Among other objectives, this program seeks to promote rural rootedness by strengthening the communities that inhabit these areas. Currently, this project is being executed in several departments of the Chaco region, but its effectiveness and impact are not precisely known, especially regarding how land tenure operates to access benefits. A recent evaluation of some aspects of this initiative in the province of Salta indicates that it has some weaknesses, mainly in terms of participation since its operation is top-down with little community involvement in the objectives, which could compromise its effectiveness (Busck-Lumholt et al. 2022). Further studies are needed to determine if this initiative effectively promotes rural rootedness and an improvement in the quality of life of indigenous and local peoples.

3. Implement interventions in the supply chains of commodities associated with deforestation. More than a quarter of the global food production is now traded internationally, and much of the agricultural commodities consumed in the Global North are imported from far-away producer regions (D'Odorico et al. 2013; Pendrill et al 2022). This spatial decoupling of agricultural production and consumption results in the displacement of social or environmental impacts from richer to poorer countries, with little value gained in poorer producing countries - a phenomenon called "unequal ecological exchange" (Dorninger et al. 2021). Supply-chain interventions are potentially powerful to reduce such outsourcing of social-ecological impacts. In particular, many companies have adopted zero-deforestation commitments and vowed to increase supply chain sustainability and transparency (Lambin & Thorlakson, 2018). Likewise, new trade agreements, such as the EU-MERCUSR agreement (Kehoe et al. 2020), and new EU due diligence policies (https://ec.europa.eu/commission/presscorner/detail/en/ip_22_114), seek to implement cleaner supply chains.

Supply chain initiatives have been key for reducing deforestation in Brazil (Levy et al 2023; Nepstad et al. 2014). Currently, the supply chains of beef and soy are well-documented in Brazil, allowing for the design and implementation of intervention strategies for these commodities' supply chains (Zu Ermgassen et al. 2020a; Zu Ermgassen et al. 2020b). This information not only enables compliance with international agreements on the trade of deforestation-free products but also the certification of products consumed in the domestic market. In this regard, an application has also been developed in Brazil that allows consumers to obtain information on the origin and production conditions of beef sold in supermarkets (https://www.dopastoaoprato.com.br/). The Domestic market in Argentina is currently moving slowly with regards to voluntary certifications of products that meet certain production standards

This strategy presents both technical and political challenges. From a technical perspective, a significant amount of information is currently lacking to ensure the traceability of production. Initiatives like Trase (https://www.trase.earth/) seek to address this gap, but the use of secondary information based on national statistics means that there are still information gaps in accurately reconstructing the supply chains of many commodities associated with deforestation. As for the political challenges, it remains uncertain how the government, producers, and trading companies will adapt to the due diligence policy of the European Union, and what incentives or penalties they will face for non-compliance. A possible avenue for moving this strategy forward, and increasing its potential compliance, is to associate it with export taxes ("retenciones"). These taxes could be reduced to farmers that comply with the Forest Law or other environmental standards.

4. Implementing a National Cadaster System. Argentina faces significant shortcomings in registering land tenure and rural property ownership. This represents a critical barrier to designing, implementing, and evaluating public policies aimed at regulating rural land use, either to promote certain types of primary production and/or protect the rural environment, its biodiversity and ecosystem services, and the people that depend on them. While provincial governments are responsible for registering rural property and maintaining up-to-date rural cadasters, their capacities in terms of human resources and technology are insufficient to carry out this task, or they simply lack the political will to make this information transparent and accessible. Faced with a similar problem (or even greater due to the vast extent of unregistered public lands), the Brazilian State used new technologies (remote sensing, relational databases) to develop a transparent and accessible rural environmental cadaster (dos Santos et al. 2021).

The implementation of a rural environmental cadaster in Argentina has great potential to positively impact the development of at least two types of public policies and public-private initiatives

aimed at increasing the environmental sustainability of agricultural production and exports. First, it represents a piece of key information to support the design and implementation of policies that intervene in supply chains, as it facilitates the traceability of agricultural commodities exported to international markets and allows for establishing whether a given product originates from a rural property that has good environmental performance (and therefore can be certified as a 'sustainable source') or not (and therefore is excluded from market access).

Secondly, the rural environmental cadaster would also allow for a more effective implementation of the Forest Law, by improving the monitoring of compliance of the OTBN and both the design and monitoring of the Compensation Fund. In many provinces, the OTBN establishes land use restrictions at the level of the rural property, in addition to the zoning of land uses at the provincial level. However, the control and supervision of these restrictions are deficient due to the absence of updated rural cadasters. The existence of the rural environmental cadaster would enable monitoring of compliance with these regulations at the level of the rural property, as occurs with the regulations established by the Native Vegetation Protection Law in Brazil (Brancalion et al. 2016). Furthermore, the Compensation Fund aims to economically incentivize rural landowners who conserve and sustainably manage native forests for the environmental services they provide. This compensatory mechanism has great potential to promote good environmental practices among landowners with native forests on their farms. However, its implementation is also limited by the difficulty of monitoring land use and management of native forests at the level of rural property. Moreover, as the previous strategy, tax exemptions could also be useful for increasing the adoption and compliance. The rural environmental cadaster would not only improve monitoring of the Compensation Fund but also allow for the segmentation of rural properties according to size, tenure, etc., and direct incentives and compensations towards those properties with a higher risk of abandonment (thus promoting rural settlement) or with a higher risk of deforestation (thus increasing the additionality of the policy).

The challenge of this strategy is technical but mainly political. It is necessary to evaluate its institutional feasibility and social acceptance. Regarding the former, it is necessary to assess how costly it is in economic terms and seek international funding if it is impossible to be funded with national funds. Regarding the latter, agricultural producers generally have a poor relationship with national and provincial governments from Peronist political parties. Therefore, it is necessary to evaluate the acceptance by agricultural producers to participate in this initiative under different contexts. For example, knowing their willingness to participate in the inclusion of their property in the cadastral system is a requirement to market their products nationally and internationally and/or to access specific markets that allow them to obtain greater economic returns (e.g., through environmental certifications). In addition to knowing the acceptability of producers, it would be interesting to conduct a pilot test in some regions or provinces. The provinces of Córdoba and Santa Fe could be good candidate areas where to test this initiative since the agribusiness sector generally has a good relationship with the provincial government.

Concluding remarks

In this document, we have briefly described the limitations and challenges that the Forest Law currently faces in the Argentine Chaco. We have also outlined strategies that have been effective in reducing deforestation in other regions of the world, including the barriers and challenges to implementing these strategies in Argentina. Our list is not exhaustive, as other strategies have not been included, such as carbon credits, which were excluded due to conflicting global results (Balmford et al. 2023). It is important to highlight that a combination of different strategies should be implemented through policy mixes or hybrid governance, as the synergy between them will lead to the best outcomes in terms of environmental, economic, and social impacts (Pacheco et al. 2021).

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