Informing forest conservation regulations in Paraguay

MEDS capstone project proposal
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Proposers, clients and collaborators

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Objectives

Paraguay's National Forest Institute (INFONA) is considering proposals to change its requirements for forest conservation on private properties in the Paraguayan Chaco. However, it is difficult to know how changes to specific requirements (e.g. area of forest reserves, widths of riparian corridors) would translate into the total area of forests that landowners protect. This project will support a more informed public debate about conservation policy in Paraguay by pursuing three objectives:

1. Assess the extent to which (a) existing land use permits align with legal requirements for forest conservation; and (b) property owners' land use decisions comply with permits.
2. Predict future deforestation patterns using a machine learning model.
3. Develop an interactive tool that allows policymakers to explore the impacts that alternate forest protection requirements would have on the fate of the Chaco's forests.

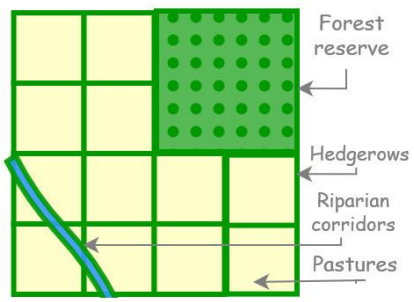
Significance

The Chaco is a 1.1 million km^2 ecoregion in South America that, since 1985, has lost 28 percent of its woodlands as a result of widespread conversion to extensive cattle ranching and cropping. The Paraguayan Chaco in particular has emerged as a global hotspot of deforestation, losing forests at an annual rate of 1.3% per year between 1985 and 2020 (Baumann et al. 2022; Stanimirova et al. 2022). However, as global public attention has turned to the Chaco's rapid loss of forests, Paraguayan policymakers have sought to implement reforms to maintain forest cover in agricultural frontiers. Specifically, a variety of regulations require private land owners to protect forests on their properties. In 2022, Paraguayan policymakers are considering changes to these regulations that could dramatically increase the area of forests that landowners are permitted to convert to agricultural production. However, policymakers do not have access to the necessary tools to fully understand either (a) the full extent of compliance with existing rules; or (b) the impacts that new requirements would have on the extent of forests and agricultural areas. This project will fill these gaps by integrating multiple, newly released datasets into an analysis pipeline that clearly communicates the practical consequences of potential changes to land use requirements. Through our partners in Paraguay's National Forest Institute, we believe that these tools will have the potential to directly influence future land use policy design, implementation and enforcement.

Background

Paraguay's existing laws impose three conservation requirements upon medium and large (>50 hectare) properties in the Chaco:

- Forest reserve: Property owners must set aside a minimum of 25% of their property as a "forest reserve."
- Hedgerows: Property owners are allowed to clear individual fields or pastures up to a size of 100 hectares. Each of these clearings must be surrounded by a forested hedgerow that is at least 100m wide.
- Riparian corridors: Property owners much protect a 100m wide strip of forests on either side of all rivers and streams.



Given the rapid pace of deforestation in the Chaco, relatively low enforcement capacity, and frequent links between agricultural investments and broader illicit activities, it is likely that many properties do not comply with these requirements. However, the extent of illegal deforestation in Paraguay is largely unknown. This MEDS project will quantify the scale of illegal deforestation by comparing remotely sensed data on land use change against geospatial data detailing land use permits.

In addition, policymakers are now considering several amendments to the existing conservation requirements. Proposed changes include:

- Allowing land owners to count hedgerows and riparian corridors towards their forest reserve requirements;
- Adjusting requirements for the width of hedgerows for smaller fields;
- Increasing forest reserve requirements to 50% of properties within a large, recently declared biosphere reserve, the Reserva de Biosfera Chaco Paraguayo; or
- Prohibiting all further deforestation within the Chaco, a requirement that would mirror land use requirements in Eastern Paraguay's Atlantic Forest.

This MEDS project will give policymakers a tool that allows them to explore simulated, future land use under each of these policy scenarios, enabling a more informed discussion of the trade-offs inherent in each policy change.

Equity

Similar to many other Latin American countries, Paraguay has sought to provide public conservation benefits by requiring private landowners to protect forests on their properties. However, these unfunded mandates can have unequal impacts on the private landowners that are asked to bear the cost of providing a public good. This dynamic can weaken public support for environmental regulations, reducing their long-term sustainability. In addition, in the presence of corruption, selective enforcement of land use restrictions can favor wealthier and more politically connected individuals. Improved and standardized information detailing regulatory compliance could yield more equitable implementation of land use requirements.

Data

The MEDS group will have access to all datasets necessary to complete the proposed research. These data are described below, and can be accessed in this Google Drive directory.

1. Land use: Maps of forest cover (2000-2020), as generated by INFONA.
2. Permitted land use: INFONA's spatial database of land use permits issued in the Chaco between 1994-2022.
3. Waterways: Network of all streams and rivers that require the protection of riparian corridors, as mapped by Paraguay's National Cadastral Service.
4. Road network: Network of all roads in Paraguay, as mapped by the National Cadastral Service. This data can be used to improve the predictive model of deforestation.
5. Indigenous lands, wildlife protection areas and biome boundaries: Provides boundaries of public protected areas which can be used to refine the machine learning model of deforestation.

Possible approaches

We believe that the proposed objectives can be achieved through a combination of geospatial analyses and machine learning models. Specifically, we envision four discrete tasks:

1. Geospatial overlays to compare remotely sensed land use against the permitted use of land: The group would compare permits against mapped land use patterns to quantify the level of illegal clearing in the Chaco.
2. Rule-based, geospatial simulations of land use configurations: The group would develop an R or Python module that simulates potential permitting patterns under a range of chosen input parameters (e.g. forest reserve requirements, hedgerow widths).
3. Machine learning model of deforestation: The group would train a convolutional neural network that predicts deforestation based upon past deforestation patterns and permitting decisions (Ball et al. 2022).
4. Work with clients to integrate the results of these three analyses into a decision-support tool that allows policymakers to explore the deforestation impacts of potential changes to private forest conservation requirements.

Computational tools and needs

Group project members will need to conduct geospatial analyses and develop machine learning models in either R or Python. Given the computational needs involved in training convolutional neural networks at a high spatial resolution, and generating model predictions over large areas, it is possible that group members will need access to additional computing resources. The client has access to a cluster at the Earth Research Institute that can be used for this project. Finally, the interactive web application may require hosting services to enable public access.

Deliverables

1. Tabular data detailing the extent to which individual INFONA permits align with legal requirements for forest conservation. Data should be accompanied with well-annotated and reproducible code that generates the results.
2. Tabular data detailing the extent to which property-level land use violates approved permits. Data will be accompanied with well-annotated and reproducible code that generates the results.
3. Machine learning code that predicts deforestation dynamics in the Chaco under alternative policy scenarios.
4. Interactive web application, possibly in the form of an RShiny app, that communicates the land use implications that alternate forest conservation requirements would have on the total area of forest and agricultural land in the Chaco.

Audience

The primary audience for this analysis will be policymakers in Paraguay's National Forest Institute (INFONA). Secondary audiences will include the Paraguayan public, as well as environmental and agricultural producer organizations who may be interested in how changes to private conservation requirements might affect land use in the Chaco.

Supporting materials

References

Ball, James G. C., Katerina Petrova, David A. Coomes, and Seth Flaxman. 2022. "Using Deep Convolutional Neural Networks to Forecast Spatial Patterns of Amazonian Deforestation." *Methods in Ecology and Evolution*. https://doi.org/10.1111/2041-210X.13953.

Baumann, Matthias, Ignacio Gasparri, Ana Buchadas, Julian Oeser, Patrick Meyfroidt, Christian Levers, Alfredo Romero-Muñoz, Yann le Polain de Waroux, Daniel Müller, and Tobias Kuemmerle. 2022. "Frontier Metrics for a Process-Based Understanding of Deforestation Dynamics." *Environmental Research Letters* 17 (9): 095010. https://doi.org/10.1088/1748-9326/ac8b9a.

Stanimirova, Radost, Jordan Graesser, Pontus Olofsson, and Mark A. Friedl. 2022. "Widespread Changes in 21st Century Vegetation Cover in Argentina, Paraguay, and Uruguay." *Remote Sensing of Environment* 282 (December): 113277. https://doi.org/10.1016/j.rse.2022.113277.

Budget and justification

The proposed project is not anticipated to require additional funding beyond the standard project support made available to all MEDS capstone projects.

Client support

As the lead author of this proposal, Robert Heilmayr commits to providing the data and computational resources that are detailed throughout this document. He is willing to serve as the project's faculty advisor to ensure the group's success towards the project's stated objectives.