Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/land10101037/s1, Figure S1: Non-Multidimensional Scaling, Figure S2: validation of Earth System Models, Figure 3: climate projections of coupled Earth System Models, Figure S4: model performances, Table S1: field observations coordinates, Table S2: weights of the explaining climatic variables in the best and worst modes, Table S2: ODMAP v1.0 standardized protocol of the species distribution modelling process [75], Table S3: Habitat Suitability Variation indexes. .

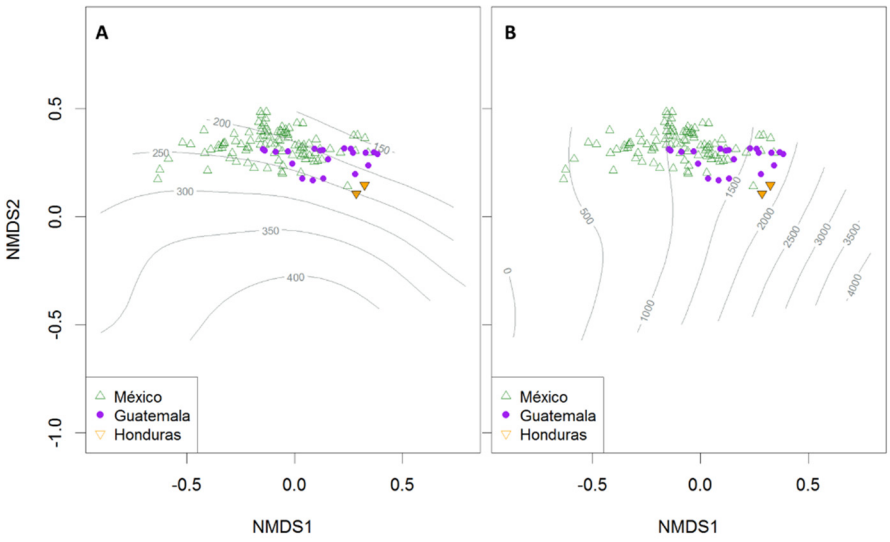

Figure S1. Non-Multidimensional Scaling (NMDS) for *Pinus hartwegii* México, Guatemala and Honduras presences represented over **A**: Bio 05 (maximum temperature of Warmest Month in °C×10), and **B**: Bio 12 (annual precipitation in mm).

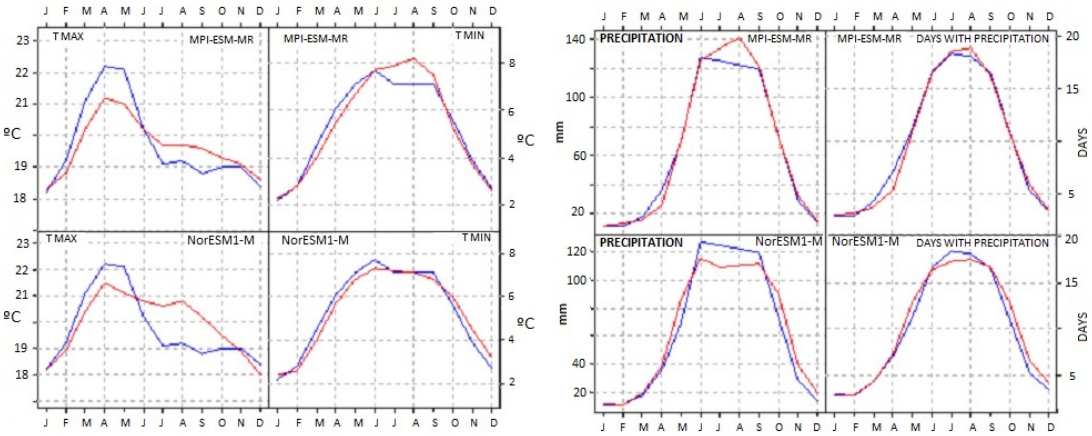

Figure S2. Validation of Earth System Models (red) with historical climatic data (blue) in Izta Popo National park. Meteorological stations used to reproduce present climate conditions are shown on Figure 1. Historical data: Mexican Meteorological Service (https://smn.conagua.gob.mx/es/; visited on October 2013). Methodology: [79]

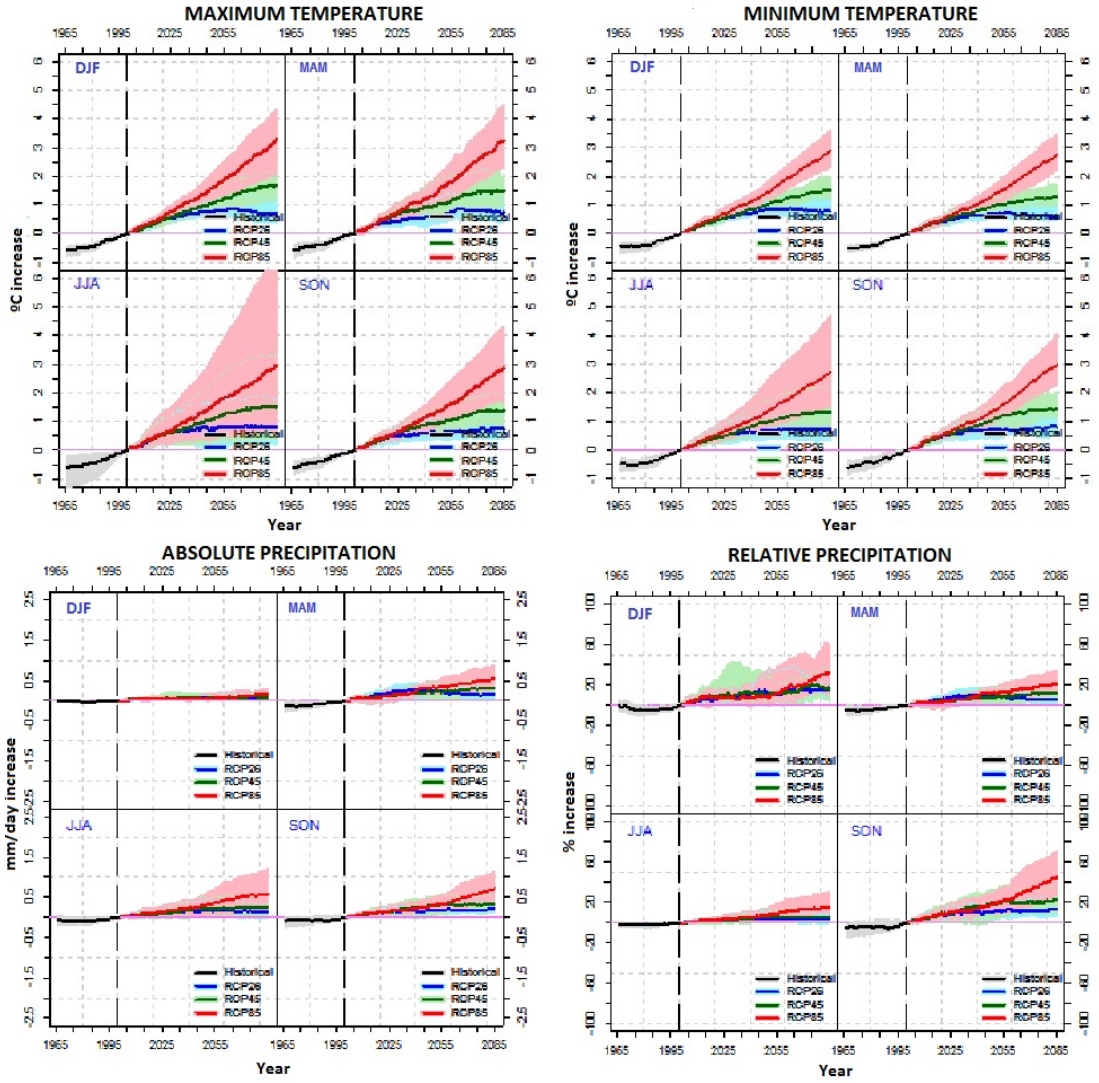

Figure S3. Climate projections of MPI-ESM-MR, NorESM1-M, GFDL-ESM2M and CanESM2 coupled Earth System Models in Izta Popo National Park. Blue, green and red lines: medians for RCP2.6, 4.5 and 8.5 respectively. Shaded areas: 10th to 90th percentiles respectively. Black line: Historical data of meteorological stations (Figure 1) Data from the Mexican Meteorological Service (https://smn.conagua.gob.mx/es/; visited on October 2013). DJF: December, January, February. MAM: March, April, May. JJA: June, July, August. SON: September, October, November. Methodology: [79]

For the four seasons (dry season, Nov.–Apr., and the three periods of the wet season), simulated precipitation for the twenty-first century displayed as relative increase compared to the amount simulated for the 1976–2005 Historical period. The vertical dotted line marks the end of the Historical data (2005). Data grouped for every RCP simulation of every global climate model selected and for the last 30years of every station. T values are displayed Ribalaygua..

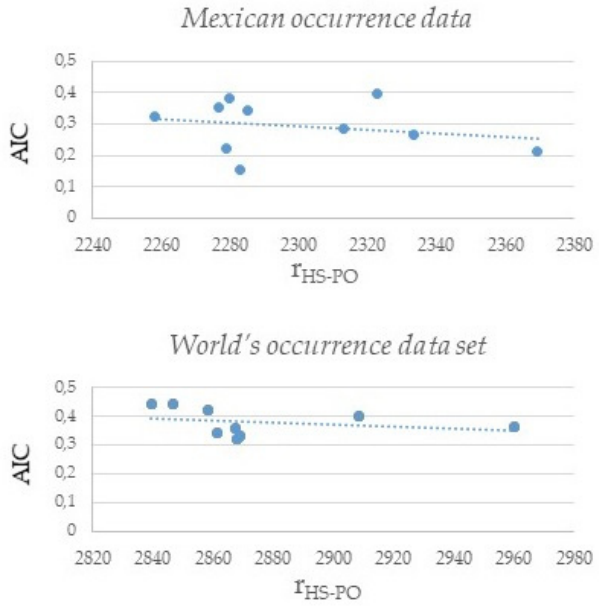

Figure S4. Akaike Information Criterion (AIC) and Pearson correlation coefficient between the habitat suitability and *P. hartwegii* occupation ($r_{HS\text{-}PO}$) performances of the models fitted with the Mexican occurrence data set (set 1- upper figure) and the 1 world's occurrence data set (set 2- lower figure) after removing the most complex models (AIC>3000)

Table S1. Field observations points (X, Y coordinates -WGS84- and altitude) used to assess the predefined classes (vegetation types) where *Pinus hartwegii* participates (visited on September 2011 to March 2012).

Vegetation types	X	Y	Altitude (m a.s.l.)
Pino-Encino-Oyamel forest	534414	2135083	3,403
Pino-Encino-Oyamel forest	534104	2134946	3,311
Pino-Encino-Oyamel forest	533717	2134800	3,310
Pine forest	533902	2134477	3,292

Table S2. *Standardized protocol of the species distribution modelling process, following the ODMAP v1.0 [Zurell etal., 2020]*Date: 2021-09-09

Overview
Authorship
Contact : ignacio.garciaamorena@upm.es
Study link: Manuscript ID: land-1348076
Model objective
Model objective: Forecast and transfer
Target output: continuous habitat suitability index
Focal Taxon
Focal Taxon: Pinus hartwegii Lindl.
Location
Location: Izta Popo National Park, Mexico
Scale of Analysis
Spatial extent: 98.58219, 98.77804, 18.46929, 18.99345 (xmin, xmax, ymin, ymax)
Spatial resolution: 1
Temporal extent: 2050/2070
Temporal resolution: 20 years
Biodiversity data

Observation type: standardised monitoring data
Response data type: presence-only
Hypotheses
Hypotheses: Accordingly to regional scale analysis of many plant species, P. hartwegii distributions follow a climatic gradient (as also observed on local vegetation maps).
Assumptions
Model assumptions: Occurrences are reported without errors; All relevant drivers are included in the model; Predictor variables are estimated without errors; Species is in pseudo-equilibrium with the environment; the entire realised niche is encompassed by data; correlation structure between predictors does not change with time; the model extrapolates in a biological sensible manner
Algorithms
Modelling techniques: maxent
Model complexity: Different calibration options are included in the analysis (auto-features, LQP; Beta = 0,1,5; two sets of explanatory variables
Model averaging: None
Workflow
Model workflow: Twenty-four SDMs were fitted for present climate conditions combining two sets of current occurrence data and different levels of complexity. Occurrence coincidences in 1 km pixels were aggregated, and ecological outliers were discarded after performing non-metric multidimensional scaling (NMDS) ecological analysis of their annual and seasonal related precipitations and temperatures. 10,000 background points randomly selected in the studied area were used to build all the models. The selection of climatic variables was based on a stepwise selection following a physiologically-relevant criteria among the less correlated variables (Pearson $r<0.75$; variance inflation factor<5). The models were calibrated with 70% of occurrence data, random selected. The remaining 30% were reserved to perform a usual non-independent validation AUC statistic (Area Under the receiver operating characteristic curve), and by calculating the Pearson correlation coefficient between the habitat suitability values and the ad-hoc production of a P. hartwegii remote sensing data based map. To account for the goodness of fit and the model complexity, the AICc was calculated.
Software
Software: Maxent modeling algorithm ver-sion 3.3.3k (Phillips et al., 2006); ENMtools (Warren et al., 2010), for AICc calculations. Vegan Package (Oksanen et al., 2016) for NMDS analysis
Code availability: ENMtools: https://doi.org/10.1111/j.1600-0587.2009.06142.x; Vegan package: https://cran.r-project.org/web/packages/vegan/index.html
Data availability: http://www.worldclim.org/

Data
Biodiversity data
Taxon names: Pinus hartwegii Lindl., Pinaceae
Taxonomic reference system: GBIF Backbone Taxonomy
Ecological level: species
Data sources: Mexican Forest Inventory (provided by the Comisión Nacional Forestal - CONAFOR); Atlas of the world's conifer (Farjon & Filer, 2013), provided by Farjon, A.
Sampling design: Uniform design in CONEFOR; Random in Farjon & Filer (2013)
Sample size: Sample size unknown
Clipping: Mexico; Mexico, Guatemala & Honduras
Cleaning: Poorly georeferenced data were removed, occurrence coincidences in 1 km pixels were aggregated, and ecological outliers were discarded after performing non-metric multidimensional scaling (NMDS) ecological analysis of their annual and seasonal related precipitations and temperatures
Background data: 10,000 background points randomly selected
Errors and biases: Unknown geographical precision in Farjon's data
Data partitioning
Training data: 70% random selection of occurrence data for model training
Validation data: cross-validation with remaining 30% occurrence data
Predictor variables
Predictor variables: BIO1-BIO19

Data sources: http://www.worldclim.org/; accessed in 2014
Temporal extent: 1950-2000
Dimension reduction: stepwise selection following a physiologically-relevant criteria among the less correlated variables (Pearson r<0.75; variance inflation factor<5)
Transfer data
Data sources: MPI:https://doi.org/10.1002/jame.20023; NorESM1-M: http://www.worldclim.org/Cmip5_30s (accessed on 01 Oct 2014)
Spatial resolution: 30 arc-second
Temporal extent: 2050/2070 (20 yr)
Models and scenarios: ESMs: NorESM1-M & MPI-ESM-MR; Scenarios: RCP2.6, RCP4.5 and RCP8.5

Model
Variable pre-selection
Variable pre-selection: Stepwise selection following a physiologically-relevant criteria among the less correlated variables (Pearson r<0.75)
Multicollinearity
Multicollinearity: Variance inflation factor<5
Model selection - model averaging - ensembles
Model selection: (a) Pearson correlation coefficient between the habitat suitability values and the ad-hoc production of a P. hartwegii remote sensing data based map. (b) The goodness of fit and the model complexity (AICc)
Analysis and Correction of non-independence
Threshold selection
Threshold selection: "Maximum test sensitivity plus specificity", "10 percentile training presence" , "0.25 habitat suitability threshold", and "0.5 habitat suitability thresh-old"

Assessment
Performance statistics
Performance on training data: AIC
Performance on validation data: AUC
Prediction
Prediction output
Prediction unit: km

Table S2. Weights of the explaining climatic variables in the best (model 5) and worst model (model 20).

Model number	Variable	Percent contribution
5	Bio 5	70
	Bio 8	12.8
	Bio 9	10.4
	Bio 6	2.6
	Bio 12	2.4
	Bio 15	1.7
	Bio 18	0.1
20	Bio 5	94.4
	Bio 9	3.3
	Bio 1	1.2
	Bio 17	0.8
	Bio 15	0.3
	Bio 12	0.1

Table S3. *Pinus hartwegii* Habitat Suitability Variation index (HSV) of Maxent model number 5, for 2050 and 2070 averaged time period (t). NorESM1-M (Nor) and MPI-ESM-MR (MPI) future climatic models and different CO_2 Concentration pathways (RCP). Shadowed in grew: HSV of the 0.5 threshold.

t	Climate model	RCP	Threshold	HSV (%)	t	Climate model	RCP	Threshold	HSV (%)
2050	MPI	2.6	0.25	0.404	2070	MPI	2.6	0.25	0.202
			0.5	-5.945				0.5	-6.359
			10p	-0.000				10p	0.000
			max	-0.000				max	0.000
		4.5	0.25	0.202			4.5	0.25	0.000
			0.5	-18.663				0.5	-20.319
			10p	0.000				10p	0.000
			max	0.000				max	0.000
		8.5	0.25	-2.424			8.5	0.25	-18.038
			0.5	-23.188				0.5	-43.744
			10p	0.000				10p	-9.399
			max	0.000				max	0.000
	Nor	2.6	0.25	0.404		Nor	2.6	0.25	0.404
			0.5	-5.945				0.5	-7.187
			10p	0.000				10p	0.000
			max	0.000				max	0.000
		4.5	0.25	0.404			4.5	0.25	0.202
			0.5	-13.753				0.5	-16.622
			10p	0.000				10p	0.000
			max	0.000				max	0.000
		8.5	0.25	0.000			8.5	0.25	-8.225
			0.5	-17.243				0.5	-32.032
			10p	0.000				10p	-2.817
			max	0.000				max	0.000