

Introduction

- The Amazon Biome is rich in ecological diversity, containing over 25% of the world's terrestrial species (Malhi et al., 2011; Plotkin, 2020), almost 15% of the planet's freshwater (Ghai et al., 2011), and nearly 50% of global tropical forest carbon stocks (Saatchi et al., 2011), which amounts to approximately 20% of the planet's terrestrial carbon (Plotkin, 2020).
- The Sierra del Divisor region in the remote southwestern Amazon borderlands of Ucayali, Peru and Acre, Brazil is a hotspot of cultural and biological diversity with at least 20 threatened mammalian species (Vriesendorp et al., 2006; and groups including nomadic Isonahua, Asháninka, Nawa, rubber tappers, ribereños, farmers, and miners (Salisbury et al., 2013).
- Forests are extremely vulnerable to road-building; 75% of deforestation (83%) and degradation (66%) occurred within 20 km of a road in the Peruvian Amazon (Oliveira et al., 2007)
- The Brazilian President recently intensified Brazil's promotion of the road between Acre and Ucayali (MRE Brasil, 2022), whose construction threatens the ecosystems and people of the Sierra del Divisor (Muniz, 2022).

Carbon and Deforestation

- Intact native forests are a net carbon sink, storing between 0.81-1.14 Pg C per year (Phillips et al., 1998; Brienen et al., 2015; Pan et al., 2011).
- Between 2003-2014, carbon losses exceeded gains on every continent; tropical America exhibited the largest carbon losses (516.0 ± 69.5 Tg C per year) and a net change of 324.8 ± 73.5 Tg C per year (Baccini et al., 2017).

Land Cover/Ecosystem Types

- The unique ecosystems of the Sierra del Divisor provide many ecosystem services to both the animals and the various cultural groups living in the region (Vriesendorp et al., 2006; Salisbury et al., 2013).
- As roads expand into remote areas, heterogeneous landscapes within protected areas and Indigenous territories become increasingly important for the conservation of biological and cultural diversity (Martínez-López et al., 2021; Ricketts et al., 2010).

Nighttime Lights (NTL)

- Artificial light pollution is an environmental concern because artificial light changes the natural amount of brightness/darkness in an ecosystem (Mu et al., 2021).
- Nighttime lights have been used in many studies as a proxy for infrastructure development and population density (Andrade-Núñez & Aide, 2020; Fan et al., 2019).

Linguistic Diversity

- Languages have been used as a measure of cultural diversity (Salisbury & Weinstein, 2014).
- Deforestation threatens Indigenous peoples, including their languages and traditional forest knowledge, which could be critical for improving conservation practices in the 21st century (Aswani et al., 2018; Amano et al., 2014; Fernández-Llamazares et al., 2021).

Data and Methods

Source	Date	Application
GTASO	2019	Administrative boundaries, Proposed road routes, Indigenous territories, official conservation areas
RAISG	2020	Indigenous territories and ethnicities, official conservation areas
NASA's Black Marble (VIIRS) Product VNP46A2	09/10/2020-09/17/2020	Nighttime lights
Spawn & Gibbs 2020	2020	Global aboveground and belowground biomass carbon density maps for the year 2010
Buchhorn et al. 2020	2020	Land cover map for the year 2015
USGS (Sayre)	2017	Unique ecosystem types for the 2000s
Dr. Yunuen Reygadas (Landsat derived)	2000-2020	Forest change and loss (deforestation)
Salisbury & Weinstein 2014 (Ethnologue)	2009	Linguistic diversity

Table 1. Summary of data used in socio-ecological analyses (also see map sources).

- Mixed methods included geospatial analysis (ESRI ArcGIS Pro Version 2.8), data cataloging and refinement, and meta-analysis of previous studies on the impact of roads in tropical forests.
- Performed buffer analysis to find how many unique land cover and ecosystem types are present within the 20 km road buffer.
- Counted the number of languages within the 20 km road buffer.
- Used remote sensing to find amount of nighttime lights within the 20 km road buffer and calculated zonal statistics (Fig. 1).
- Calculated aboveground biomass estimates within 8 m and 20 km of the proposed road (Fig. 2 & 3).
- Calculated amount of aboveground biomass lost from 2000-2010, and the amount left as of 2020 (Fig. 4 & 5).

Nighttime Lights

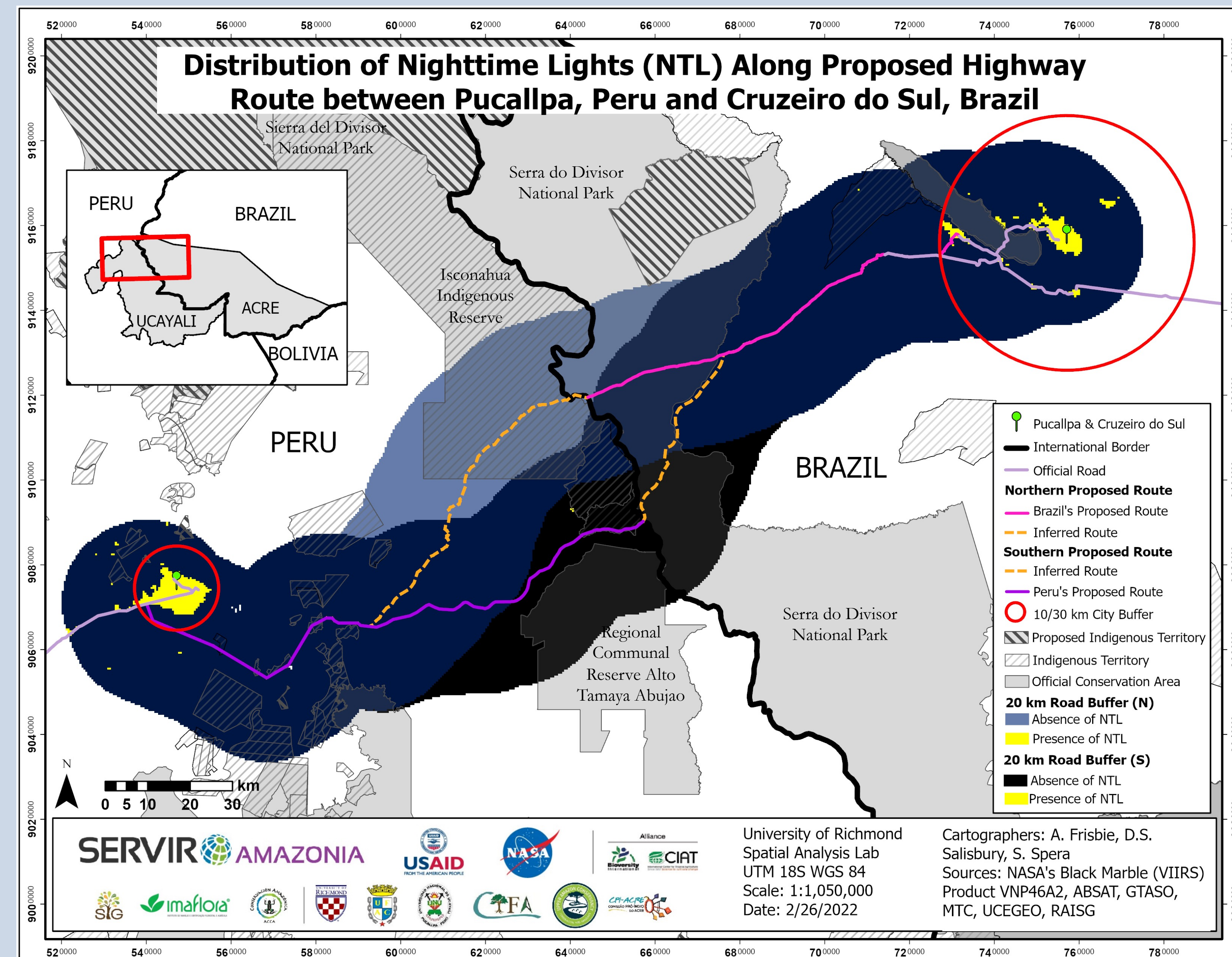


Figure 1. Nighttime lights visible from space in the remote southwestern Amazon borderlands of Peru and Brazil.

- Less than 2% of the 20 km buffers around the northern and southern routes of the proposed Pucallpa-Cruzeiro do Sul are lit at night, highlighting the remoteness of this region of the Amazon.
- The majority (>95%) of light is within 10 km of Pucallpa, Peru or 20 km of Cruzeiro do Sul, Brazil.
- Both the northern and southern route of the proposed Pucallpa-Cruzeiro do Sul road would cut through an area approximately 200 km long, which remains relatively devoid of infrastructure and development (<5% lit at night) (Fig. 1).

Land Cover/Ecosystem Types

Characteristics of the land within the 20 km buffer zone around the proposed Pucallpa-Cruzeiro do Sul road:

- > 90% forested (northern route: 91.18%, southern route: 91.30%)
- Many distinct ecosystem types (northern route: 18, southern route: 19)
- Primarily pluvial forest (rainforest)
- 11 different land cover classifications (bare/sparse vegetation, built-up area, cropland, evergreen broadleaved (closed canopy forest), evergreen broadleaved (open canopy forest), herbaceous vegetation, herbaceous wetland, permanent water bodies, shrubland, unknown type (closed canopy forest), and unknown type (open canopy forest))

Languages

- There are at least 6 Indigenous languages spoken within the 20 km buffer zone around the proposed Pucallpa-Cruzeiro do Sul road (northern and southern routes), including: Poyanáwa, Sharanahua, Yaminahua, Asháninka, Asháninka, and Shipibo-Conibo. Spanish and Portuguese are also spoken within the 20 km buffer zone.

Carbon and Deforestation

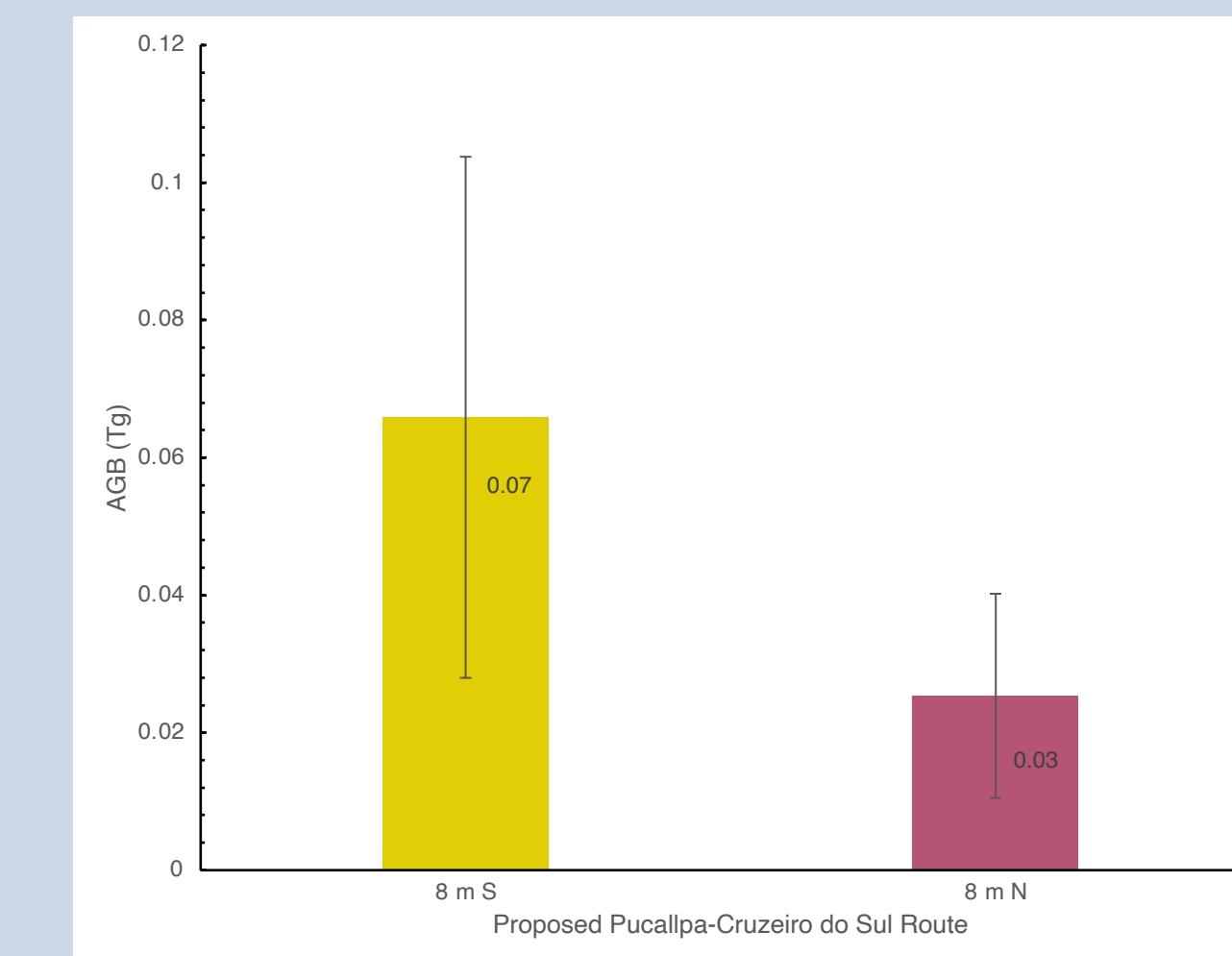


Figure 2. Aboveground biomass (Tg) within 8 m of the proposed Pucallpa-Cruzeiro do Sul road (northern and southern routes).

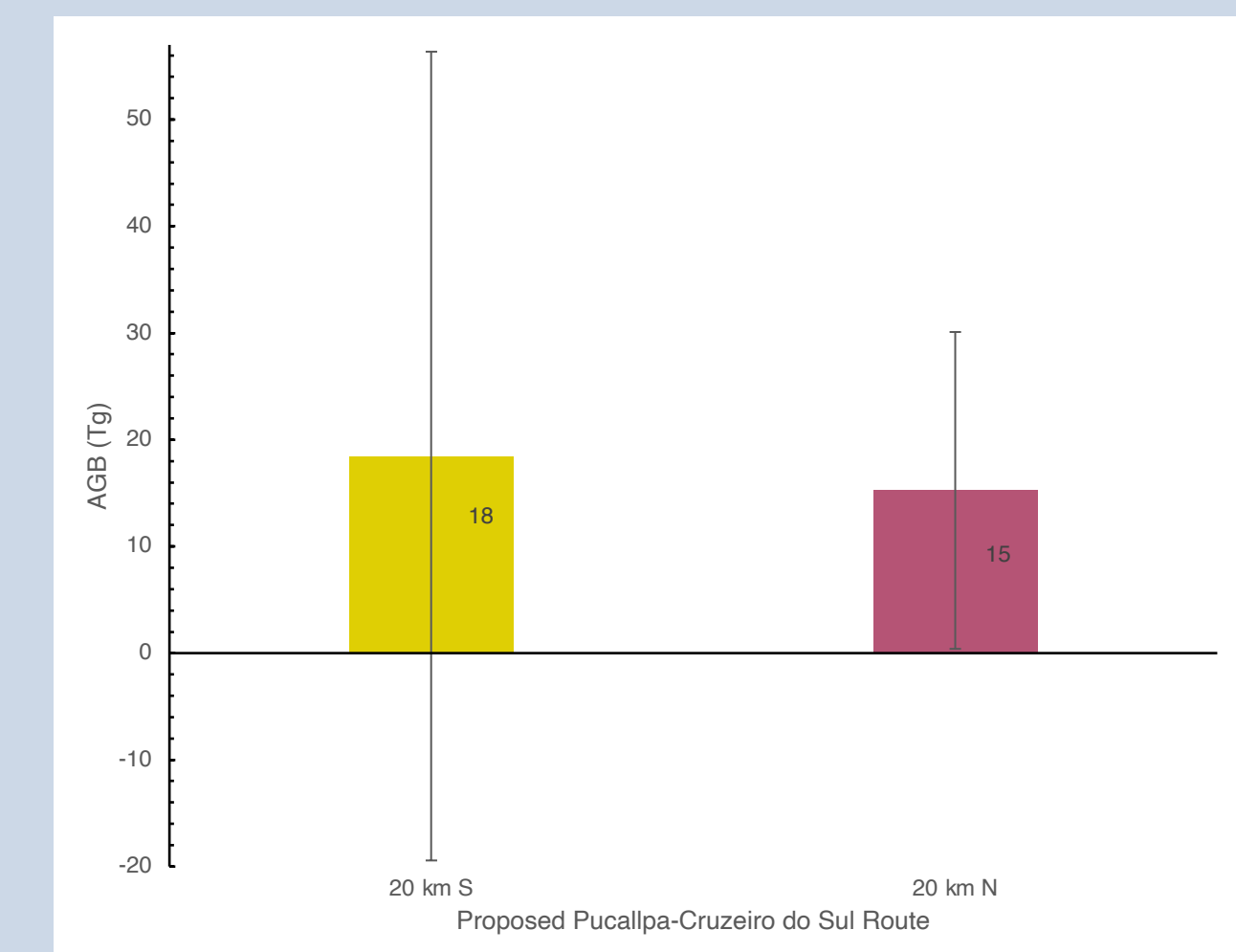


Figure 3. Aboveground biomass (Tg) within 20 km of the proposed Pucallpa-Cruzeiro do Sul road (northern and southern routes).

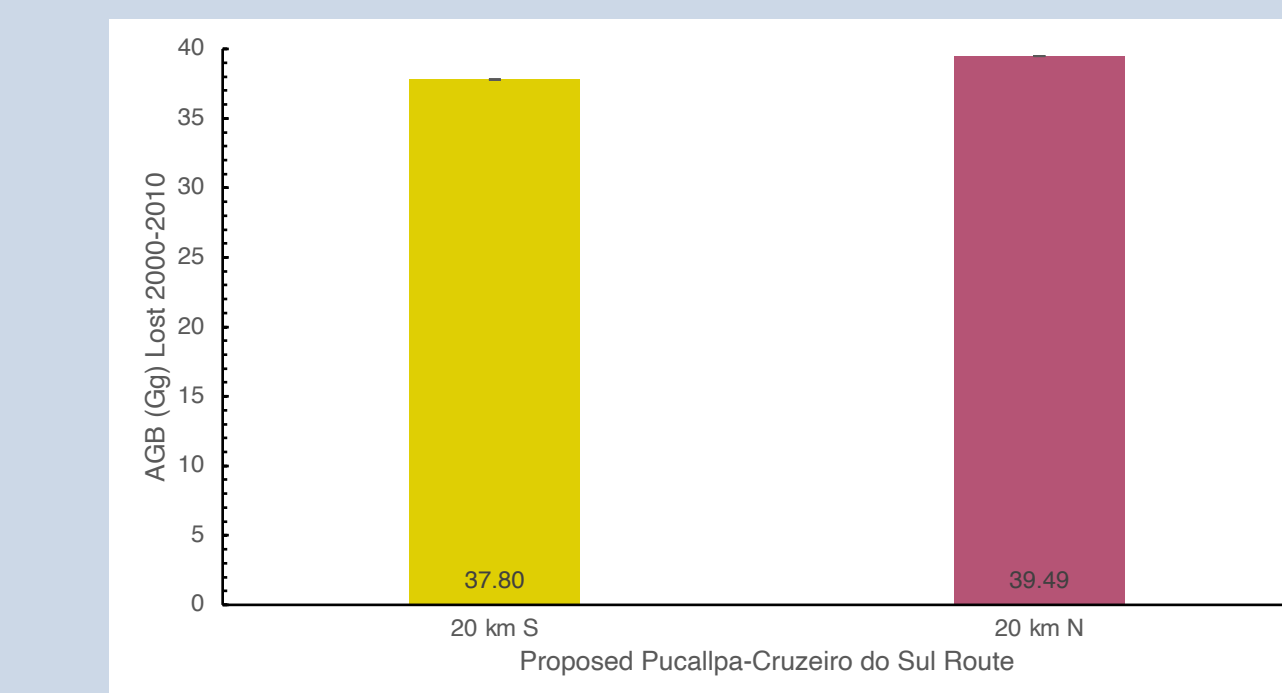


Figure 4. Aboveground biomass lost from deforestation (Gg) during 2010-2020 within 20 km of the proposed Pucallpa-Cruzeiro do Sul road (northern and southern routes).

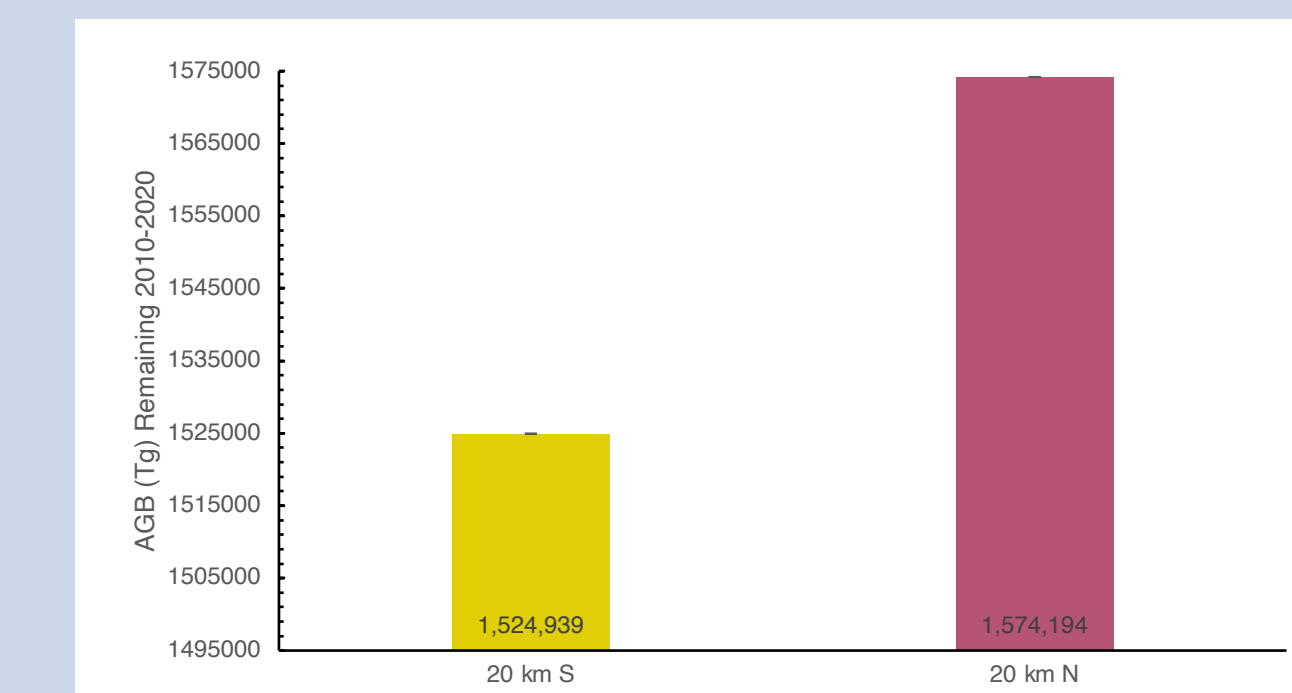


Figure 5. Aboveground biomass (Tg) remaining as of 2020 within 20 km of the proposed Pucallpa-Cruzeiro do Sul road (northern and southern routes).

- There is approximately 70 (southern route) and 30 (northern route) Gg of carbon stored in the aboveground biomass within the proposed road route, which is estimated to be about 8 m wide.
- There is approximately 18 (southern route) and 15 (northern route) Tg of carbon stored in the aboveground biomass within 20 km of the proposed road route.
- Between 2010-2020, approximately 3% of the ~12,000 km² 20 km buffer zone around the proposed Pucallpa-Cruzeiro do Sul road (northern and southern routes) was deforested.
- Approximately 37.80 (southern route) and 39.49 (northern route) Gg of carbon were released from the 20 km road buffer zones during 2010-2020 as a result of deforestation, which amounts to less than 0.01% (northern route and southern route) of the total carbon within the 20 km buffer zones (Fig. 4).
- New road construction could release 1,524,939 (southern route) or 1,574,194 (northern route) more Tg of sequestered carbon remaining in aboveground biomass, primarily trees and other vegetation cover within 20 km of the proposed road (Fig. 5).
- These estimates are conservative, since they do not account for belowground biomass sequestered, for example, in soil.

Discussion

- The use of spatial analysis and remote sensing allows for an objective representation of the consequences of road building for stakeholders, informing local community members and policy makers.
- This road continues to remain a talking point for Brazilian and Peruvian governments (MRE Brasil 2022), civil society (SOS Amazônia et al., 2021), and Indigenous organizations (ORAU, 2022) thus requiring persistent and renewed analysis and discussion
- The disconnect and lack of foresight in the road planning between both governments further exposes a lack of cooperation and information on both sides regarding this road proposal.
- As roads through remote Amazonian regions continue to be proposed, further research is necessary to explore the potential cultural and ecological impacts of road-building in these areas.
- Roadbuilding in the borderlands of Acre and Ucayali could have important socio-environmental impacts such as a loss of the characteristic remoteness of the region, a loss of biodiversity within unique ecosystems, a decline in the cultural diversity, and the release of carbon dioxide into the atmosphere.

