Interreg
Austria-Hungary
European Union – European Regional Development Fund
REIN-Forest

Programme INTERREG V-A Austria-Hungary

ATHU150 – REIN-Forest

„Biodiversity conservation of the native forest in the border region and fostering their ability against the impacts of climate change"

Common modelling documentation of the reproductive material's output (species distribution models)

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Authors:

Heino KONRAD (BFW)

MÓRICZ Norbert (SOE ERTI)

NAGY László (SOE ERTI)

SZAMOSVÁRI Erik (BFW)

Marcela VAN LOO (BFW)

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Contents

Highlights

Local application and interpretation of the existing species distribution models resulted in detailed information on the future distribution, probability of occurrence and vulnerability of European beech (*Fagus sylvatica*) and sessile oak (*Quercus petraea*) in the target area. The results of this analysis provided input for the development of regional seed transfer strategy, the selection of the demonstration sites and pre-adapted reproductive material sources.

Background

The average surface temperature of the Earth has risen about 1.18 °C since the late 19th century. Most of the warming occurred in the past 40 years, with the seven most recent years being the warmest. Forest ecosystems are heavily affected by the changing climate conditions. Extensive calamities and forest damages have been witnessed in Central Europe in connection with rising temperature, drought frequency and severity, and, in general, with the decline of water availability. The speed of the climate change is faster by about a magnitude than the rate that our tree species have encountered during their evolution.

Climate change disrupts the link between climate and the local adaptation of forest tree populations. Therefore, adaptive silvicultural practices are required to maintain the forests' ecosystem services. Adaptation measures include, among others, the planting of alternative tree provenances or species which are putatively better adapted to the expected future climate. This includes the utilization of forest seeds and seedlings from the warm regions of the tree species natural ranges in order to increase forest resilience in climate change.

The Interreg Central Europe project SUSTREE developed European-wide species distribution models for 7 key tree species in order to assess their vulnerability under present and expected climate conditions. Additionally, seed transfer models have been developed for the identification of the optimal seed sources pre-adapted to the expected changes. The species distribution models and seed transfer models were integrated into the decision support tool SusSelect for forest and conservation managers.

REIN-Forests aims to foster the resilience and stability of the forest cover in the Austrian-Hungarian border region by developing local reproductive material transfer strategy for European beech and sessile oak, and by establishing demonstration sites to assess, monitor and validate the benefits of the assisted migration. In order to establish a solid technical platform for the development of seed transfer recommendations, SUSTREE species distribution maps have been downscaled and applied for the Interreg AT-HU programme area.

Aims

The main goal of the activity is to establish model-based information background on the present status and future perspectives of European beech and sessile oak dominated forests across the AT-HU programme area (Fig.1), capitalizing on and applying existing approach, knowledge and continental scale models developed within the framework of SUSTREE project (CHAKRABORTY ET AL. 2021). The regional species distribution models (SDMs) will provide input for future REIN-Forest activities, the development of a regional seed transfer strategy and the selection of the demonstration sites.

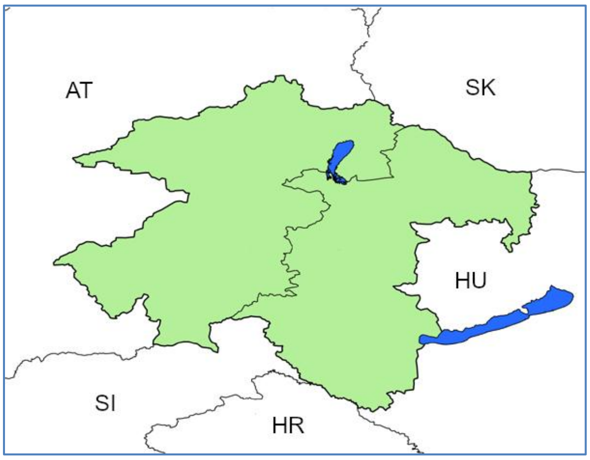

Figure 1. The Interreg AT-HU programme area

Data and methods

SUSTREE species distribution models

Occurrence data

Species occurrence data were obtained from MAURI ET AL. (2017) which is one of the most exhaustive, harmonized European tree species occurrence data set available. In order to balance the presence and absence locations, pseudo-absences were generated according to SENAY ET AL. (2013). This way, absence locations being both geographically and climatically different from the observed presence locations have been identified.

Climate data

The SUSTREE models are based on the EURO-CORDEX database (www.eurocordex.net) that contains 10 km resolution gridded data for daily mean, minimum and maximum near-surface air temperature and precipitation. The resolution of the data has been refined to 1 km and 83 climate variables have been extracted for the baseline period of 1961-1990 and for future time frames 2041-2060, 2061-2080, 2081-2011 (CHAKRABORTY ET AL. 2020). For the modelling of future climate, two representative concentration pathways, RCP 4.5 and RCP 8.5 have been considered. The 'moderate' RCP 4.5 scenario assumes 650 ppm atmospheric CO_2 concentration and a 1.0–2.6°C increase in global annual temperature by 2100 whereas the 'pessimistic' RCP 8.5 assumes 1,350 ppm CO_2 and 2.6–4.8°C increase in annual temperature by 2100 (VAN VUUREN ET AL. 2011). Seven potential predictor variables explaining most of the variation in the observed occurrence of each species were selected with a recursive feature elimination approach (RFE) implemented within the Random forest algorithm (BREIMAN 2001).

Modelling and evaluation

BIOMOD2 (THUILLER ET AL. 2016) has been selected for the platform of modelling potential species distribution. This R package offers a computational platform for multi-method modelling that generates the probability of presence outputs for each of the modelling approaches as well as a variety of ensemble projections. The model algorithms include GLM (Generalized Linear Models), GAM (Generalized Additive Models), GBM (Generalized Boosted regression Models), CTA (Classification Tree Analysis), ANN (Artificial Neural Networks), SRE (Surface Range Envelop or BIOCLIM), FDA (Flexible Discriminant Analysis), MARS (Multivariate Adaptive Regression Spline), RF (Random Forest for classification and regression), and MAXENT.Tsuruoka. Predicted probabilities from the individual models of the BIOMOD2 were ensembled in a consensus model which combined the median probability over the selected models with true skill statistics (TSS > 0.7). The estimated ensemble model predictions were presented as geotiff rasters (Fig. 2 and 3). Model evaluation was done by splitting the occurrence dataset into 75% for model training and 25% for model testing. Apart from this, BIOMOD2 allows specifying the number of runs for each combination of training and testing data. Therefore 10 independent runs, each with a randomly selected set of training and test data were implemented.

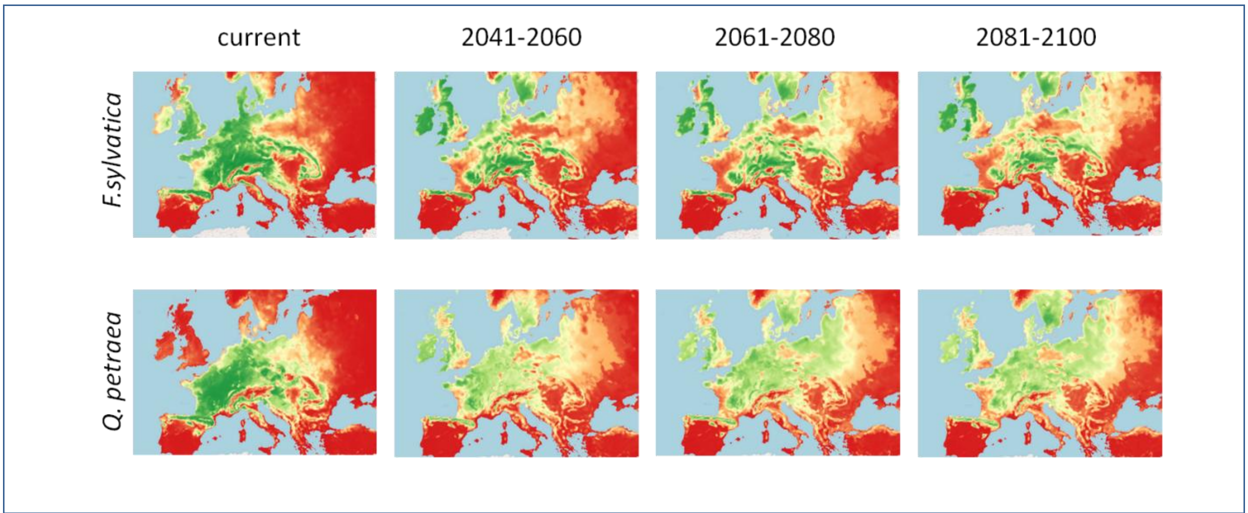

Figure 2. SUSTREE species distribution maps for beech and sessile oak, RCP 4.5

(CHAKRABORTY ET AL. 2021, red: low, green: high probability of occurrence)

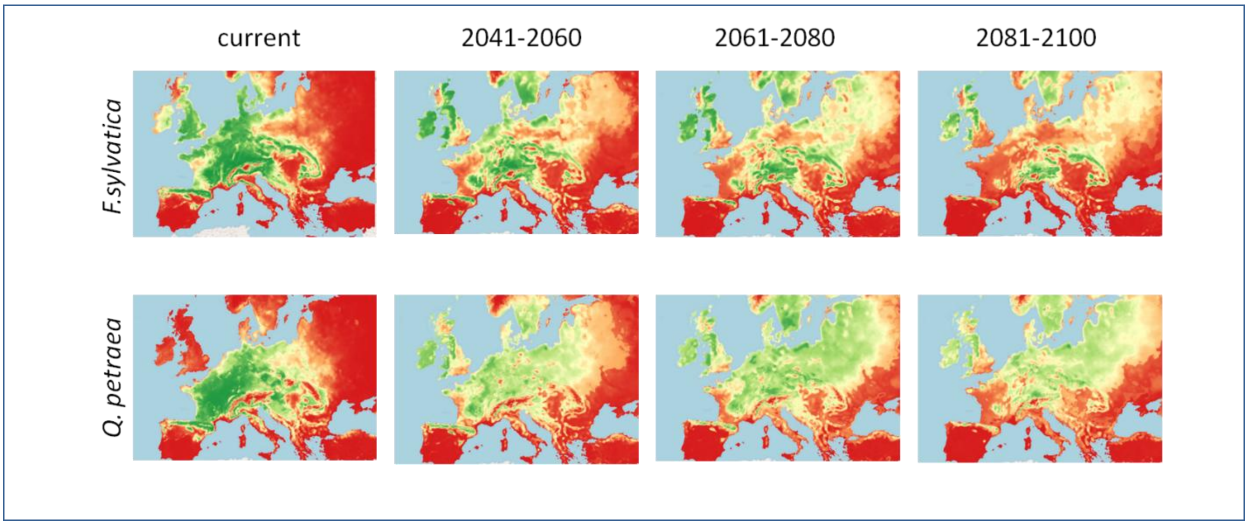

Figure 3. SUSTREE species distribution maps for beech and sessile oak, RCP 8.5

(CHAKRABORTY ET AL. 2021 red: low, green: high probability of occurrence)

Forest cover data and local application of the models

Recent forest cover map for Europe (COPERNICUS LMS 2018) has been obtained from the Copernicus Land Monitoring Service that provides public geographical information on land cover and its changes, land use, vegetation state, water cycle and Earth's surface energy variables for environmental terrestrial applications. The forest cover density map has been clipped using the Interreg AT-HU program area shape file. In order to exclude minor tree groups, amenity plantings, forest strips, etc., pixels with more than 50% density have been selected and the resolution has been aligned to the 1 km grid of the SUSTREE SDMs. Total forest area and actual forest coverage (%) has been computed for each unique SDM pixel. Pixels with more than 75% forest coverage were included in the forest grid and considered as closed forest stands for the local application of SDMs.

Each probability of occurrence map for European beech and sessile oak has been masked by the regional forest grid and exported to tiff rasters. Distribution of the forest areas by probability classes (in 10% intervals) has been computed for the two species, for both climate scenarios and three time frames, 2041-2060, 2061-2080, 2081-2100.

Vulnerability maps have been developed using the occurrence maps of the RCP 8.5 scenario. Forest pixels have been assigned to vulnerability classes based on the relative decrease in projected probability of occurrence between the present state and the period 2081-2100 (Table 1).

	Decrease in probability of occurrence
Non-vulnerable	below 15%
Moderately vulnerable	15-50%
Severely vulnerable	over 50%

Table 1. Vulnerability classes

Results

Notable shifts in species composition of natural forests have been projected by the SDMs. Both of the model species will face habitat, or at least, demographic losses throughout their occurrences in majority of the modelled area by the end of the century.

European beech

Beech is projected to lose its dominance in its lowland or colline occurrences along the SW border of Hungary despite the fact that those stands are amongst the most productive beech forests presently (Fig. 5). Less articulated decrease is expected in the sub-Alpine region near Kőszeg and Sopron where the species still has some, although limited, vertical buffer and stable extrazonal habitats where the temperature increase is buffered by soil characteristics and surplus water availability. The habitat suitability of beech will most likely decrease also in the Austrian project area according to both climate change scenarios. European beech will become less competitive over time (Table 2, Fig. 4) due to limiting factors such as high summer temperature, drought and moisture availability during the growth period, which is particularly predicted at the lower parts of Burgenland, Southern Styria and the areas around Vienna (Fig. 5). At the Eastern Alps, its foothills and at higher altitudes, where still cooler temperature and more precipitation are expected, slightly milder magnitude of the decrease is predicted compared to lower elevations.

Probability of occurrence %	1961-1990	2041-2060		2061-2080		2081-2100	
		RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
0-10	0,9	9,6	1,7	1,7	0,2	1,5	1,1
10-20	1,2	12,9	8,0	14,6	4,5	13,8	26,6
20-30	3,8	10,2	7,7	2,0	12,2	8,2	11,4
30-40	2,8	17,6	16,7	8,5	9,5	13,3	13,2
40-50	5,5	7,9	18,0	19,8	25,2	15,6	11,4
50-60	9,6	4,4	6,7	14,6	11,0	9,2	7,0
60-70	12,3	2,9	4,4	4,9	4,6	4,4	5,4
70-80	13,0	3,3	5,3	5,1	5,2	5,3	6,2
80-90	12,0	4,8	23,8	17,2	23,1	23,5	15,9
90-100	38,8	26,5	7,7	11,6	4,5	5,3	1,9

Table 2. Projected changes in probability of occurrence of European beech (*Fagus sylvatica*) in the Austrian-Hungarian border region

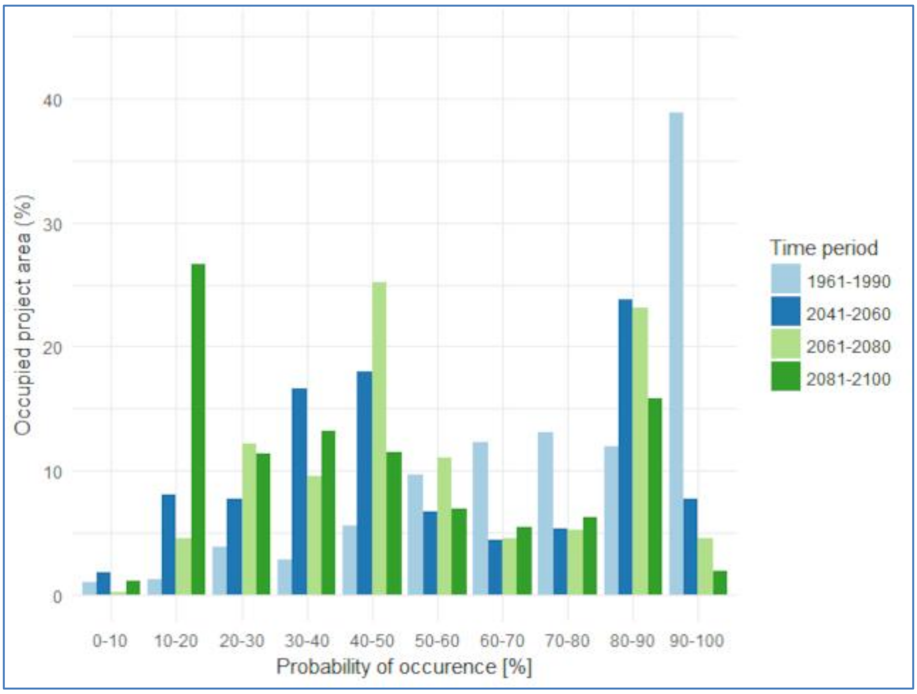

Figure 4. Projected changes in probability of occurrence of European beech (*Fagus sylvatica*) in the Austrian-Hungarian border region, RCP8.5

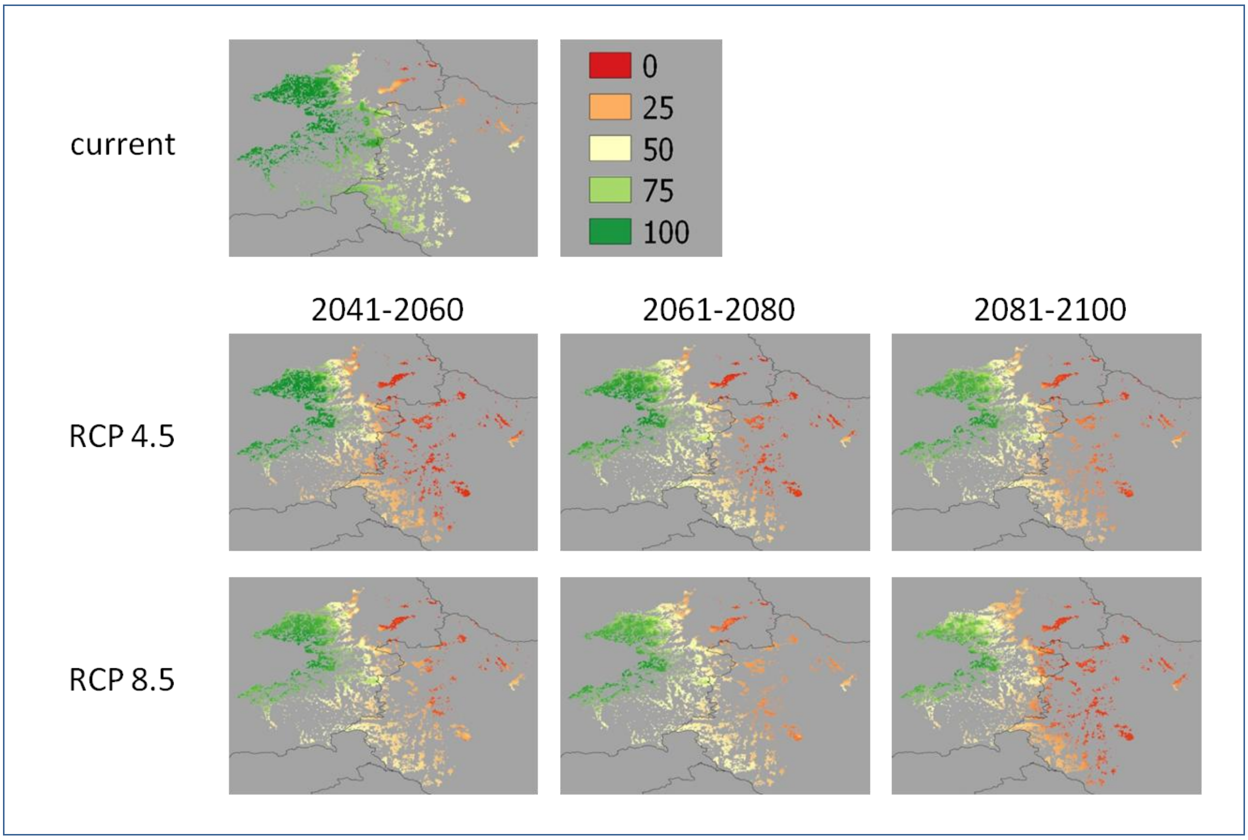

Figure 5. Projected changes in probability of occurrence of European beech (*Fagus sylvatica*) in the Austrian-Hungarian border region

According to the vulnerability assessment, the vast majority of the low elevation beech occurrences is to be considered moderately vulnerable at the shortest term (2041-2060) only, and severely vulnerable for the end of the century (Fig. 6). Typically, the vulnerability model shows high – and continuously increasing – exposition to adverse climatic regimes in the Hungarian side of the program area, in Burgenland and Southern Styria. However, at the higher altitudes of the Eastern Alps, beech will most probably keep its dominance in forest stands or, at least, is projected to suffer minor losses.

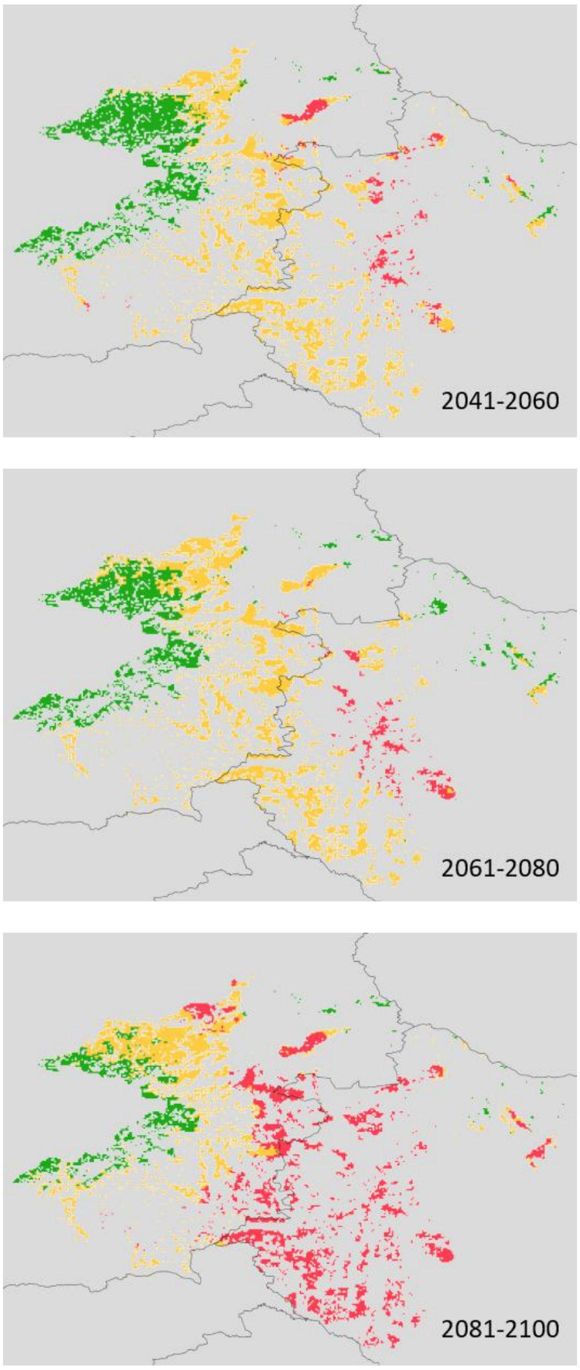

Figure 6. Vulnerability of European beech (*Fagus sylvatica*) stands in the Austrian-Hungarian border region (green: non-vulnerable, yellow: moderately, red: severely vulnerable)

Sessile oak

Near the xeric (lower) limits of the sessile oak occurrences, the presence of this species will diminish and it will most probably disappear or occur as mixture species only in thermophilous formations. The modelled drop in probability of occurrences suggests notable compositional change in the core area where the oak is obviously dominant at the moment (Table 3, Fig. 7). The species will move towards the actual beech zone and replace beech-dominant forests where the vertical buffer is available. In the Austrian project area, sessile oak may shift its range to the hills and slopes of the Eastern Alps as a result of unsuitable climate, drought and probably lowering ground water table from low-mid elevations (Fig. 8).

Probability of occurrence %	1961-1990	2041-2060		2061-2080		2081-2100	
		RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
0-10	0,1	0,3	0,1	0,0	0,0	0,0	0,0
10-20	0,3	8,4	1,8	2,0	2,7	7,3	8,3
20-30	1,1	7,4	1,6	2,8	2,7	7,2	12,5
30-40	3,0	4,9	4,4	6,0	7,1	3,1	18,3
40-50	5,3	18,4	9,5	8,6	16,3	11,4	22,0
50-60	9,2	28,7	32,7	33,9	28,3	31,0	11,6
60-70	8,8	25,7	42,8	44,0	23,3	26,1	14,2
70-80	7,9	6,0	5,8	2,8	19,1	13,2	12,4
80-90	29,2	0,3	1,3	0,0	0,5	0,6	0,7
90-100	34,9	0,0	0,0	0,0	0,0	0,0	0,0

Table 3. Projected changes in probability of occurrence of sessile oak (*Quercus petraea*) in the Austrian-Hungarian border region

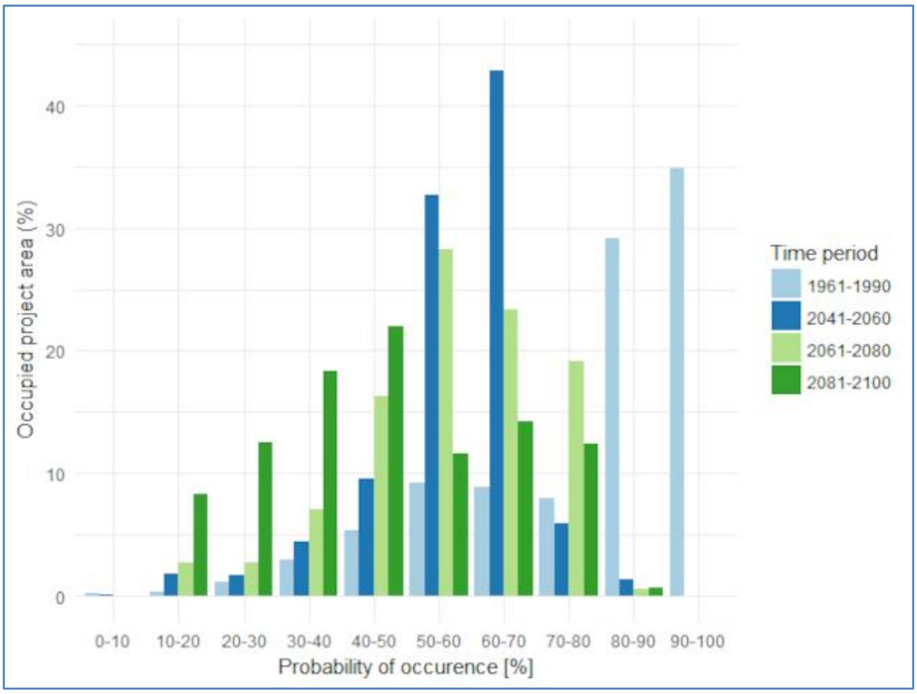

Figure7. Projected changes in probability of occurrence of sessile oak (*Quercus petraea*) in the Austrian-Hungarian border region, RCP8.5

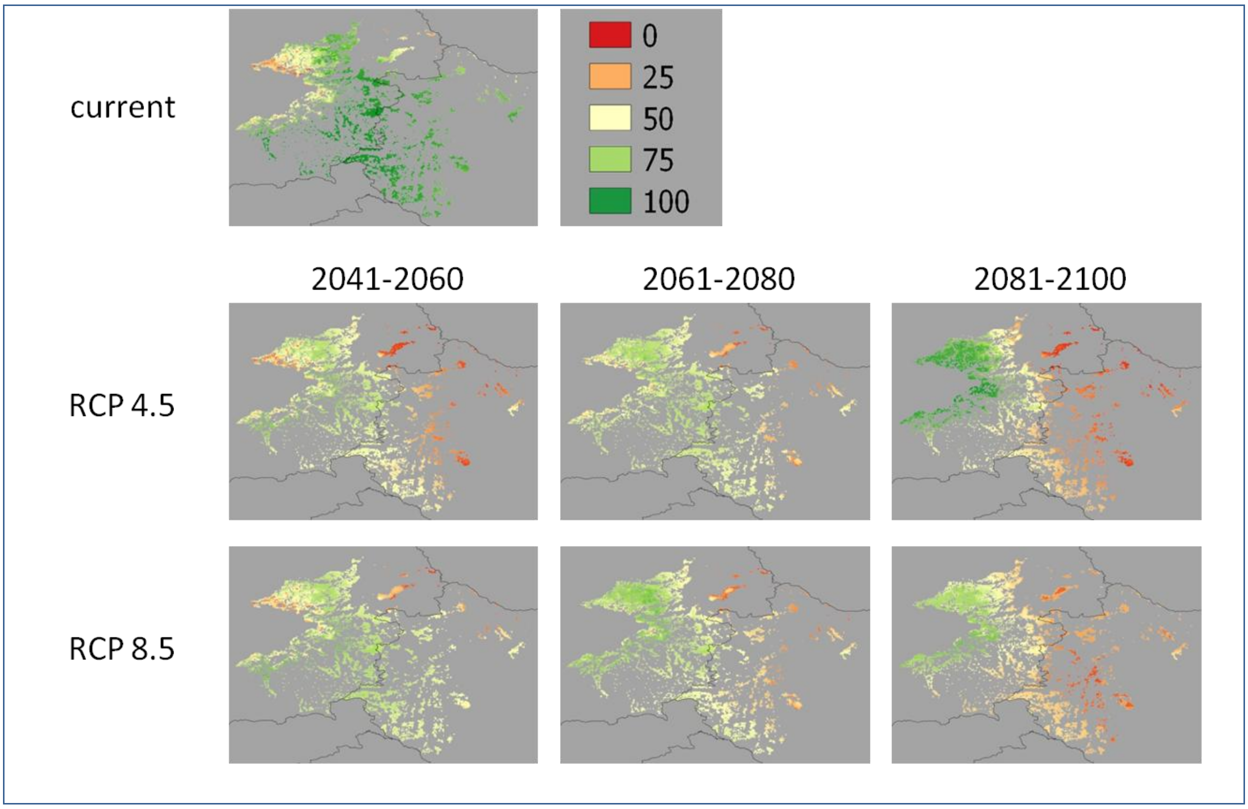

Figure 8. Projected changes in probability of occurrence of sessile oak (*Quercus petraea*) in the Austrian-Hungarian border region

The vulnerability assessment for the sessile oak shows generally high vulnerability in lowland and colline oak stands, as well as possibility for range extension in the sub-Alpine and Alpine sites of Austria, where sessile oak might be able to capitalize on local habitat losses of beech (Fig. 9).

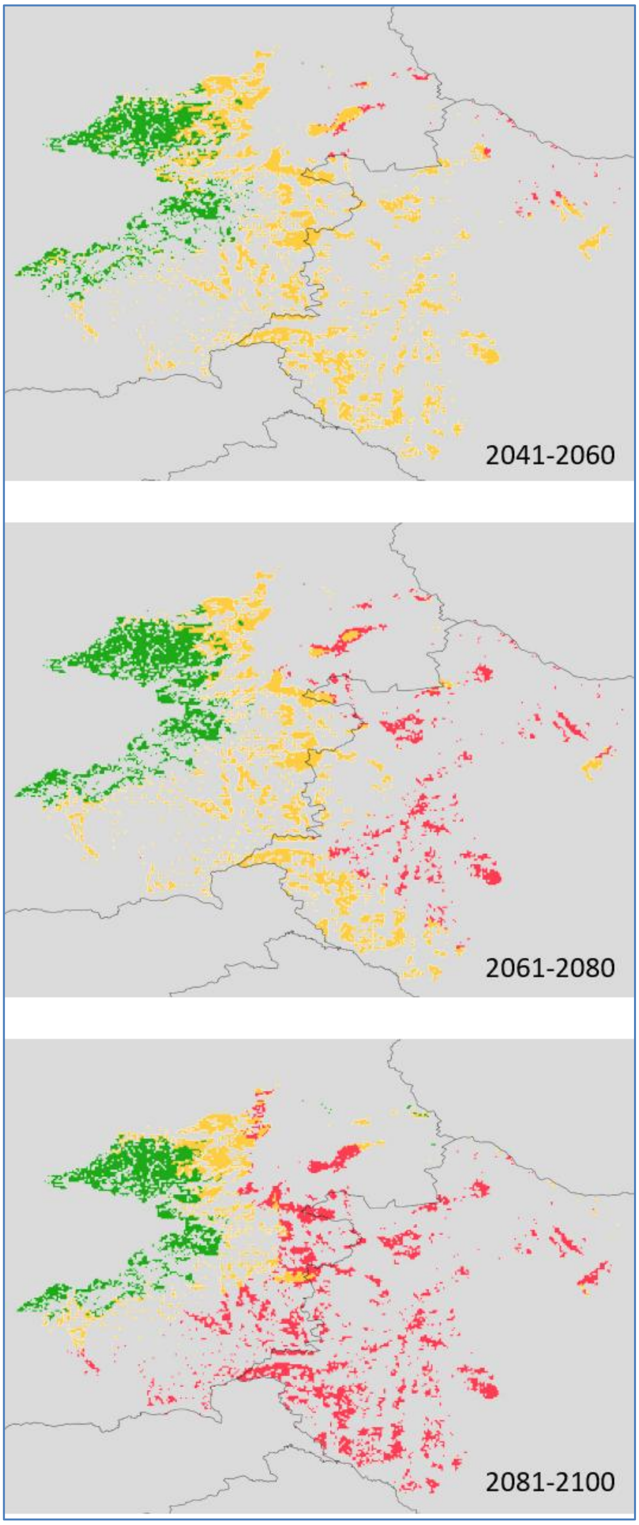

Figure 9. Vulnerability of sessile oak (*Quercus petraea*) stands in the Austrian-Hungarian border region (green: non-vulnerable, yellow: moderately, red: severely vulnerable)

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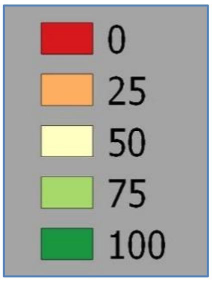
Annexes

Annex I

Probability of occurrence maps for European beech and sessile oak for the Austrian-Hungarian border region for the periods 1961-1990 (considered as present state), 2041-2060, 2061-2080 and 2081-2100 based on RCP4.5 and RCP 8.5 scenarios.

The following maps share the same colour coding based on the probability percentage.



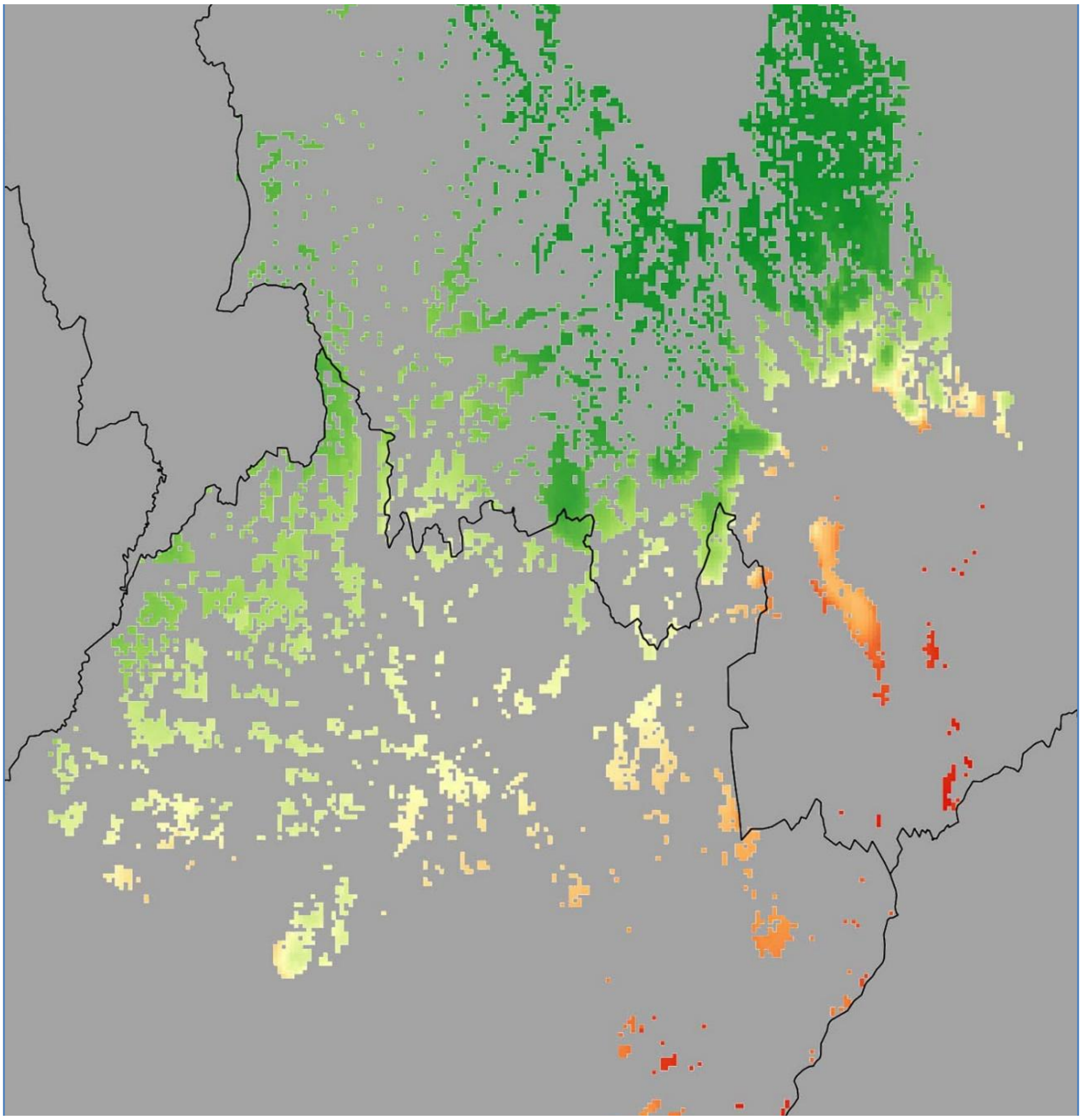


Figure AI.1. Probability of occurrence of European beech in the Austrian-Hungarian border region in the period 1961-1990 (considered as present state).

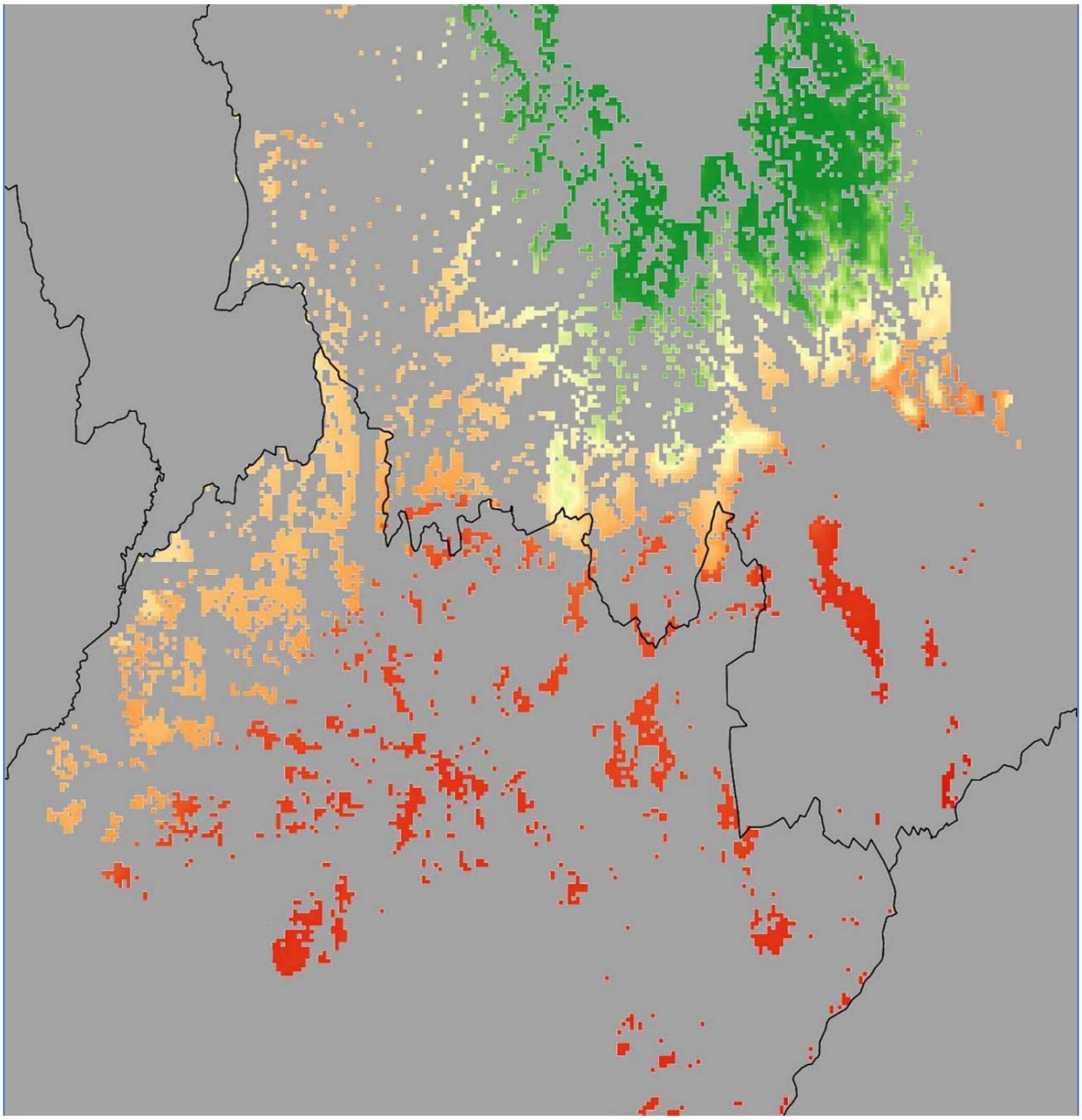


Figure AI.2. Probability of occurrence of European beech in the Austrian-Hungarian border region in the period 2041-2060, based on RCP4.5.

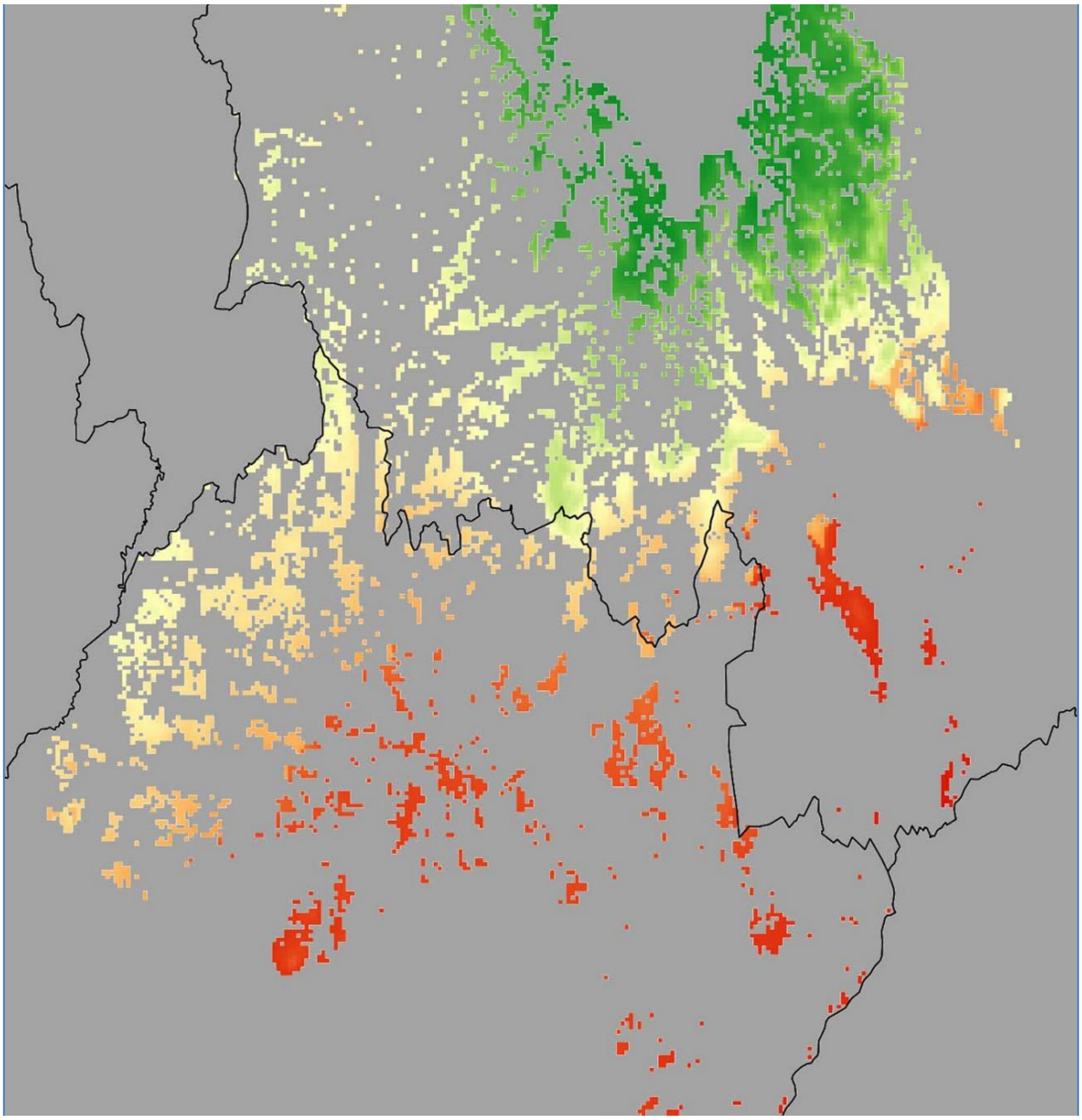


Figure AI.3. Probability of occurrence of European beech in the Austrian-Hungarian border region in the period 2061-2080, based on RCP4.5.

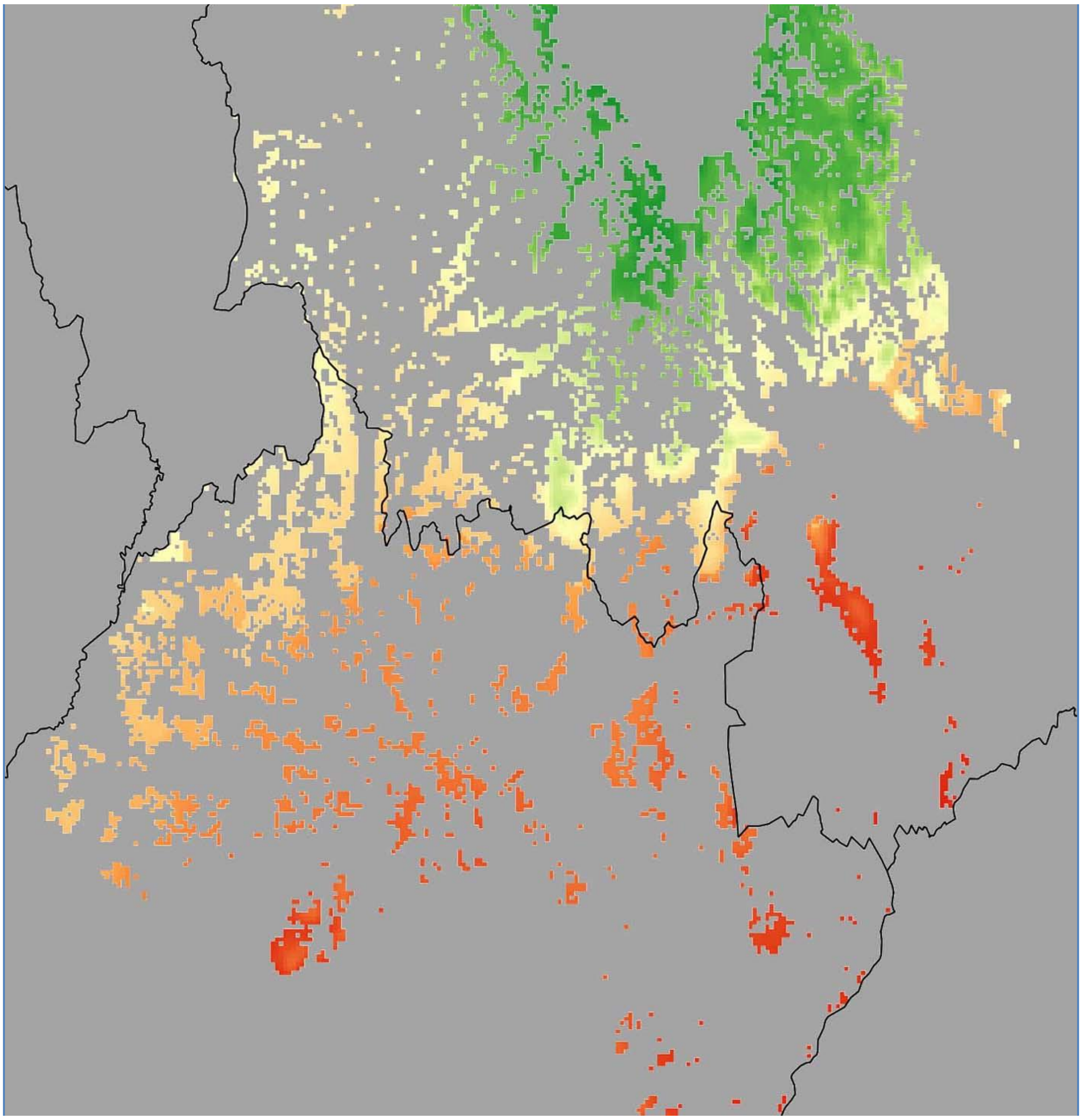


Figure AI.4. Probability of occurrence of European beech in the Austrian-Hungarian border region in the period 2081-2100, based on RCP4.5.

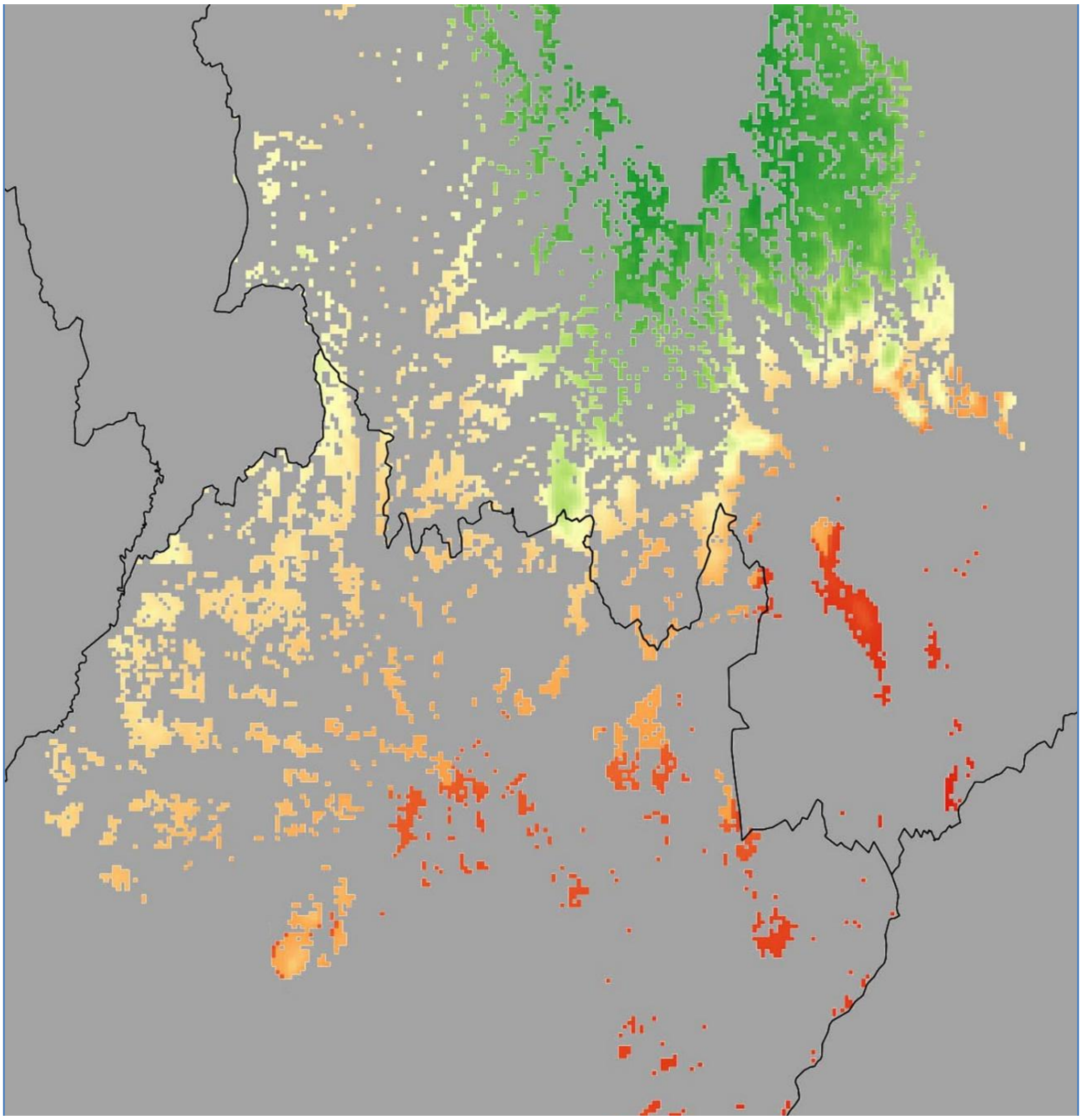


Figure AI.5. Probability of occurrence of European beech in the Austrian-Hungarian border region in the period 2041-2060, based on RCP8.5.

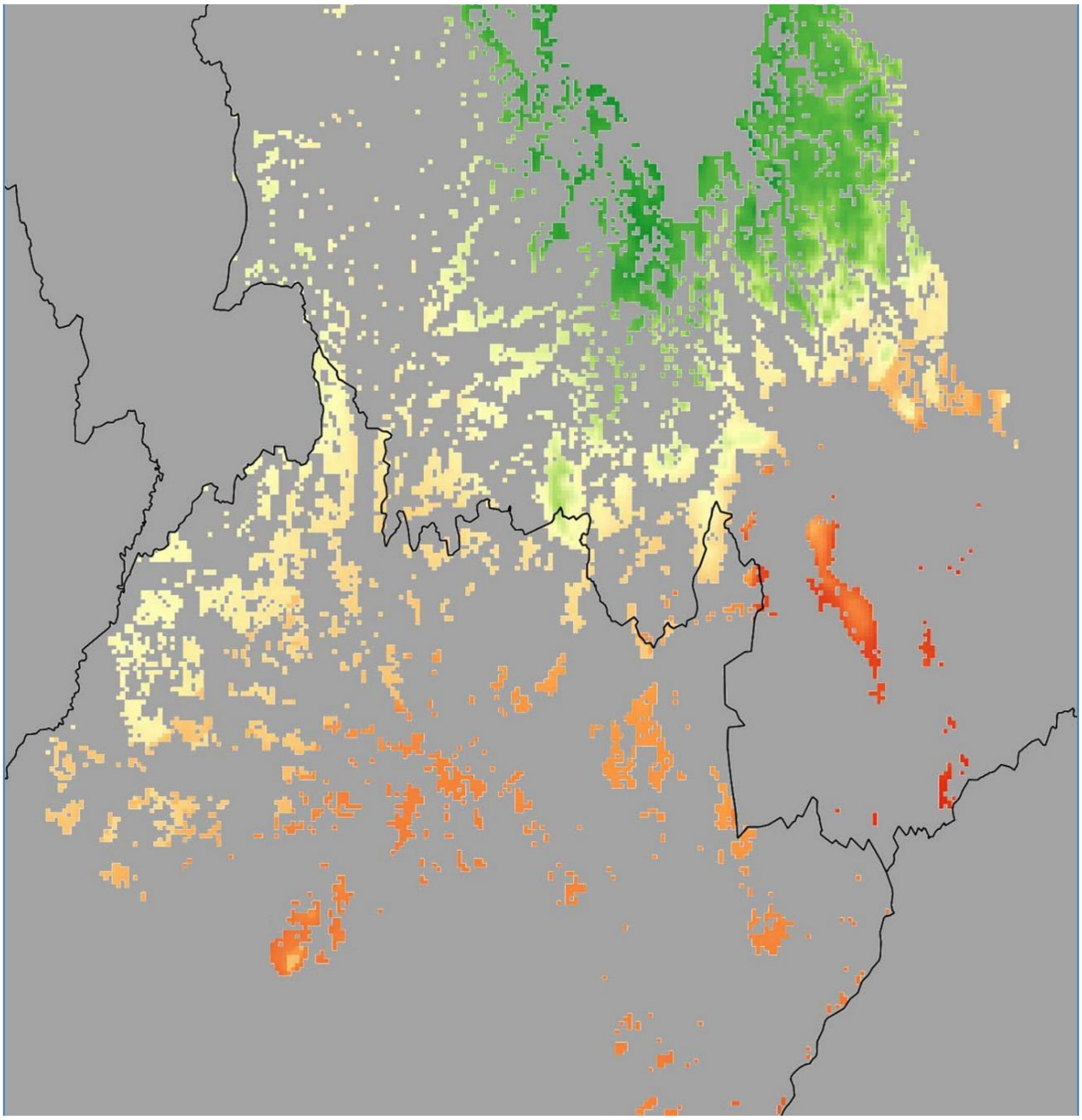


Figure AI.6. Probability of occurrence of European beech in the Austrian-Hungarian border region in the period 2061-2080, based on RCP8.5.

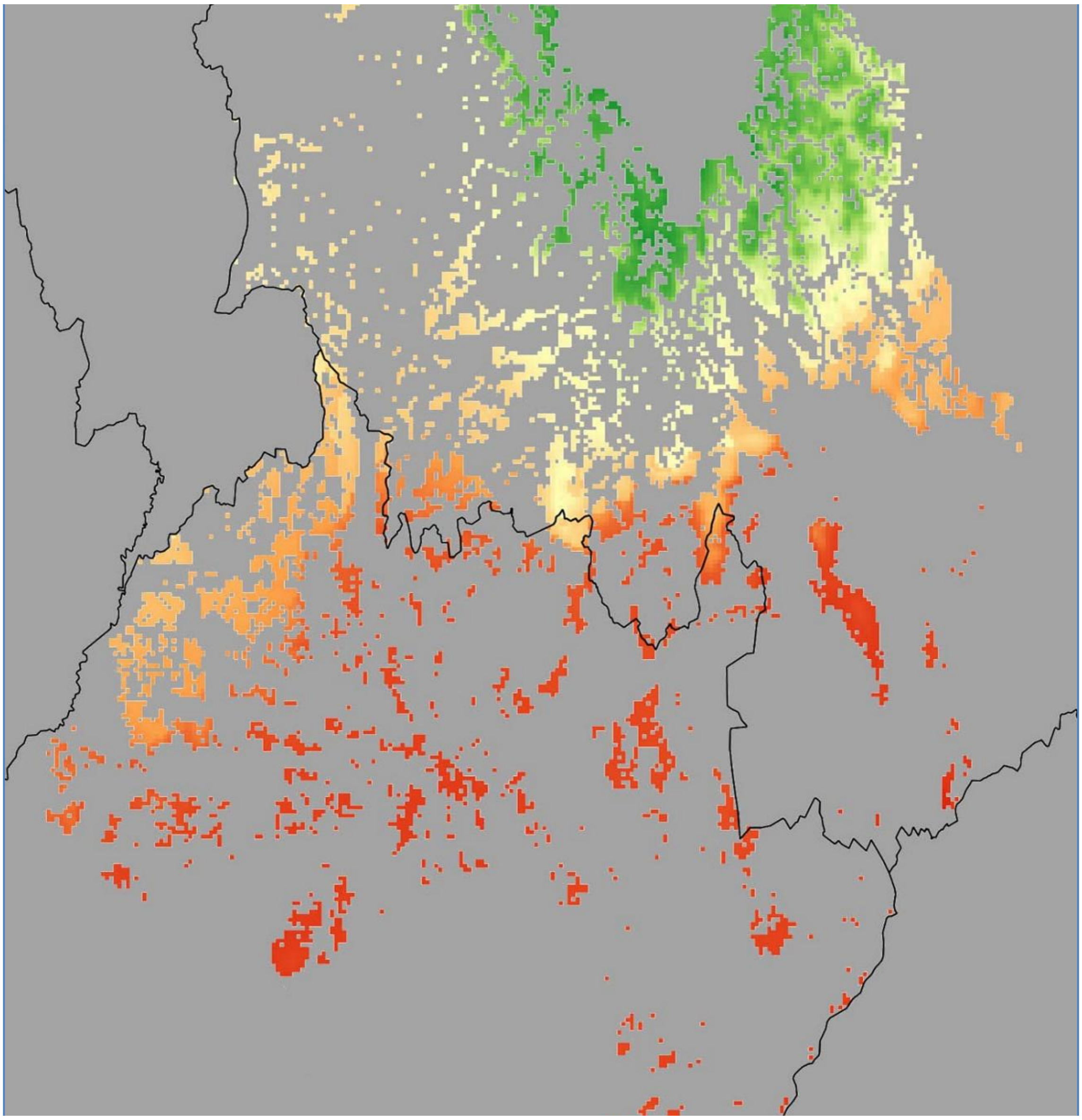


Figure AI.7. Probability of occurrence of European beech in the Austrian-Hungarian border region in the period 2081-2100, based on RCP8.5.

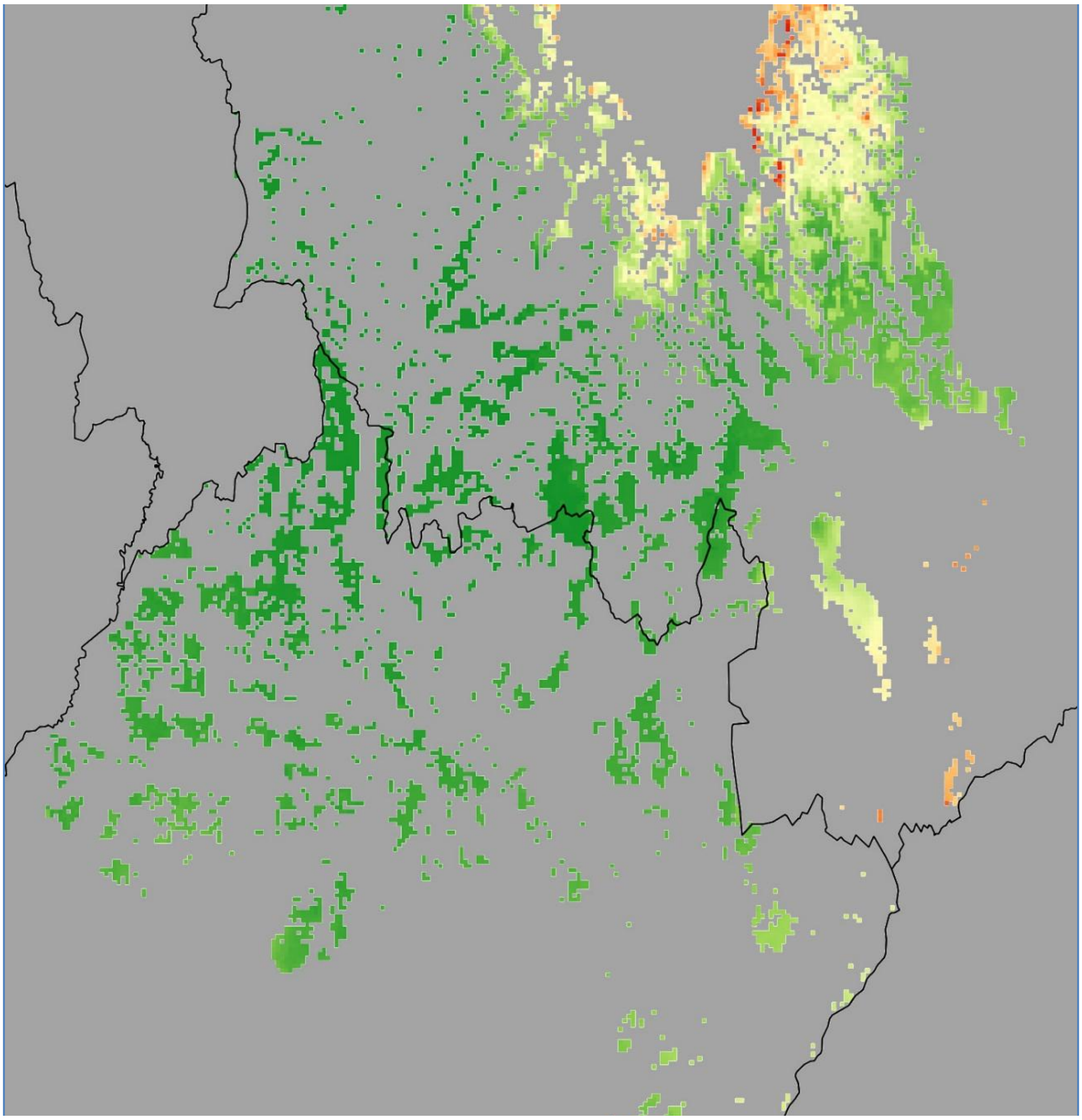


Figure AI.8. Probability of occurrence of sessile oak in the Austrian-Hungarian border region in the period 1961-1990 (considered as present state).

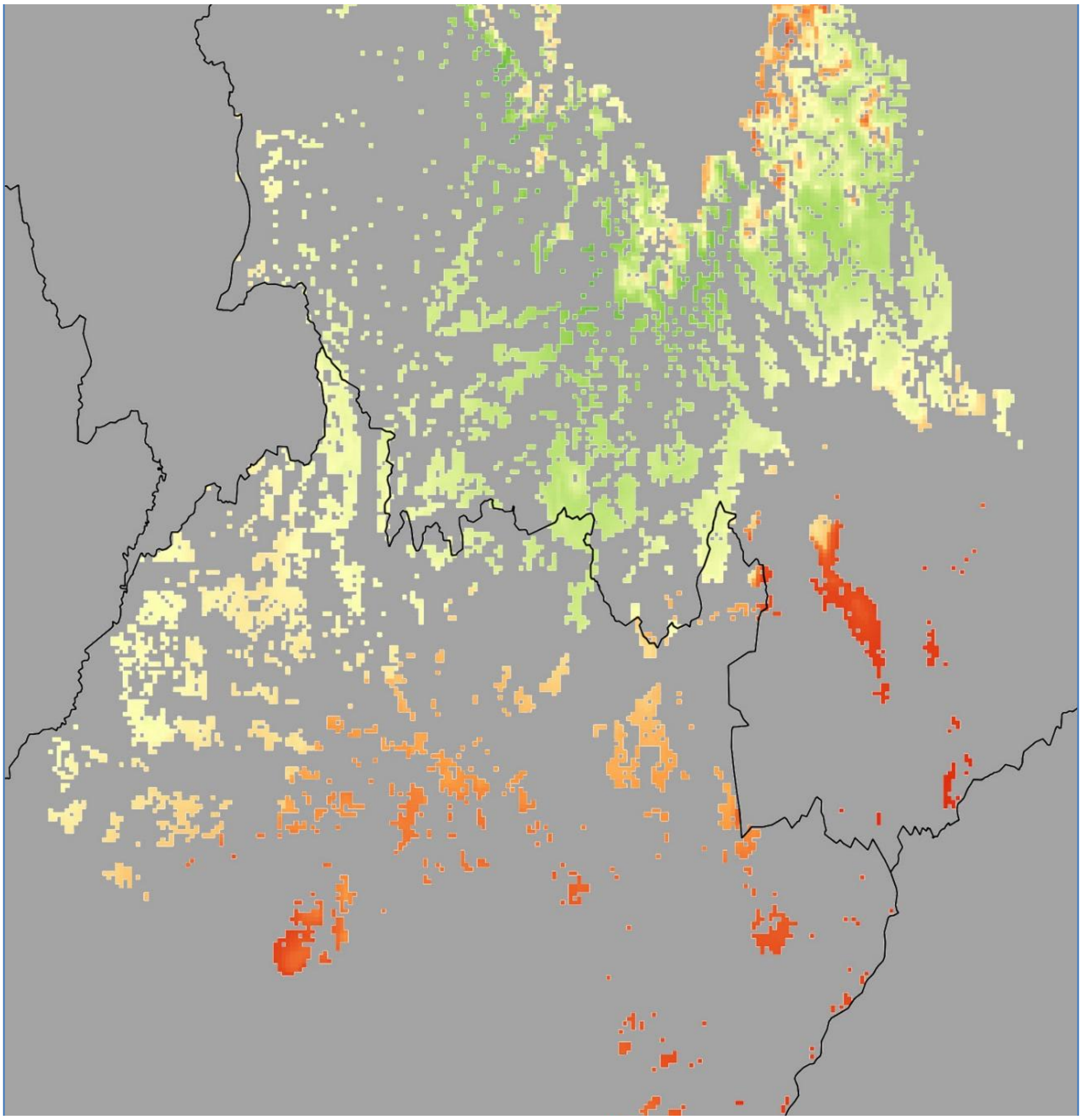


Figure AI.9. Probability of occurrence of sessile oak in the Austrian-Hungarian border region in the period 2041-2060, based on RCP4.5.

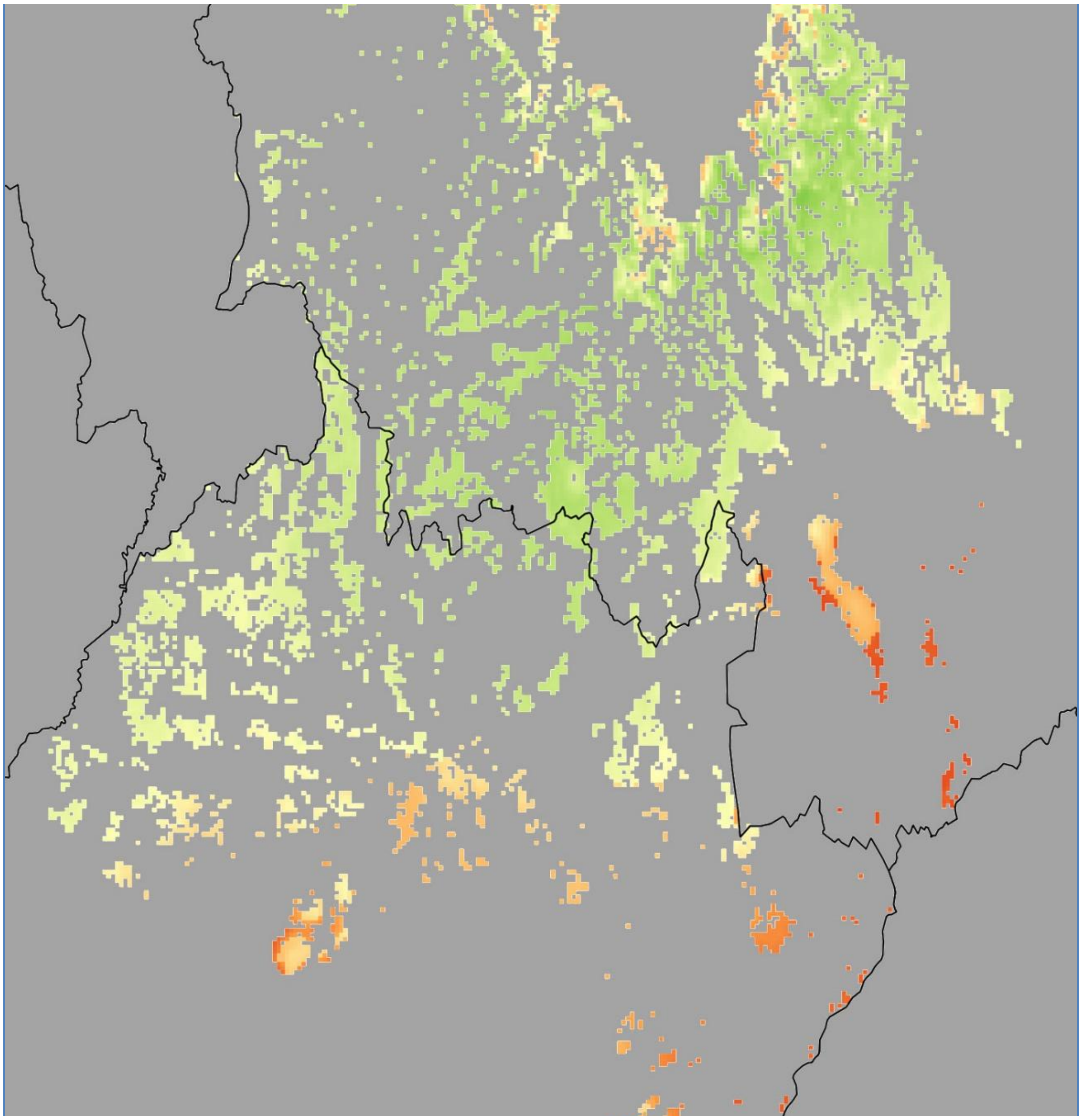


Figure AI.10. Probability of occurrence of sessile oak in the Austrian-Hungarian border region in the period 2061-2080, based on RCP4.5.

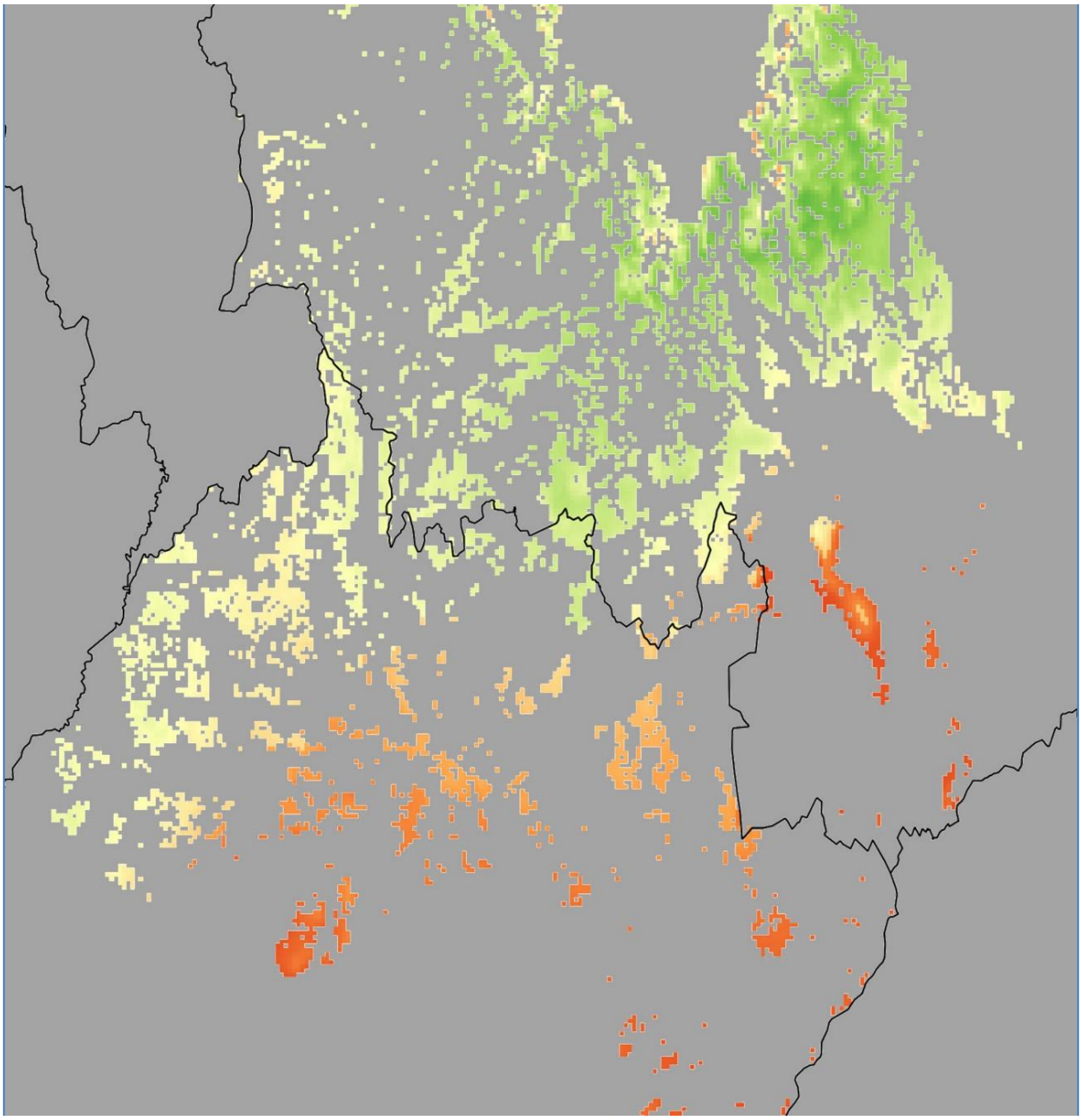


Figure AI.11. Probability of occurrence of sessile oak in the Austrian-Hungarian border region in the period 2081-2100, based on RCP4.5.

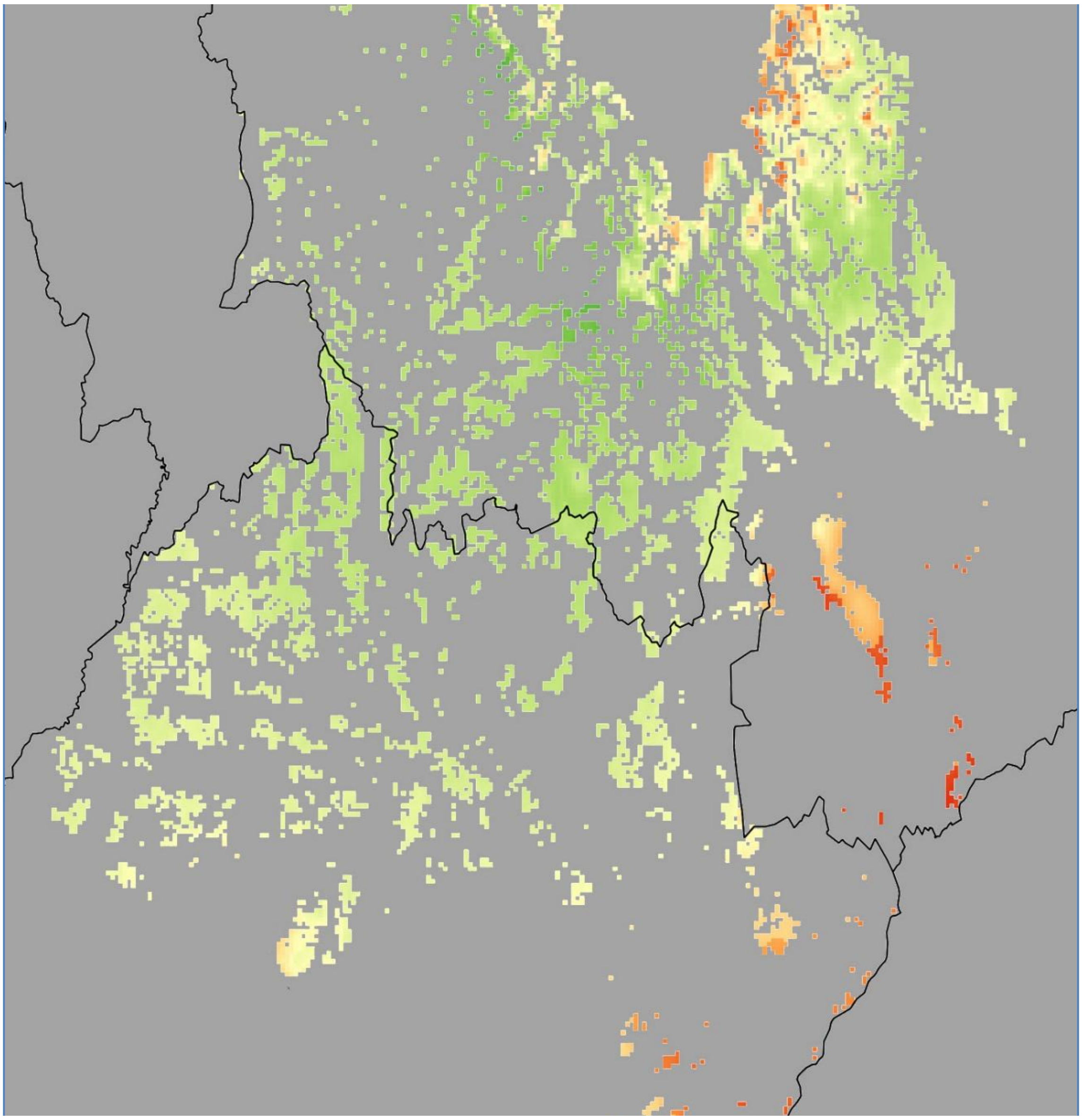


Figure AI.12. Probability of occurrence of sessile oak in the Austrian-Hungarian border region in the period 2041-2060, based on RCP8.5.

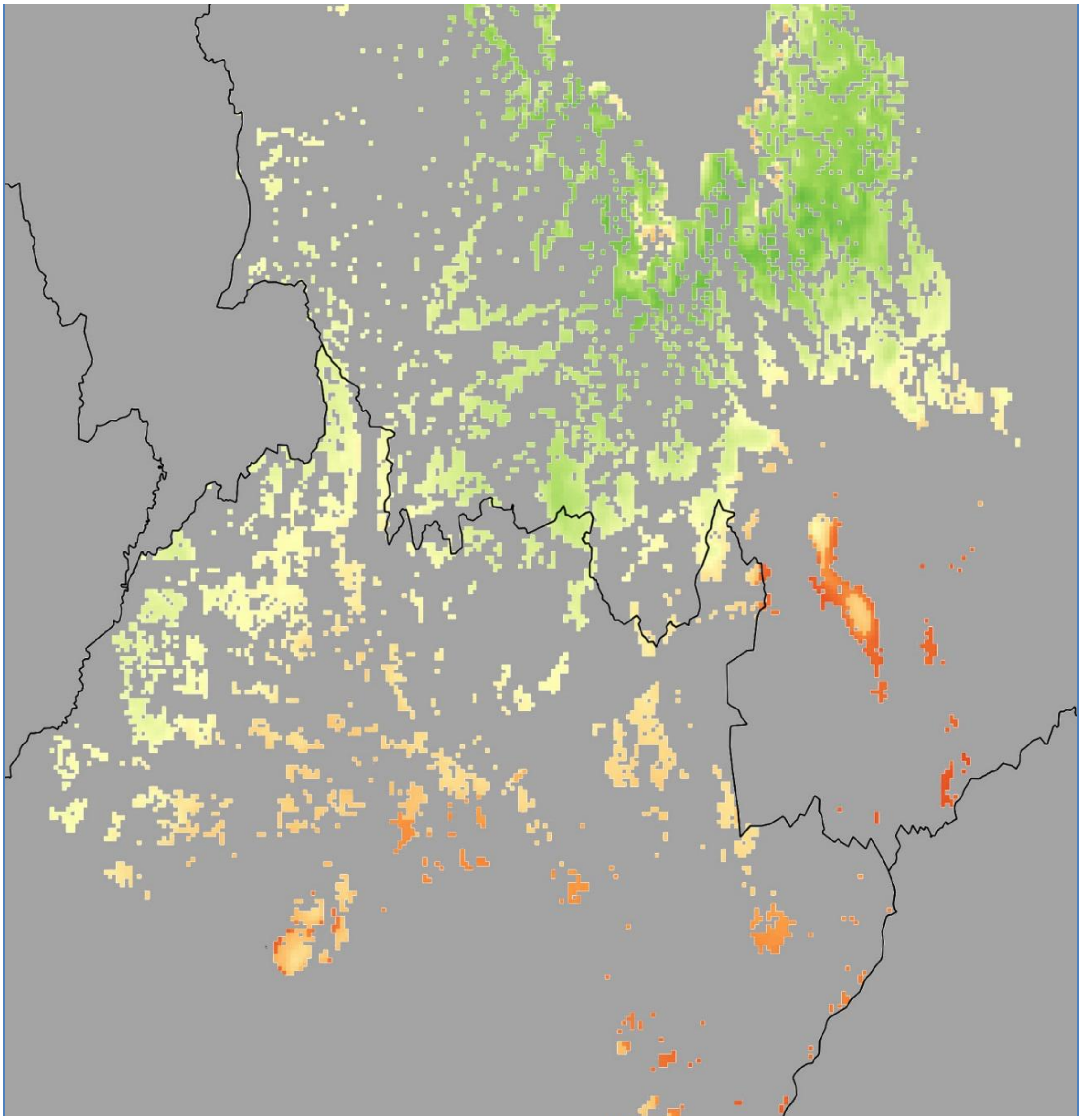


Figure AI.13. Probability of occurrence of sessile oak in the Austrian-Hungarian border region in the period 2061-2080, based on RCP8.5.

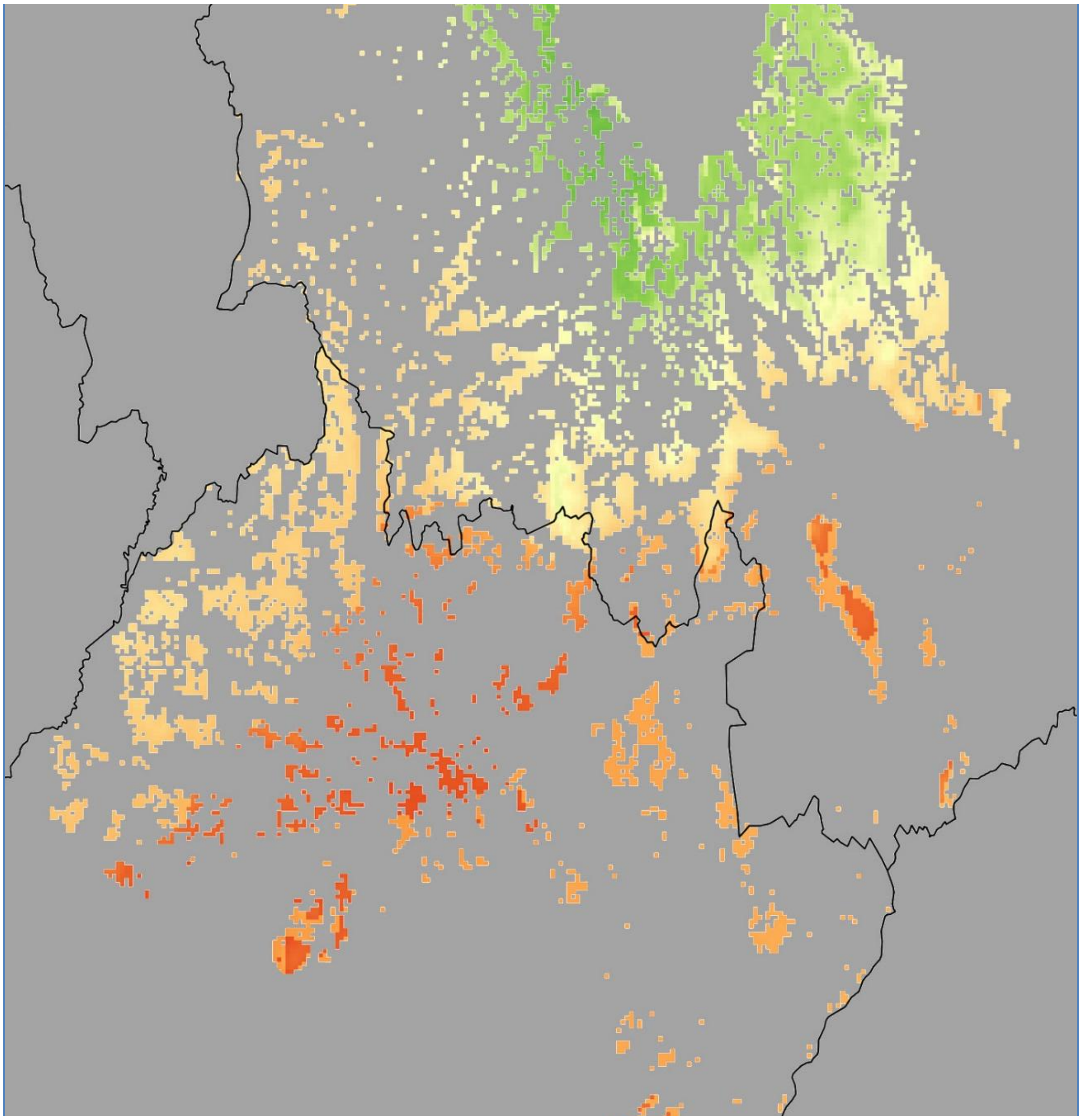


Figure AI.14. Probability of occurrence of sessile oak in the Austrian-Hungarian border region in the period 2081-2100, based on RCP8.5.

Annex II

Vulnerability maps for European beech and sessile oak for the Austrian-Hungarian border region for the periods 2041-2060, 2061-2080 and 2081-2100 based on the RCP 8.5 scenario.

The following maps have been derived from the species distribution maps to illustrate the projected decrease in the probability of occurrence of a given species in time. The colour codes are uniform and show non-vulnerable, moderately vulnerable and severely vulnerable stands in green, yellow and red, respectively.

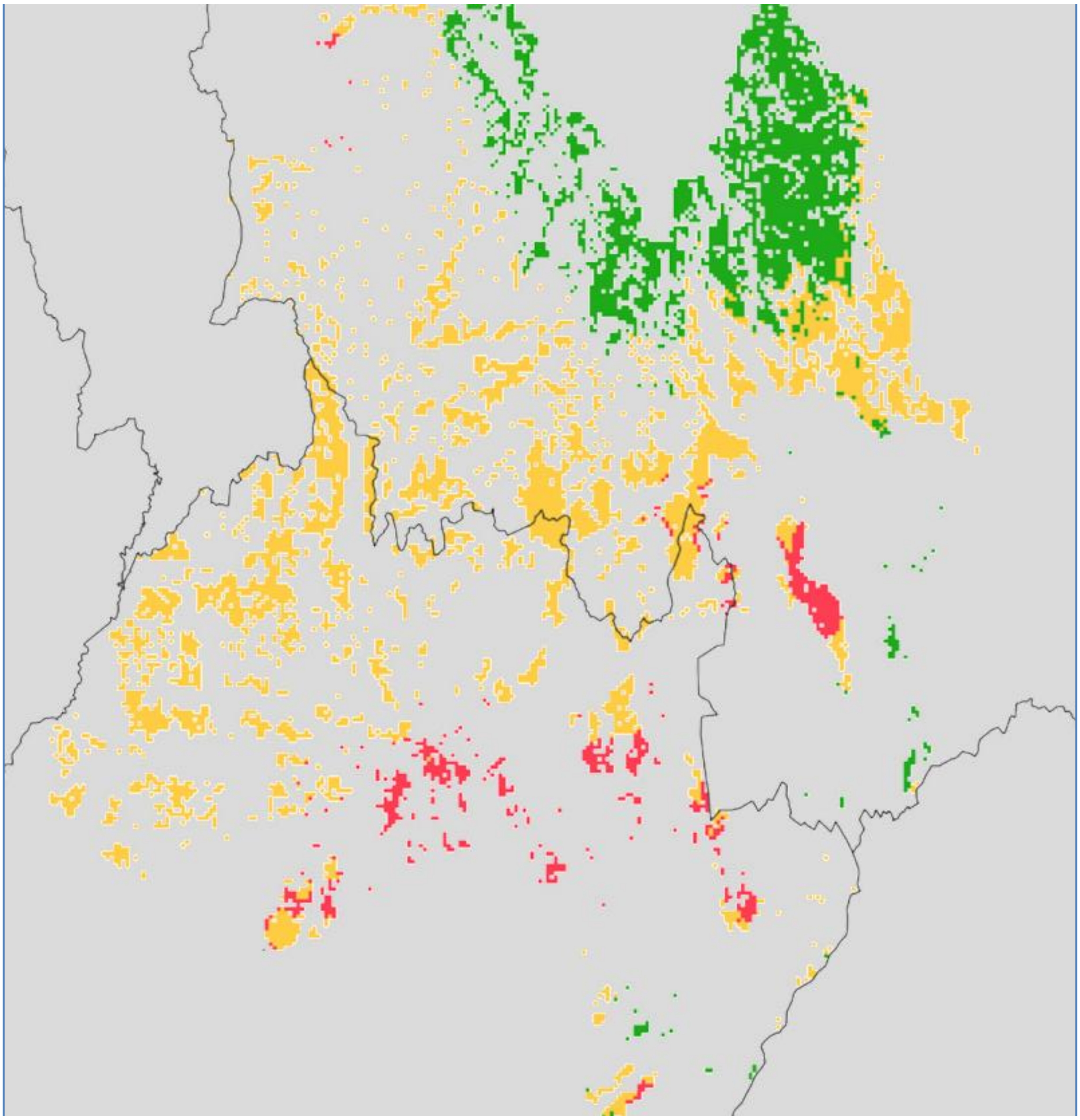


Figure AII.1. Vulnerability of European beech stands in the Austrian-Hungarian border region for the period 2041-2060, based on RCP 8.5.

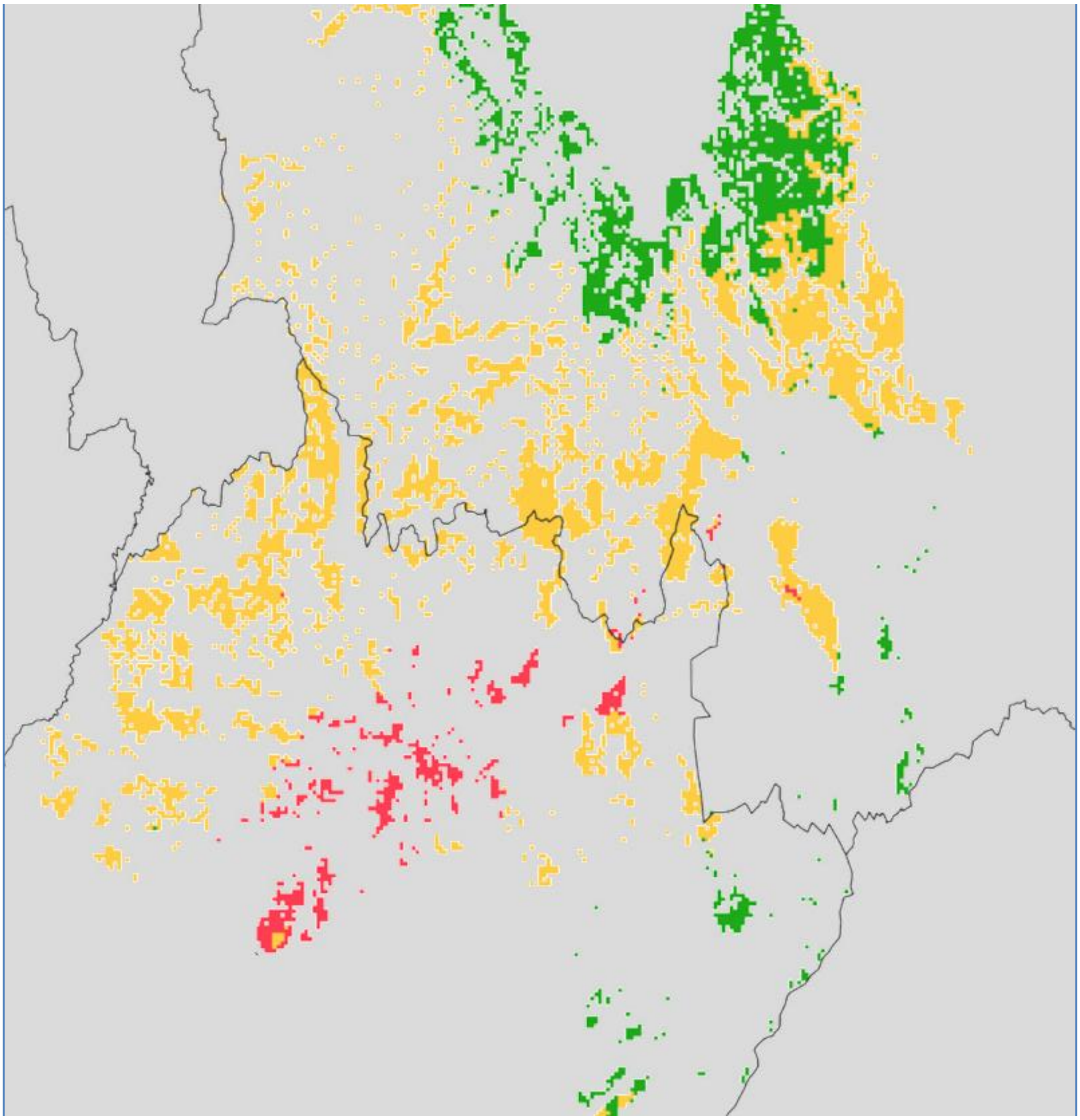


Figure AII.2. Vulnerability of European beech stands in the Austrian-Hungarian border region for the period 2061-2080, based on RCP 8.5.

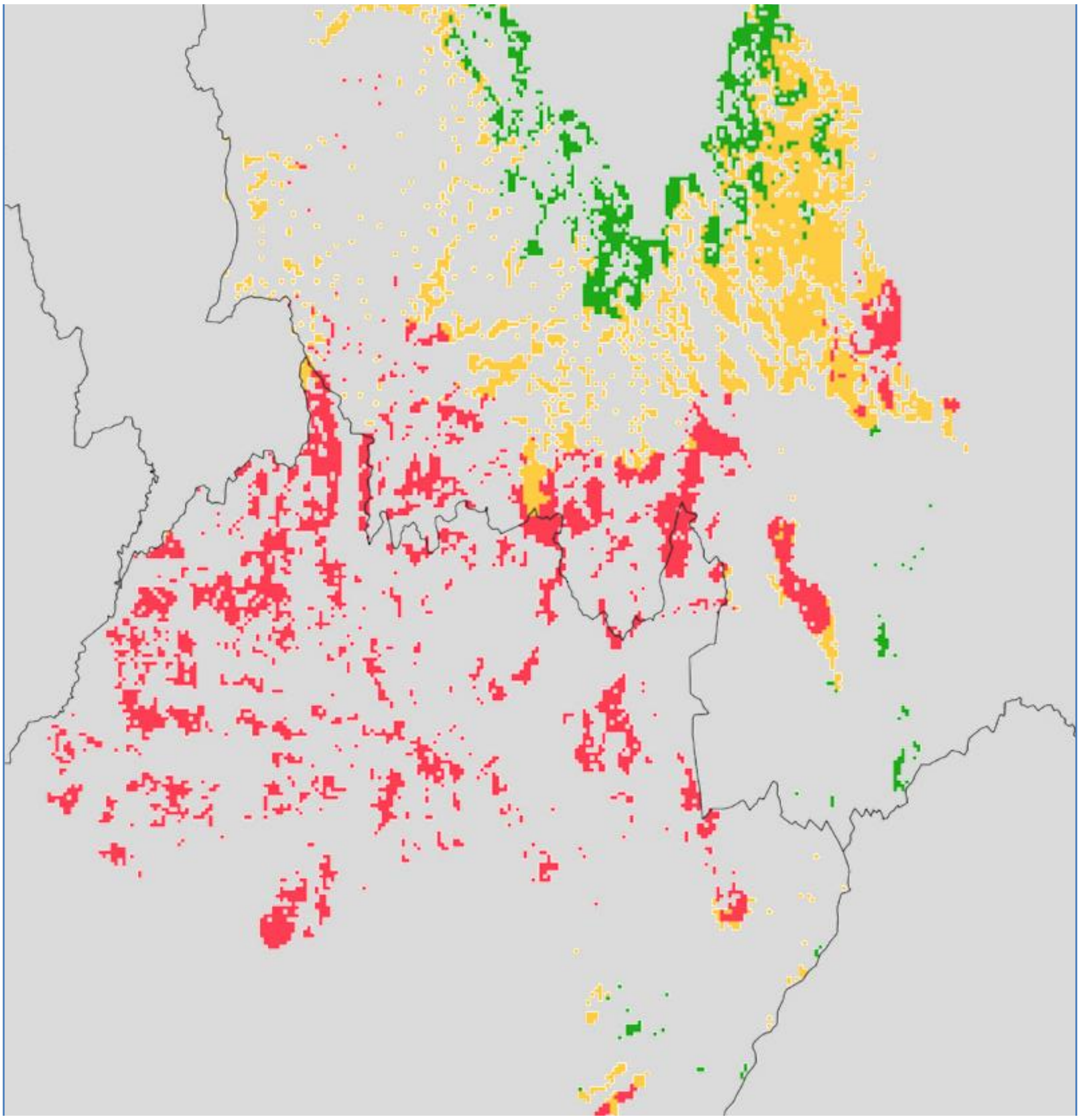


Figure AII.3. Vulnerability of European beech stands in the Austrian-Hungarian border region for the period 2081-2100, based on RCP 8.5.

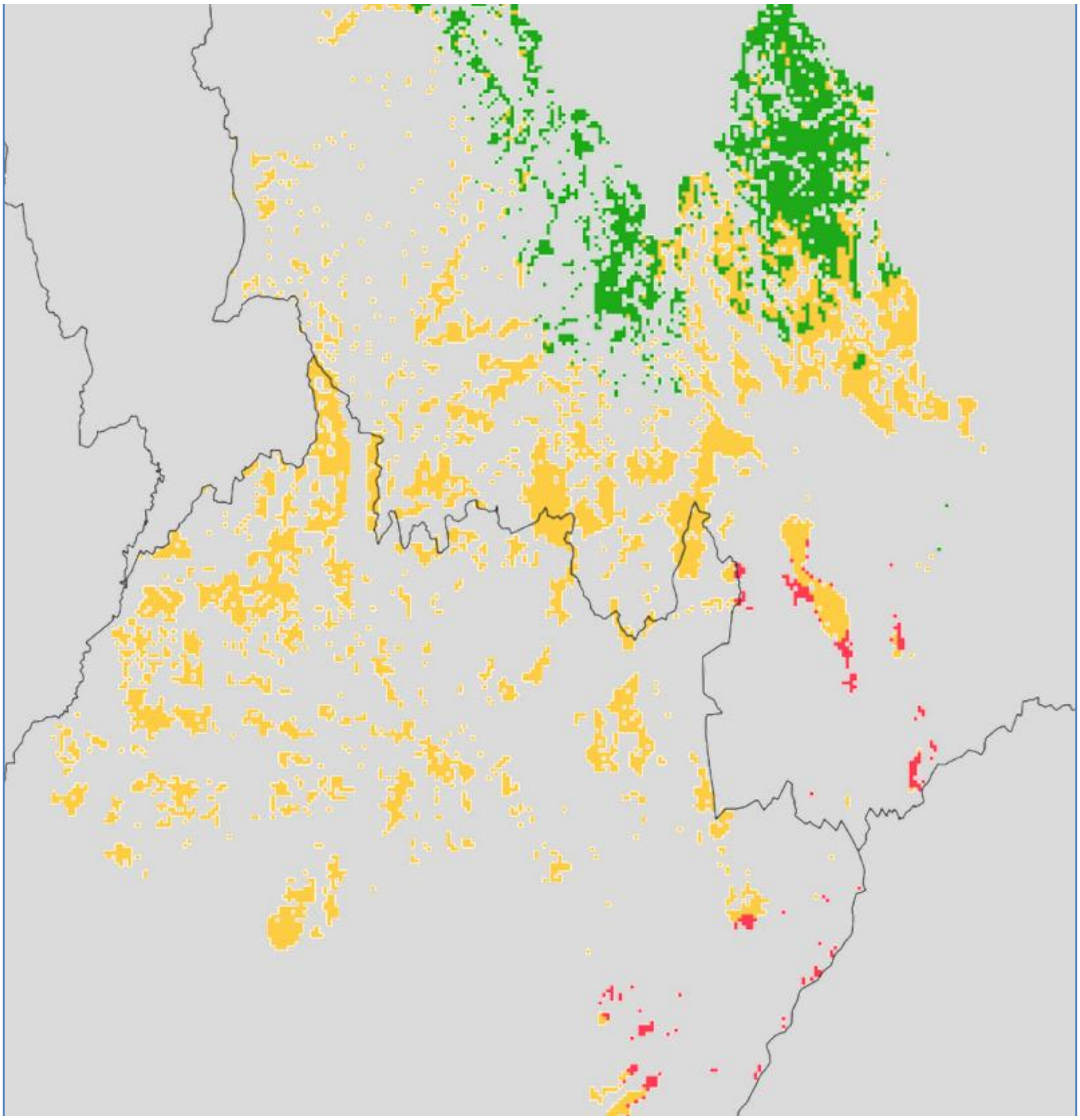


Figure AII.4. Vulnerability of sessile oak stands in the Austrian-Hungarian border region for the period 2041-2060, based on RCP 8.5.

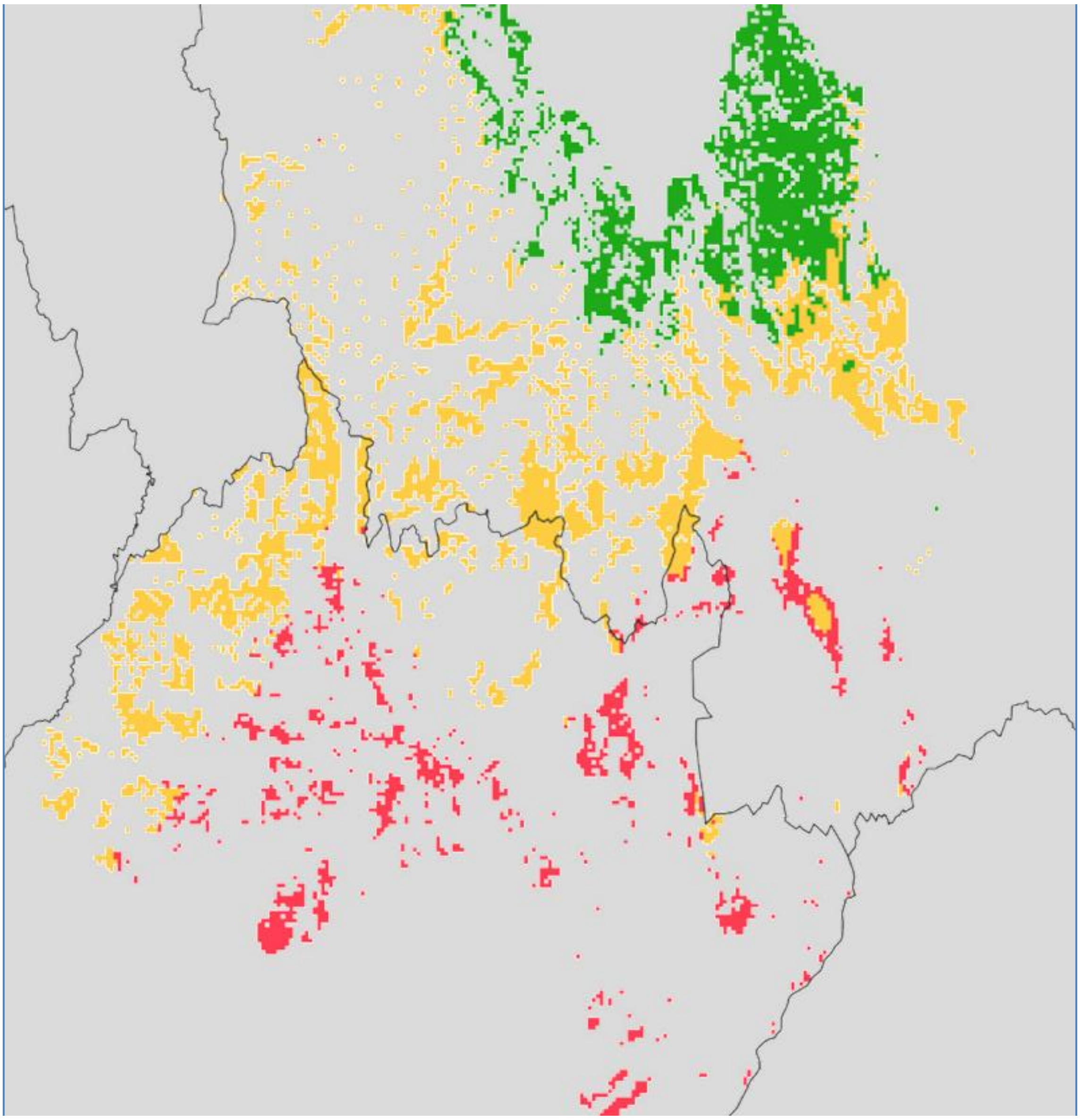


Figure AII.5. Vulnerability of sessile oak stands in the Austrian-Hungarian border region for the period 2061-2080, based on RCP 8.5.

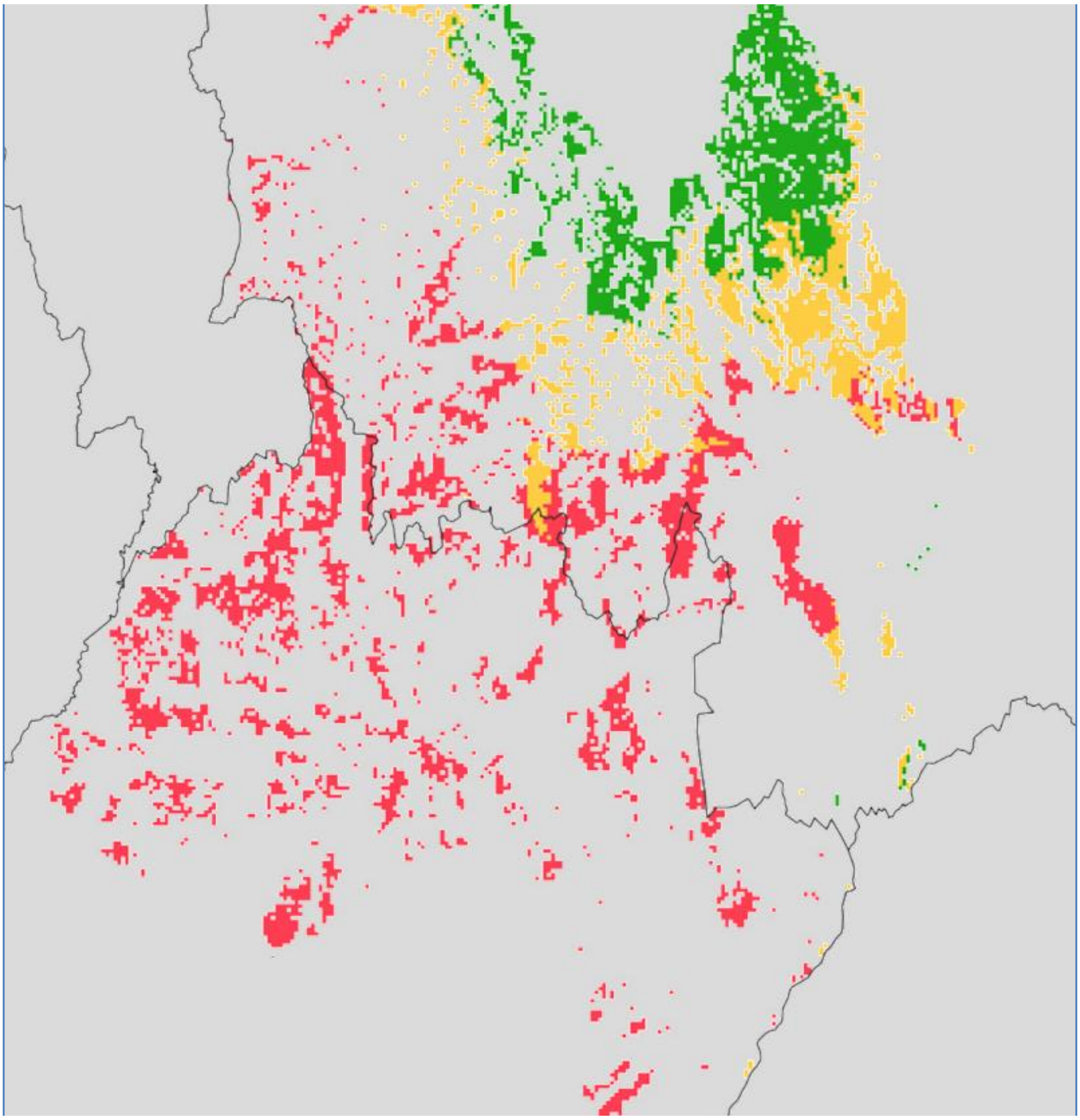


Figure AII.6. Vulnerability of sessile oak stands in the Austrian-Hungarian border region for the period 2081-2100, based on RCP 8.5.