Land-System Change Boundary Assessment for Portugal

Bruna Almeida[1], Pedro Cabral[2], Sibyll Schaphoff[1], Fabian Stenzel[1], Dieter Gerten[1]

[1]Potsdam Institute for Climate Impact Research (PIK), Member of the Leibniz Association, P.O. Box 6012 03, D-14412 Potsdam, Germany; [2]School of Remote Sensing and Geomatics Engineering, Nanjing University of Information Science and Technology, Nanjing, 210044, China

INTRODUCTION

The **Planetary Boundaries (PB) framework** identifies nine critical Earth system processes (**climate change, stratospheric ozone depletion, ocean acidification, atmospheric aerosol loading, biogeochemical flows, biosphere integrity, freshwater change, land-system change, and novel entities**). **Land-System Change (LSC)** captures the transformation of natural landscapes primarily driven by deforestation and land conversion for agriculture, infrastructure, and urban development, and it can be measured by the remaining natural forest extent relative to the estimated forest cover during the Holocene-like period. Transgressing LSC boundary can trigger severe environmental consequences, and it is associated with the loss of key ecological functions, including carbon storage, moisture recycling, and habitat availability for wildlife.

METHODS, RESULTS & ANALYSIS

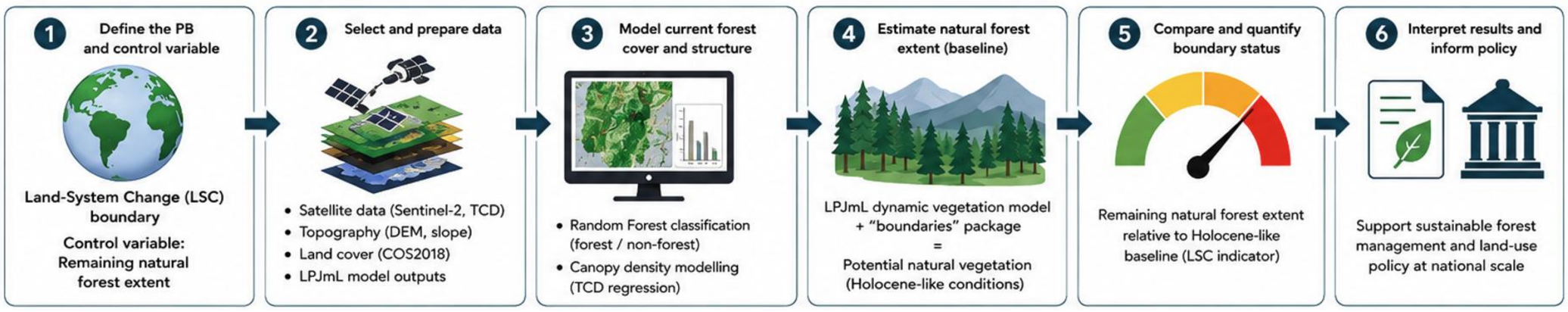

Fig. 1. Steps taken for PB assessment at the country level. The workflow includes: (1) establishing the boundary and key indicator, (2) gathering multi-source datasets, (3) deriving current forest cover and canopy structure, (4) modelling the natural baseline under minimal human impact, (5) assessing risk levels relative to the safe operating space, and (6) providing evidence to support sustainable policy and land-management decisions.

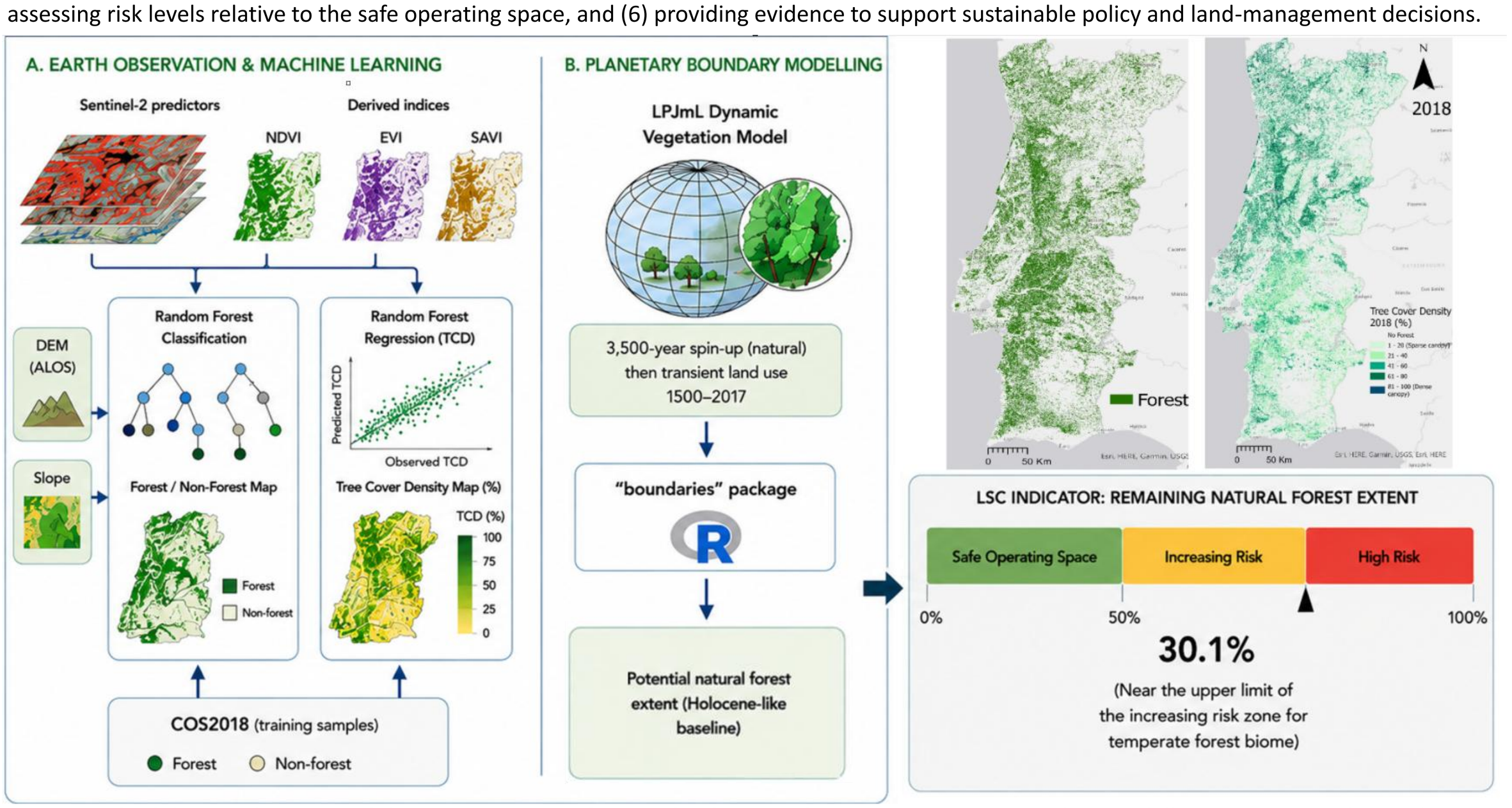

Fig. 2. Methodology and outputs of the LSC assessment for mainland Portugal. It integrates RS, ML, and PB modelling using Sentinel-2 predictors, vegetation indices, DEM and slope variables, Random Forest classification and regression, and LPJmL dynamic vegetation model outputs processed through the *"boundaries"* package. The resulting outputs include forest cover maps, Tree Cover Density (TCD) patterns, potential natural forest extent under Holocene-like conditions, and the national LSC indicator, quantifying the remaining natural forest extent relative to the safe operating space.

CONCLUSIONS

This study highlights the value of integrating Earth observation and PB modelling to support spatially explicit environmental monitoring and sustainable land-use governance. The findings demonstrate the potential of combining RS, ML, and PB approaches for national-scale LSC assessments, while addressing forest transformation, canopy structure, modelling uncertainty, and the policy relevance of sustainability indicators.

This research was supported by the Leibniz Association's Lab "Systemic Sustainability – Biodi-versity, Climate, Agriculture and Food within Planetary Boundaries" (LL SYSTAIN), FCT (Fundação para a Ciência e a Tecnologia), under the project - UIDB/04152/2020 (DOI: 10.54499/UIDB/04152/2020) - Centro de Investigação em Gestão de Informação (Mag-IC)/NOVA IMS) and Fundação Gaspar Frutuoso. F.S. acknowledges funding from FORMAS through the ReForMit project.