

**New law puts Bolivian biodiversity hotspot on road to deforestation**

Álvaro Fernández-Llamazares<sup>a\*</sup>, Joose Helle<sup>a,b</sup>, Johanna Eklund<sup>a,b</sup>, Andrew Balmford<sup>c</sup>,  
Mónica Moraes R.<sup>d</sup>, Victoria Reyes-García<sup>e,f</sup>, Mar Cabeza<sup>a</sup>

<sup>a</sup> Global Change and Conservation (GCC), Department of Biosciences, University of Helsinki, Helsinki, Finland

<sup>b</sup> Department of Geosciences and Geography, University of Helsinki, Helsinki, Finland

<sup>c</sup> Conservation Science Group, Department of Zoology, University of Cambridge, Cambridge, United Kingdom

<sup>d</sup> Instituto de Ecología, Universidad Mayor de San Andrés, La Paz, Bolivia

<sup>e</sup> Institució Catalana de Recerca i Estudis Avançats (ICREA), Barcelona, Spain

<sup>f</sup> Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona, Bellaterra, Barcelona, Spain

**\* Corresponding author:**

Álvaro Fernández-Llamazares, Metapopulation Research Centre, Department of Biosciences, P.O. Box 65 (Viikinkaari 1), University of Helsinki, FI-00014, Finland  
Tel: +358 407482588 | E-mail: [alvaro.fernandez-llamazares@helsinki.fi](mailto:alvaro.fernandez-llamazares@helsinki.fi)

**Keywords:** Bolivian Amazonia; deforestation; indigenous peoples; road expansion; socio-environmental conflicts.

**eTOC Blurb:** Fernández-Llamazares et al. provide a geospatial analysis of deforestation in TIPNIS, in Bolivian Amazonia, revealing that >58% of the deforestation to date is concentrated <5km from existing roads. The recent downgrading of the Park's legal protection looks set to lead to construction of a controversial road which will fuel further deforestation.

On August 2017, the Bolivian Government passed a contentious law downgrading the legal protection of the Isiboro-Sécure National Park and Indigenous Territory (TIPNIS, for its Spanish acronym), the ancestral homeland of four lowland indigenous groups and one of Bolivia's most iconic protected areas. Due to its strategic position straddling the Andes and Amazonia, TIPNIS represents not only a key biodiversity hotspot in Bolivia, but one of the most biodiverse regions on Earth, harboring exceptional levels of endemism and globally important populations of megafauna, and protecting substantial topographic and elevational complexity likely to support both wildlife migration and species range shifts in response to climate change [1]. The new law, set to authorize the construction of a deeply-contested road through the core of the Park, has reopened one of the highest profile socio-environmental conflicts in Latin America. Roads in tropical forests often seed habitat conversion, and indeed within TIPNIS >58% of deforestation is concentrated <5 km from existing roads. It therefore seems very likely that the planned road will magnify the current scale and pace of deforestation in TIPNIS, underscoring the urgent need for revisiting the road plans.

The road, preliminary plans for which date back to 2002, has faced significant levels of opposition amongst lowland indigenous peoples and environmental advocacy groups [2]. In 2011, more than 1,000 lowland indigenous peoples marched by foot to La Paz, covering over 600 km to show their disapproval of the road plans [3]. Facing massive public outcry and unprecedented media attention, the Government of Bolivia had no option but to declare the territory as strictly protected (or '*intangible*' in Spanish). However, this legislation halted the construction only of Section II of the road (the part crossing TIPNIS) as the other sections (I and III), mostly outside the indigenous territory, were already under construction. Moreover, the law did not affect the rudimentary

network of secondary roads that, since the early 2000s, crisscross the southernmost part of the Park (Figure 1)

The recent downgrading of the legal protection of TIPNIS has reawakened conflicts between the Bolivian Government and lowland indigenous communities (themselves supported by much of civil society). The Bolivian Government claim the road will enable national integration, facilitate market access for rural producers, and bring services to isolated, river-dependent lowland indigenous communities. In turn, detractors argue that the road will open a Pandora's box of social and environmental problems, including deforestation, biodiversity loss, social disruption, and violation of indigenous peoples' customary land rights [1–3], as reported for roads elsewhere in Amazonia [4,5].

In the context of a country-wide public debate over the potential impacts of the planned road, there is little discussion of ongoing environmental pressures in TIPNIS. One aspect that is generally overlooked is that, despite being a remote and relatively inaccessible protected area and indigenous territory, TIPNIS is already subject to alarming levels of deforestation within its borders (Figure 1), having lost more than 46,000 hectares of forest (3.6% of the Park) between 2000 and 2014 (Table S1).

There is good correlational evidence that roads have already played a key role in enabling this deforestation. Remarkably, 58% of the forest loss recorded in TIPNIS has taken place within 5 km from pre-existing roads (Table S2), most notably around Section I (Figure 1). This area, also known as Polygon 7, covers approximately 12% of the National Park and is delimited by a zone of coca farming expansion [3]. The rate of forest loss in Polygon 7 is eight times higher than that in the rest of TIPNIS and double that of Bolivian Amazonia (Table S1). Interestingly, Polygon 7 is also the only section of TIPNIS

that does not overlap with titled territories of the lowland indigenous communities, but is instead inhabited by highland migrants who settled in the area in the 1980s as part of a wave of Government-planned colonization of the Bolivian lowlands. The fact that migrants generally cause higher (per-capita) deforestation rates than local indigenous communities has been extensively researched in other parts of Amazonia and has been often linked to coca farming [6, 7]. In line with the growing phenomenon of “narco-deforestation” seen across many tropical forests in Latin America [7], coca cultivation by Andean settlers is commonplace in Polygon 7 and rapidly expanding towards other areas of the Park [3].

Improving food security is a frequently invoked justification for road construction in the Tropics [4]. However, the fact that most land clearing in TIPNIS is linked with coca cultivation suggests that the road is poorly justified from such perspective. With modest agricultural potential and high environmental values, TIPNIS would instead seem to present a textbook example of an environment where development of new roads should be limited [4]. Moreover, given that permanent roads generate a considerably larger deforestation footprint than secondary roads, which generally become inaccessible during the wet season [8, 9], it is crucial that the network of secondary roads in the southern area of the park is not upgraded in any way (e.g., into graveled roads). Mapping and monitoring changes in this network would help limit further deforestation within TIPNIS.

There is well-established evidence that forest loss tends to spread contagiously around newly built and/or paved roads, spawning networks of secondary roads that increase the spatial extent of habitat disruption [4, 5]. For instance, in Brazilian Amazonia, for every kilometer of legal road there are almost three kilometers of illegal roads [5]. Because of this, it has been argued that the only viable way to avoid habitat loss in areas of high conservation value is to keep them road-free [4, 5, 9].

With an expanding frontier of coca cultivation [3] and new incentives for oil and gas exploration throughout Bolivia [2], it seems likely that the downgrading of the legal protection of TIPNIS will open an area of high conservation value to further encroachment. It is in this light that the controversial plans for the TIPNIS road should be evaluated. The likely environmental impacts of road development in one of Bolivia's main biodiversity hotspots [1] would be regrettable for a country with a prominent profile as a vocal defender of conservation in global environmental fora.

As a signatory of the Convention on Biological Diversity, Bolivia has committed to conserve at least 17% of its terrestrial surface by 2020 through a network of effective protected areas. However, with high deforestation rates and facing a boom of hydrocarbon exploration, Bolivia is struggling to achieve this goal. Perhaps even more significantly, the recent developments in TIPNIS are symptomatic of current trends towards Protected Area Downgrading, Downsizing and Degazettement (PADDD) across the pan-Amazonian basin, generally associated with rising extraction-based economic policies [10]. The downgrading of the legal protection of TIPNIS risks setting a dangerous precedent in the region. Deforestation is likely to continue if urgent measures are not put in place to protect remaining Amazonian forests from ever-encroaching road expansion, while respecting the rights of local and indigenous communities. We call on Bolivia's government to revisit the TIPNIS road plans in the light of current deforestation levels within the park. The debate around road construction should be based on a rigorous understanding of the present-day social-ecological context of TIPNIS, including ongoing threats in one of Bolivia's main biodiversity hotspots.

## Acknowledgements

This work has been funded by the Academy of Finland (grant agreement nrs. 311176 and 257686) and the Kone Foundation. Reyes-García acknowledges financial support from NSF-Anthropology (NSF #0963999). We thank O. Andrés, I. Díaz-Reviriego, S. Fraixedas, R. Rocha and I.V. Sánchez for all our insightful conversations about Bolivian Amazonia through the years, and J. Nyman and J. Terraube for cartographic assistance at several stages of the project.

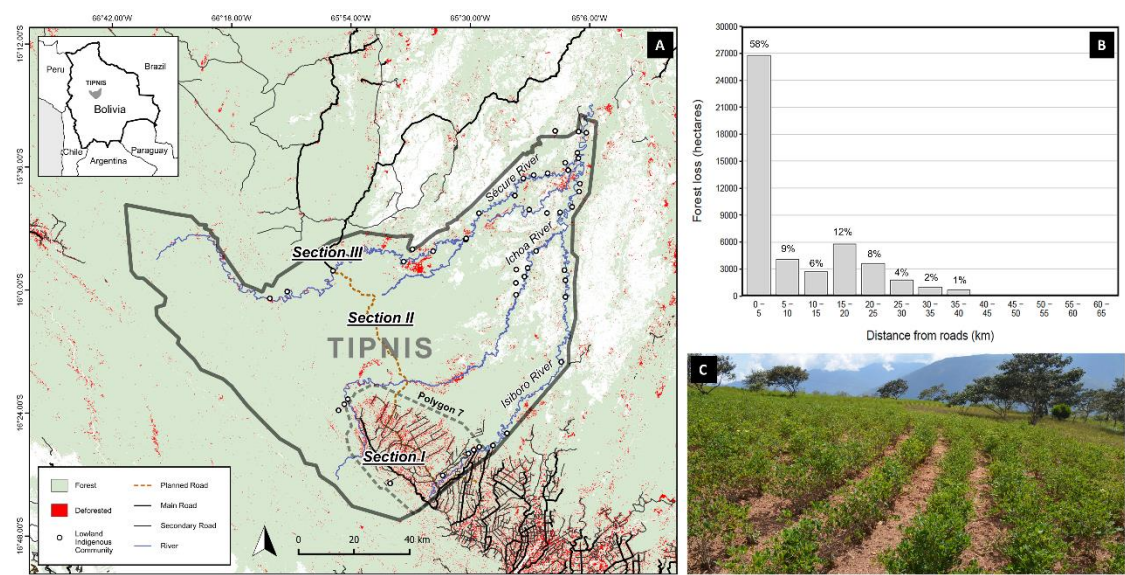
## References

1. Thomas, E. (2009). New light on the floristic composition and diversity of indigenous territory and national park Isiboro-Sécure, Bolivia. *Biodivers. Conserv.* 18, 1847–1878.
2. Fernández-Llamazares, Á., and Rocha, R. (2015). Bolivia set to violate its protected areas. *Nature* 523, 158–158.
3. Delgado, A.C. (2016). The TIPNIS Conflict in Bolivia. *Contexto Internacional* 39, 373–392.
4. Laurance, W.F., Sloan, S., Weng, L., and Sayer, J.A. (2015). Estimating the Environmental Costs of Africa’s Massive “Development Corridors”. *Curr. Biol.* 25, 3202–3208.
5. Barber, C.P., Cochrane, M.A., Souza, C.M. Jr, and Laurance, W.F. (2014). Roads, deforestation, and the mitigating effect of protected areas in the Amazon. *Biol. Conserv.* 177, 203–209.
6. Rudel, T.K. (2005). *Tropical Forests: Regional Paths of Destruction and Regeneration in the Late 20th Century* (New York: Columbia University Press).
7. Dávalos, L.M., Bejarano, A.C., Hall, M.A., Correa, H.L., Corthals, A., and Espejo, O.J. (2011). Forests and Drugs: Coca-Driven Deforestation in Tropical Biodiversity Hotspots. *Environ. Sci. Technol.* 45, 1219–1227.
8. Laurance, W.F., Albernaz, A.K.M., Schroth, G., Fearnside, P.M., Bergen, S., Venticinque, E.M., and Da Costa, C. (2002). Predictors of deforestation in the Brazilian Amazon. *J. Biogeogr.* 29, 737–748.
9. Alamgir, M., Campbell, M.J., Sloan, S., Goosem, M., Reuben Clements, G., Mahmoud, M.I., and Laurance, W.F. (2017). Economic, Socio-Political and

Environmental Risks of Road Development in the Tropics. *Curr. Biol.* 27, R1130–R1140.

10. Bernard, E., Penna, L.A.O., and Araújo, E. (2014). Downgrading, Downsizing, Degazettement and Reclassification of Protected Areas in Brazil. *Conserv. Biol.* 28, 939–950.

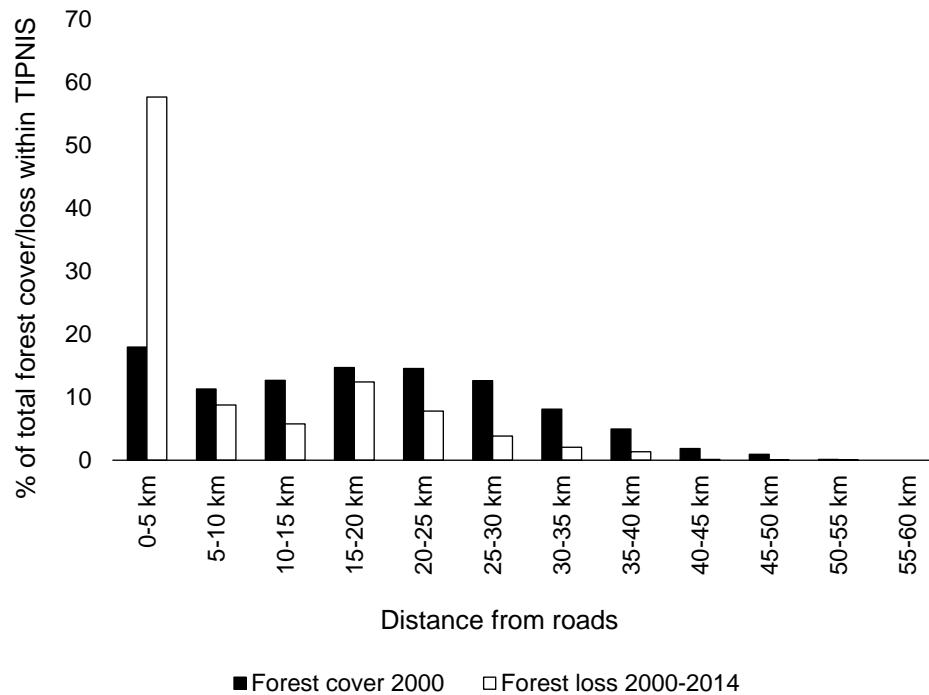
Figures



**Figure 1. A) Spatial distribution of forest loss in TIPNIS (2000-2014). B) Forest loss (ha) in TIPNIS in relation to distance from roads. C) Expanding frontier of coca cultivation. See SI for datasets used and methodological details (Tables S1 and S2).**



## Supplemental information



**Figure S1. Percentage of total forest cover (2000) and total forest loss (2000-2014) within TIPNIS in relation to distance from roads. Related to Figure 1.**

Area	Forest loss 2000-2014 (ha)	Forest loss 2000-2014 (%)
TIPNIS	46,347	3.56
Polygon 7 (12%)	24,830	15.42
Rest of TIPNIS (88%)	21,536	1.89
Bolivian Amazonia	3,087,496	6.04

**Table S1. Descriptive statistics of forest cover extent and change in TIPNIS, Polygon 7, rest of TIPNIS, and Bolivian Amazonia. Related to Figure 1.**

## **Supplemental experimental procedures**

We examined the spatial relationships between deforestation and built roads, within the Isiboro-Sécure National Park and Indigenous Territory (TIPNIS) using geospatial analysis.

The geographic limits of TIPNIS were sourced from the World Database on Protected Areas [S1]. The network of roads inside and outside of TIPNIS was obtained from OpenStreetMap [S2], including both the TIPNIS road sections, as well as secondary and unpaved roads in Polygon 7 (see Figure 1 for further details). The dataset of navigable rivers in TIPNIS was obtained from HydroSHEDS [S3]. Data on the lowland indigenous communities in TIPNIS were obtained from an undisclosed source. Finally, data on forest cover extent and change were retrieved from the Global Forest Change 2000-2014 from the University of Maryland [S4]. This corresponds to a time-series of analysis of Landsat images characterizing both forest extent and change from 2000 through 2014 at 30m resolution. In this dataset, “forest” is defined as any pixel with a canopy cover over 25%, whereas “forest cover loss” represents a stand-replacement disturbance, or a change from a forest to non-forest state, during the period 2000-2014 [S4].

ArcGIS 10.3.1. [S5] was used for gathering and organizing the spatial datasets, and performing the proximity analysis. First, the Euclidean distance tool from the proximity toolset was used to calculate proximity (distance) rasters for roads. Subsequently, all the spatial analyses were carried out using R programming language and environment version 3.3.2. [S6]. Several packages for analyzing spatial data were used, i.e., raster [S7], rgdal [S8] and sp [S9].

In order to join spatially the distances from features to forest loss, the center points of all the raster cells that were classified as deforested [S4] were used as sample points. Distance values for each sample point were extracted from the proximity (distance) rasters. The number of deforested cells within each of the selected distance ranges around roads was then extracted. Finally, the total area of forest loss (in hectares) was calculated from these cell counts. Compared to classic buffer analysis, this approach provides more reliable data for exploring spatial patterns of forest loss.

The total amount of forest loss around roads was calculated based on the cell size (0.09 ha) of the forest loss data [S4]. Thus, the accuracy of the spatial analysis is constrained not only by the uncertainties in the road data, but also by the cell size and the

image classification methods used in the production of the input data. Despite these limitations, the dataset used represents one of the main publicly available references of forest cover change data for Bolivian Amazonia. Descriptive statistics of the TIPNIS forest cover and loss data are shown in Tables S1 and S2 [AU there is no table S2?].

### **Author Contributions**

AF.L.L., J.H., J.E. and M.C. designed the study. J.H. conducted the spatial analyses. A.F.L.L. led the writing, with contributions from all co-authors. M.C. supervised the project through all its phases.

### **Supplemental References:**

- S1. UNEP-WCMC, and IUCN. (2017). The World Database on Protected Areas (WDPA). Retrieved from <http://www.protectedplanet.net> (accessed 20.6.17).
- S2. OpenStreetMap contributors. (2017). Planet dump. Retrieved from <https://planet.openstreetmap.org> (accessed 30.6.2017).
- S3. Lehner, B., Verdin, K., and Jarvis, A. (2006). HydroSHEDS Technical Documentation. World Wildlife Fund US, Washington, DC. Retrieved from <http://hydrosheds.cr.usgs.gov> (accessed 30.6.2017).
- S4. Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S.A., Tyukavina, A., Thau, D., Stehman, S.V., Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O., and Townshend, J.R.G. (2013). High-Resolution Global Maps of 21st-Century Forest Cover Change. *Science* 342(6160), 850–853. Retrieved from <http://earthenginepartners.appspot.com/science-2013-global-forest> (accessed 30.6.2017).
- S5. ESRI. (2013). ArcGIS 10.2.1. for Desktop. Environmental Systems Research Institute, Redlands, CA.
- S6. R Core Team. (2015). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. <https://www.r-project.org>
- S7. Hijmans, R.J. (2016). Raster: Geographic Data Analysis and Modelling. R package version 2.5-8. <https://CRAN.R-project.org/package=raster>
- S8. Bivand, R., Keitt, T., and Rowlingson, B. (2017). rgdal: Bindings for the Geospatial Data Abstraction Library. R package version 1.2-8. <https://CRAN.R-project.org/package=rgdal>

- S9. Bivand, R.S., Pebesma, E., and Gómez-Rubio, V. (2013). Applied spatial data analysis with R. Second edition. Springer, New York, United States.  
<http://www.asdar-book.org/>