

Supplementary Material

Cross-regional modelling of fire occurrence in the Alps and the Mediterranean Basin

İsmail Bekar^{A,F}, Çağatay Tavşanoğlu^B, G. Boris Pezzatti^C, Harald Vacik^D, Juli G. Pausas^E, Harald Bugmann^A and Gunnar Petter^A

^AForest Ecology, Institute of Terrestrial Ecosystems, Swiss Federal Institute of Technology, ETH Zurich, Universitätstrasse 16, 8092 Zürich, Switzerland.

^BDivision of Ecology, Department of Biology, Hacettepe University, Beytepe 06800, Ankara, Turkey.

^CInsubric Ecosystems Research Group, Swiss Federal Research Institute for forest, snow and landscape research WSL, Campus Cadenazzo, A Ramel 18, 6593 Cadenazzo, Switzerland.

^DInstitute of Silviculture, University of Natural Resources and Life Sciences (BOKU), Peter Jordan Str. 82, 1190 Vienna, Austria.

^ECentro de Investigaciones sobre Desertificación, Consejo Superior de Investigaciones Científicas (CIDE-CSIC), 46113 Valencia, Spain.

^FCorresponding author. Email: ibekar@ethz.ch

Table S1: Full list of the variables that were used in the study.

Variable	Description	Category
BIO 1	Annual mean temperature	Temperature
BIO 2	Mean diurnal range	Temperature
BIO 3	Isothermality (BIO2/BIO7) (* 100)	Temperature
BIO 4	Temperature seasonality	Temperature
BIO 5	Max temperature of warmest month	Temperature
BIO 6	Min Temperature of coldest month	Temperature
BIO 7	Temperature annual range (BIO5-BIO6)	Temperature
BIO 8	Mean temperature of wettest quarter	Temperature
BIO 9	Mean temperature of driest quarter	Temperature
BIO 10	Mean temperature of warmest quarter	Temperature
BIO 11	Mean temperature of coldest quarter	Temperature
BIO 12	Annual precipitation	Precipitation
BIO 13	Precipitation of wettest month	Precipitation
BIO 14	Precipitation of driest month	Precipitation
BIO 15	Precipitation seasonality (Coefficient of variation)	Precipitation
BIO 16	Precipitation of wettest quarter	Precipitation
BIO 17	Precipitation of driest quarter	Precipitation
BIO 18	Precipitation of warmest quarter	Precipitation
BIO 19	Precipitation of coldest quarter	Precipitation
Road network	Road line density	Anthropogenic
Human settlement	Percentage built up area (0-100 %)	Anthropogenic
Land cover	Categorical land cover data	Anthropogenic
Tree cover density	Tree cover density (0-100 %)	Forest
Forest type	Categorical forest type data (broadleaved or coniferous)	Forest
Aspect	Direction that a slope faces	Topography
Slope	(°)	Topography

Table S2: Variable contributions of individual variables.

	Model	Resolution	Category	Variable Name	Value contribution		Model	Resolution	Category	Variable name	Value contribution
1	AU	Coarse	Temperature	bio01	44.5	1	AU	Fine	Forest	tcoverd	37.9
2	AU	Coarse	Anthropogenic	roadnet	44.2	2	AU	Fine	Temperature	bio1	27.7
3	AU	Coarse	Temperature	bio06	5.8	3	AU	Fine	Anthropogenic	roadnet	18.7
4	AU	Coarse	Topography	slope	3.1	4	AU	Fine	Topography	aspect	6.4
5	AU	Coarse	Forest	tcoverd	2.3	5	AU	Fine	Forest	fty	4.6
						6	AU	Fine	Anthropogenic	landcover	2.7
						7	AU	Fine	Temperature	bio3	1.0
						8	AU	Fine	Precipitation	bio15	1.0
1	CH	Coarse	Forest	tcoverd	36.2	1	CH	Fine	Forest	tcoverd	46.3
2	CH	Coarse	Temperature	bio01	30.8	2	CH	Fine	Temperature	bio1	32.0
3	CH	Coarse	Precipitation	bio15	7.6	3	CH	Fine	Precipitation	bio15	6.6
4	CH	Coarse	Anthropogenic	roadnet	6.6	4	CH	Fine	Anthropogenic	roadnet	3.5
5	CH	Coarse	Temperature	bio08	5.0	5	CH	Fine	Topography	aspect	3.3
6	CH	Coarse	Temperature	bio07	4.6	6	CH	Fine	Anthropogenic	landcover	2.5
7	CH	Coarse	Topography	aspect	3.3	7	CH	Fine	Precipitation	bio18	2.4
8	CH	Coarse	Precipitation	bio18	2.0	8	CH	Fine	Anthropogenic	settl	1.4
9	CH	Coarse	Temperature	bio09	2.0	9	CH	Fine	Temperature	bio7	1.1

10	CH	Coarse	Precipitation	bio17	1.0	10	CH	Fine	Precipitation	bio19	0.8
11	CH	Coarse	Anthropogenic	landcover	0.7						
12	CH	Coarse	Forest	fty	0.1						
1	CR	Coarse	Temperature	bio08	42.6	1	CR	Fine	Temperature	bio8	41.4
2	CR	Coarse	Temperature	bio09	23.4	2	CR	Fine	Forest	tcoverd	21.5
3	CR	Coarse	Forest	tcoverd	17.2	3	CR	Fine	Temperature	bio9	19.8
4	CR	Coarse	Anthropogenic	roadnet	9.5	4	CR	Fine	Anthropogenic	roadnet	8.8
5	CR	Coarse	Temperature	bio07	2.1	5	CR	Fine	Anthropogenic	landcover	1.9
6	CR	Coarse	Topography	slope	1.6	6	CR	Fine	Temperature	bio3	1.8
7	CR	Coarse	Anthropogenic	landcover	1.5	7	CR	Fine	Precipitation	bio19	1.4
8	CR	Coarse	Precipitation	bio19	1.3	8	CR	Fine	Temperature	bio7	1.4
9	CR	Coarse	Precipitation	bio12	0.4	9	CR	Fine	Topography	slope	1.2
10	CR	Coarse	Forest	fty	0.3	10	CR	Fine	Precipitation	bio13	0.7
						11	CR	Fine	Anthropogenic	settl	0.1
1	SPA	Coarse	Anthropogenic	roadnet	38.4	1	SPA	Fine	Anthropogenic	roadnet	38.3
2	SPA	Coarse	Temperature	bio01	34.0	2	SPA	Fine	Temperature	bio1	29.9
3	SPA	Coarse	Forest	tcoverd	11.4	3	SPA	Fine	Temperature	bio3	6.2
4	SPA	Coarse	Precipitation	bio12	5.6	4	SPA	Fine	Forest	tcoverd	5.8

5	SPA	Coarse	Precipitation	bio13	5.1	5	SPA	Fine	Precipitation	bio12	5.7
6	SPA	Coarse	Temperature	bio03	2.3	6	SPA	Fine	Anthropogenic	landcover	5.5
7	SPA	Coarse	Anthropogenic	landcover	2.2	7	SPA	Fine	Precipitation	bio13	5.2
8	SPA	Coarse	Anthropogenic	settl	0.9	8	SPA	Fine	Topography	slope	2.8
						9	SPA	Fine	Anthropogenic	settl	0.6
1	TR	Coarse	Precipitation	bio19	42.8	1	TR	Fine	Forest	tcoverd	28.4
2	TR	Coarse	Forest	tcoverd	20.2	2	TR	Fine	Temperature	bio8	24.1
3	TR	Coarse	Anthropogenic	roadnet	14.7	3	TR	Fine	Anthropogenic	roadnet	18.1
4	TR	Coarse	Temperature	bio10	11.1	4	TR	Fine	Precipitation	bio12	12.2
5	TR	Coarse	Temperature	bio02	4.8	5	TR	Fine	Topography	slope	5.9
6	TR	Coarse	Anthropogenic	landcover	3.3	6	TR	Fine	Anthropogenic	landcover	5.6
7	TR	Coarse	Temperature	bio04	2.3	7	TR	Fine	Temperature	bio2	4.2
8	TR	Coarse	Forest	fty	0.7	8	TR	Fine	Forest	fty	1.5

Study Regions



Fig. S1: Fire locations in Southern Switzerland (Central and Southern Alps).

CENTRAL AND SOUTHERN ALPS OF SWITZERLAND

This study region is located in central and southern Alps and contains three cantons of Switzerland: Valais, Ticino and Grisons, covering 15 141 km². It exhibits highly diverse climate conditions from a very dry continental climate in Valais to warm and humid conditions in Ticino.

Geo-referenced fire data for the period 2000-2016 were obtained from the swiss forest fire database Swissfire (www.wsl.ch/swissfire) of the Swiss Federal Institute for Forest, Snow and Landscape Research WSL (Pezzatti *et al.* 2010). The dataset had 831 fires. This region is the most fire prone part of Switzerland (Zumbrunnen *et al.*, 2012) and has fires all year round with two major peaks in March-April and July and August. Among the three cantons, Ticino has much higher fire activity than Valais and Grisons. De Angelis *et al.* (2015) splitted the fires into “winter fires” (non-vegetative season, from December to April), stating that most of

them are of anthropogenic origin, and “summer fires” (vegetative season, from May to November), consisting of fires of both natural and anthropogenic origin.

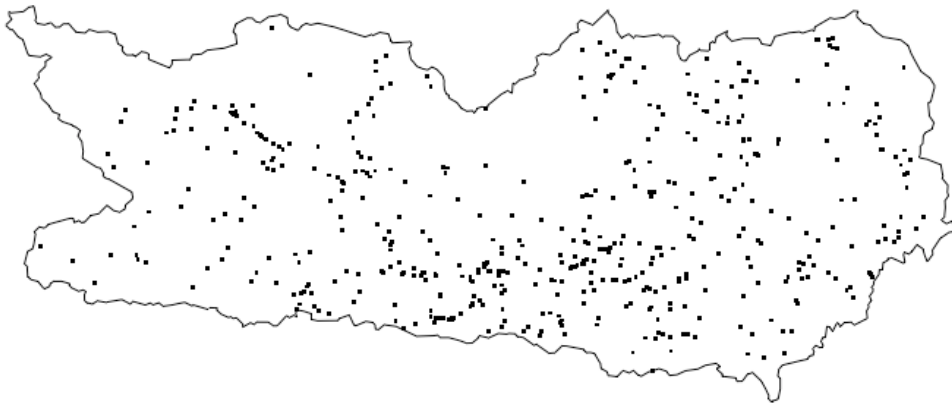


Fig. S2: Fire locations in Carinthia, Austria.

CARINTHIA

Carinthia is located in the southern part of Austria and covers 9 536 km². The region experiences a climate with high summer temperatures and cold winters; it also experiences high number of thunderstorms (Grima 2011). Vegetation is mostly dominated by alpine coniferous (*Picea abies*, *Abies alba*, *Pinus slyvestris*, *Larix decidua*) or beech forests (*Fagus sylvatica*) (Grima 2011).

Fire data for the years 2000-2017 were obtained from the forest fire database of Austria (Vacik *et al.* 2011). In total, there were 491 fires in the dataset. Most of them occurred in the period of March to September. Carinthia experiences a high number of lightning strikes, and as a result nearly a quarter of the fires are lightning-induced (Vacik *et al.* 2011).

VALENCIA

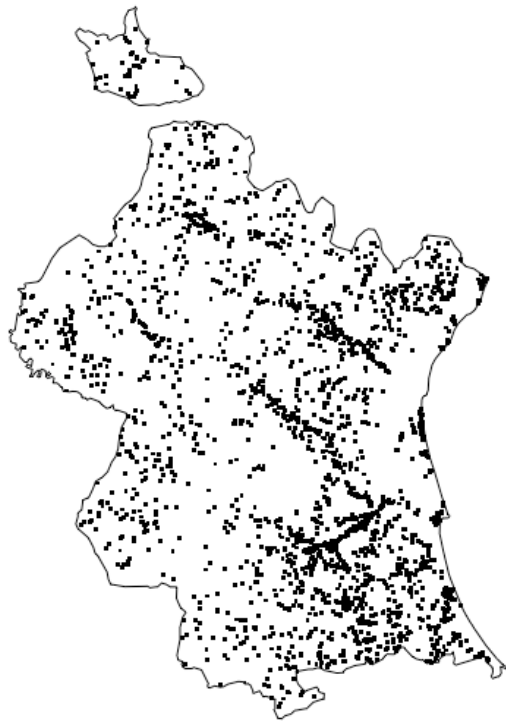


Fig. S3: Fire locations in Valencia, Spain.

The region of Valencia locates in eastern Spain along the Mediterranean coast. Area has Mediterranean-type climate with hot and dry summers and mild winters. Vegetation is mainly dominated by evergreen shrublands (*Quercus coccifera*) and pine woodlands (*Pinus halepensis*).

Fire data were gathered by the Regional Government of Valencia for the period 2001-2014. The fire regime of the region is strongly influenced by land-use changes), but for the period considered here, climate (drought) is also very relevant (Pausas 2004, Pausas & Fernández-Muñoz 2012). Ignitions are largely anthropogenic. In total, there were 2 688 fires in the region, most of them occurred during summer (June to August).

SOUTHWESTERN TURKEY



Fig. S4: Fire locations in Southwestern Turkey.

The study region covers 32 831 km² along the southwestern coast of Turkey. The climate is typical Mediterranean with hot and dry summers and rainy and mild winters. The vegetation of the low elevation levels of the study region is dominated by *Pinus brutia* forests and Mediterranean shrublands. Dominant tree species of forests changes to *Pinus nigra* and *Cedrus libani* with the increasing elevation and distance to coast (Atalay et al. 2014). We obtained fire ignition data from the General Directory of Forestry of Turkey ('OGM'). Fire statistics go back to 2000, but since we needed geo-referenced data, we were only able to use data for the period 2013-2017. Total number of fires was 2 512 for this period with a peak in the summer-drought period (June to September). The region has an intense anthropogenic pressure, especially in low elevations, but the climate is still the main driver of the fire activity in the area (Bekar, 2016).

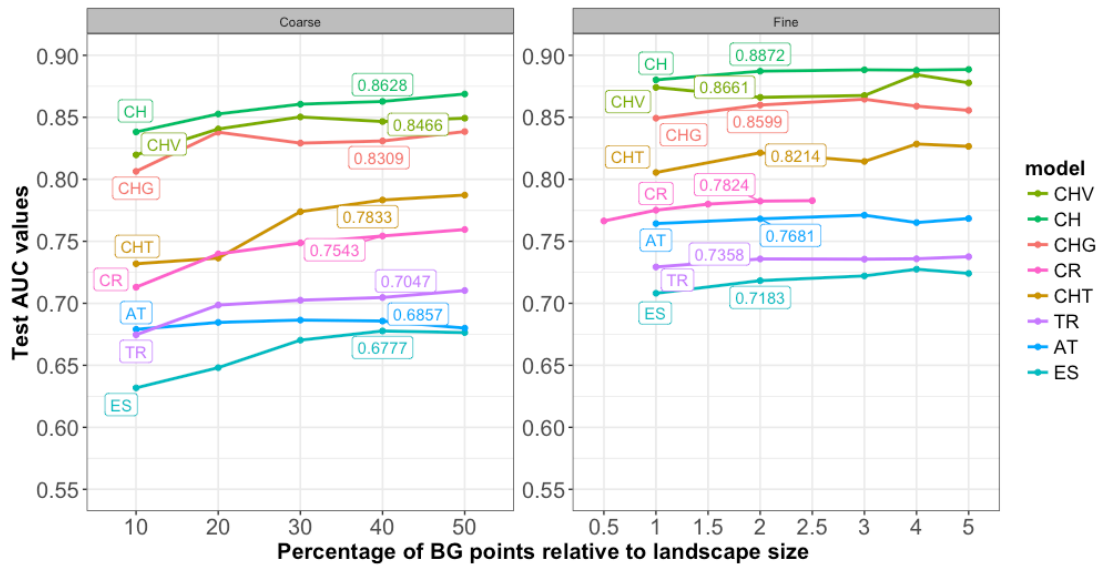


Fig. S5: Effect of the number of background (BG) points used in Maxent on model performance (AUC). CR = cross-regional; AT = Austria; ES = Spain; TR = Turkey; CH = Switzerland, CHV = Valais, CHG = Graubünden, CHT= Ticino.

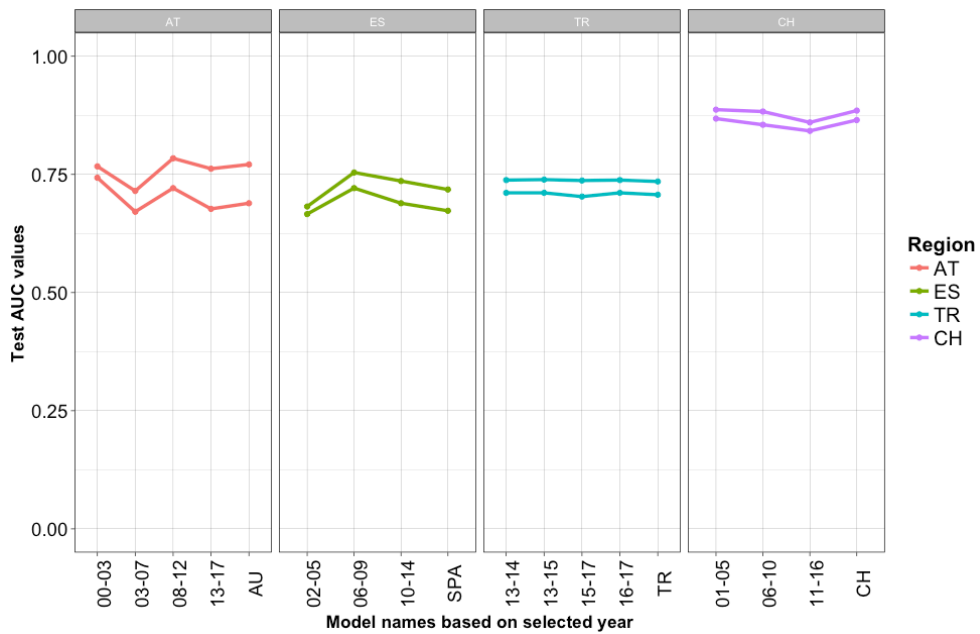


Fig. S6: The effect of using different periods of the predictor variables on model performance. CR = cross-regional; AT = Austria; ES = Spain; TR = Turkey; CH = Switzerland.

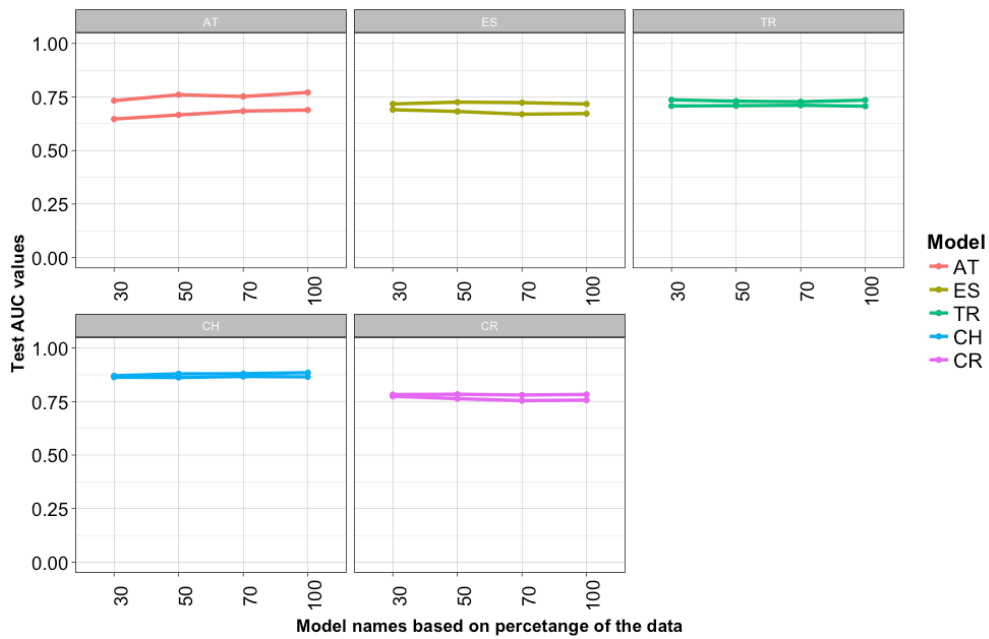


Fig. S7: The effect of sample size on model performance. CR = cross-regional; AT = Austria; ES = Spain; TR = Turkey; CH = Switzerland.

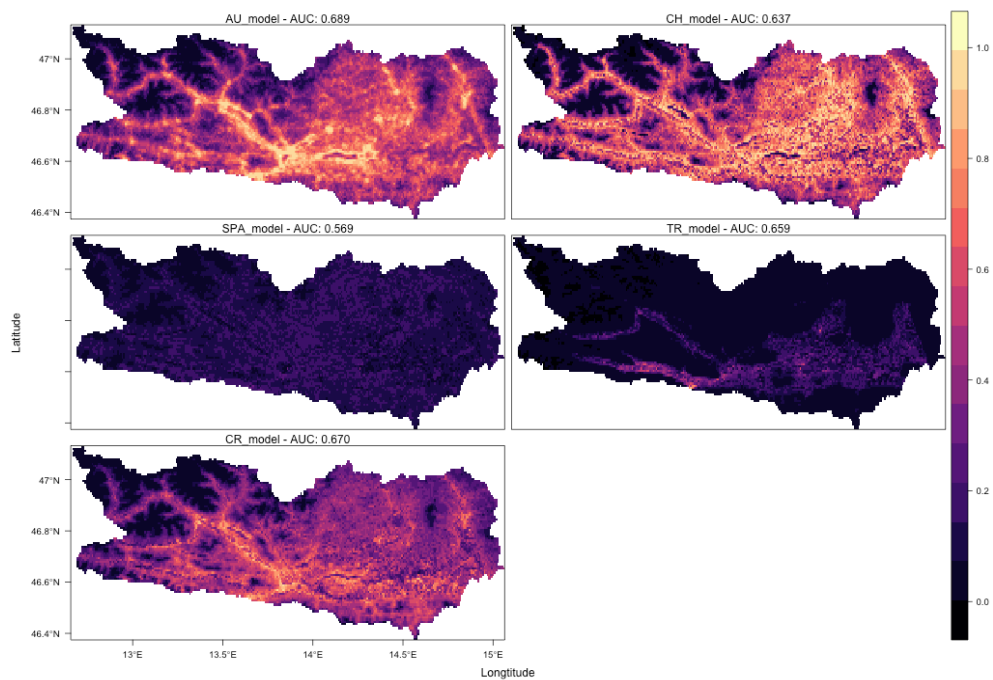


Fig. S8: Predicted fire occurrence maps for Carinthia (Austria) using the coarse resolution models of the other regions.

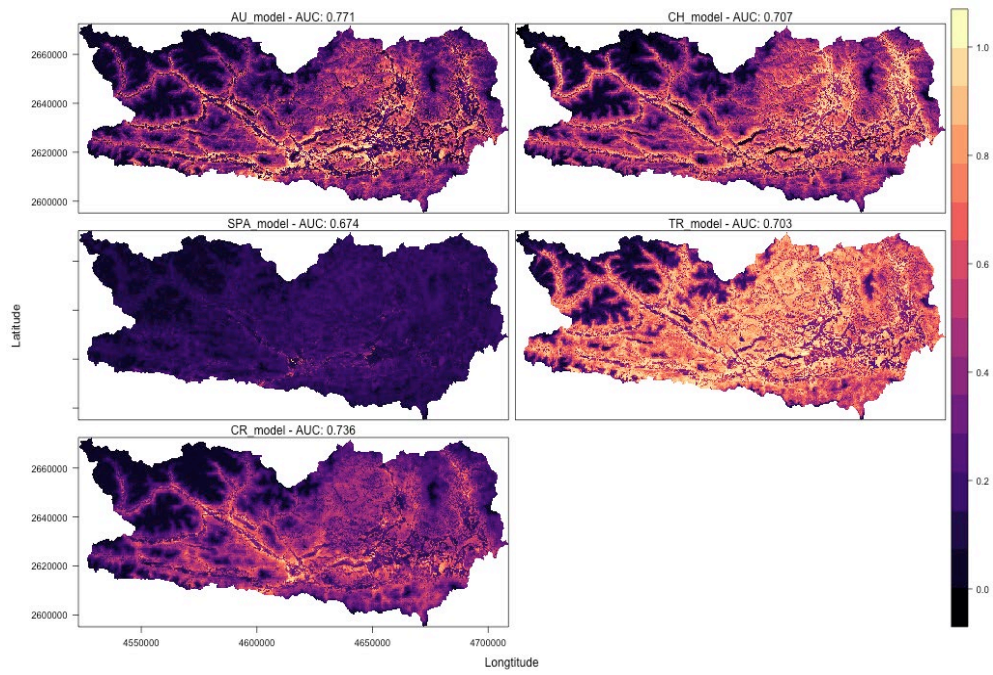


Fig. S9: Predicted fire occurrence maps for Carinthia (Austria) using the fine resolution models of the other regions.

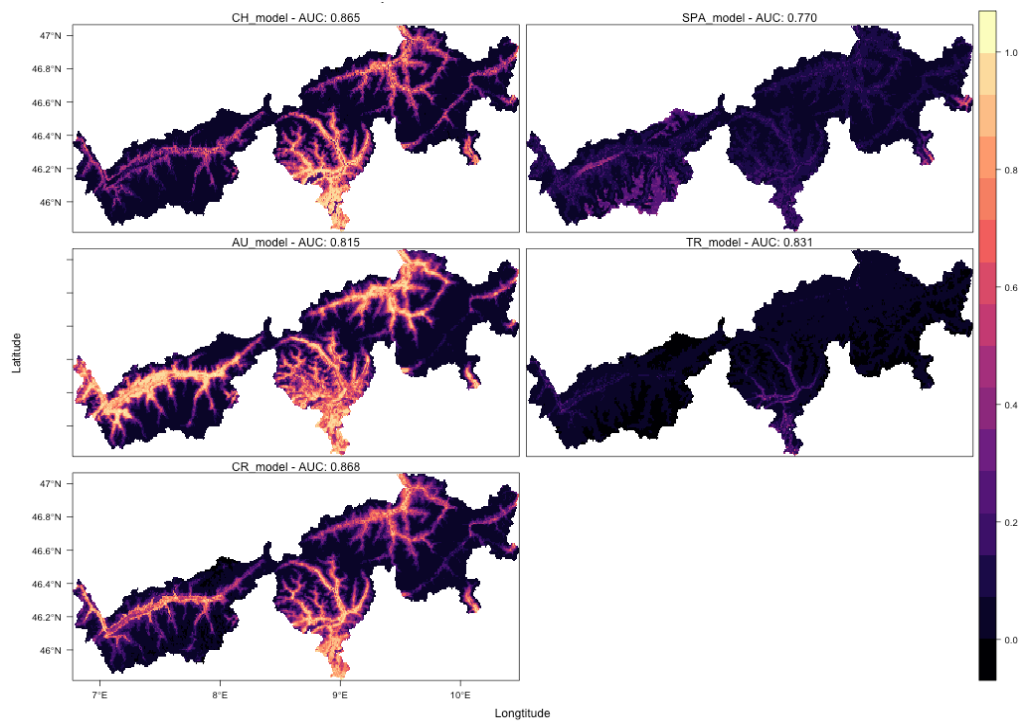


Fig. S10: Predicted fire occurrence maps for Southern Switzerland using the coarse resolution models of the other regions.

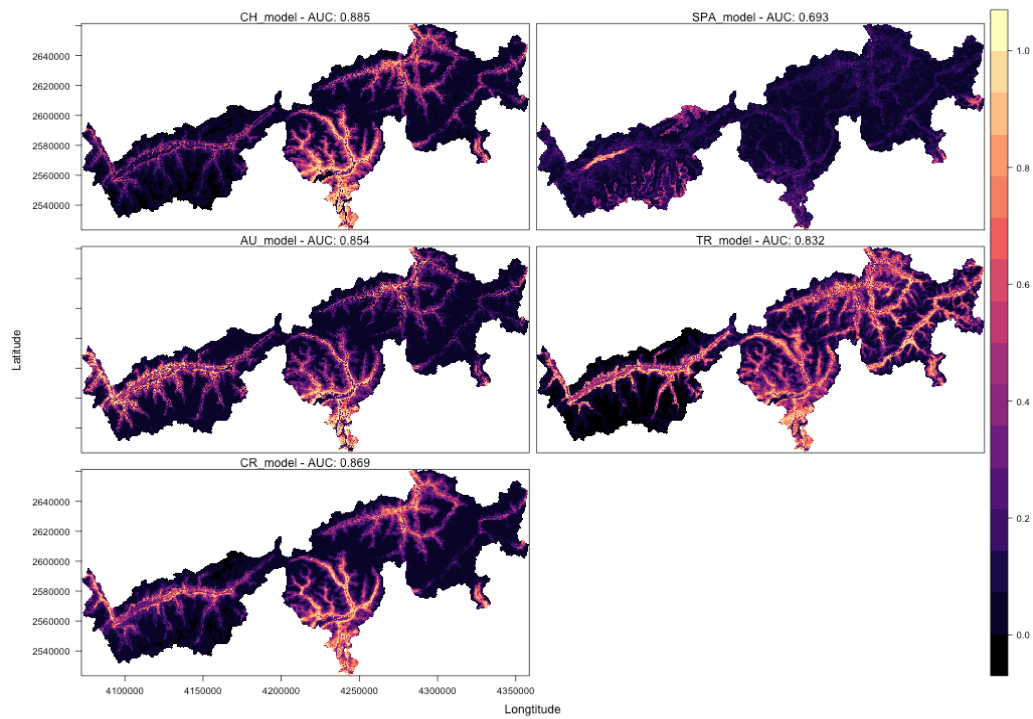


Fig. S11: Predicted fire occurrence maps for Southern Switzerland using the fine resolution models of the other regions.

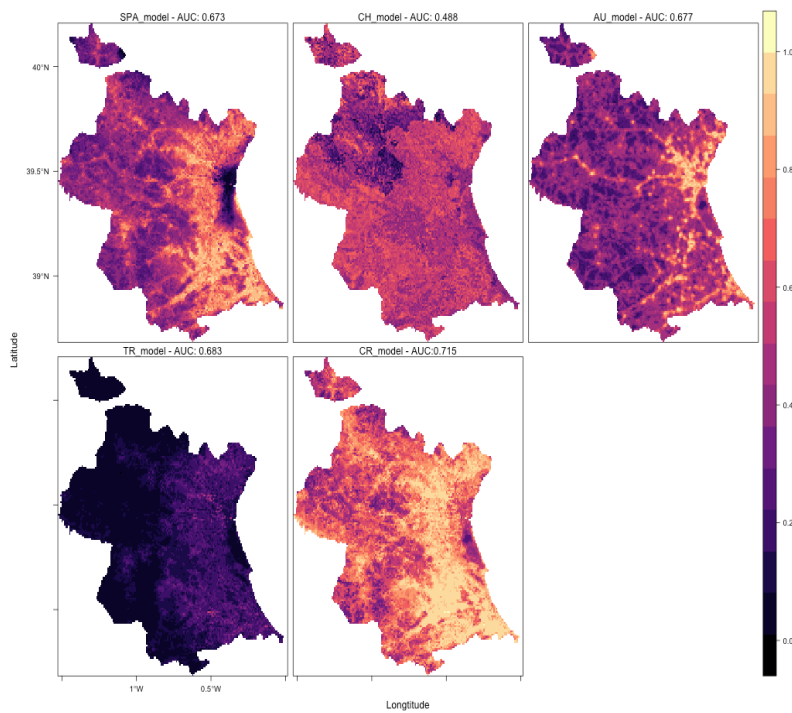


Fig. S12: Predicted fire occurrence maps for Valencia (Spain) using the coarse resolution models of the other regions.

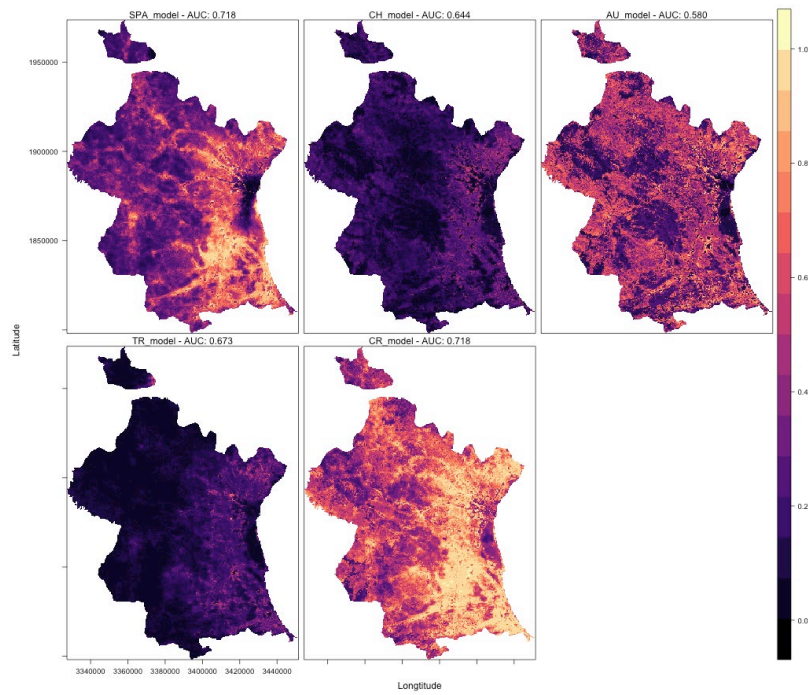


Fig. S13: Predicted fire occurrence maps for Valencia (Spain) using the fine resolution models of the other regions.

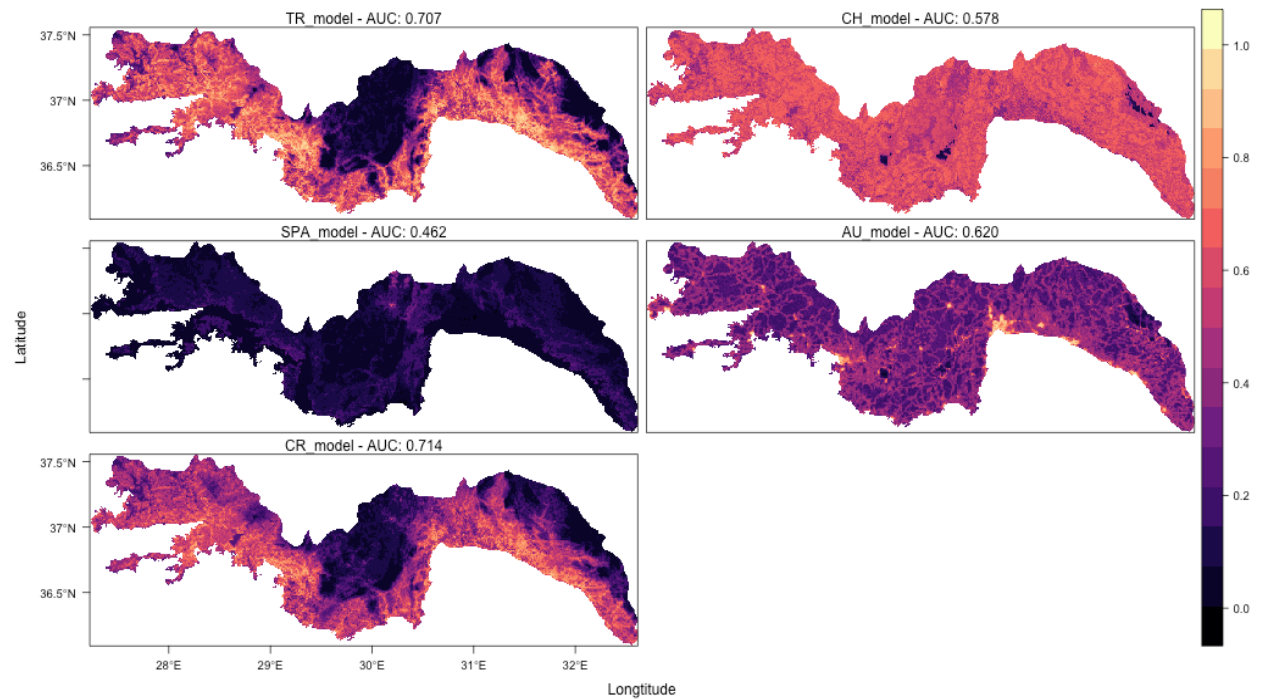


Fig. S14: Predicted fire occurrence maps for Southwestern Turkey using the coarse resolution models of the other regions.

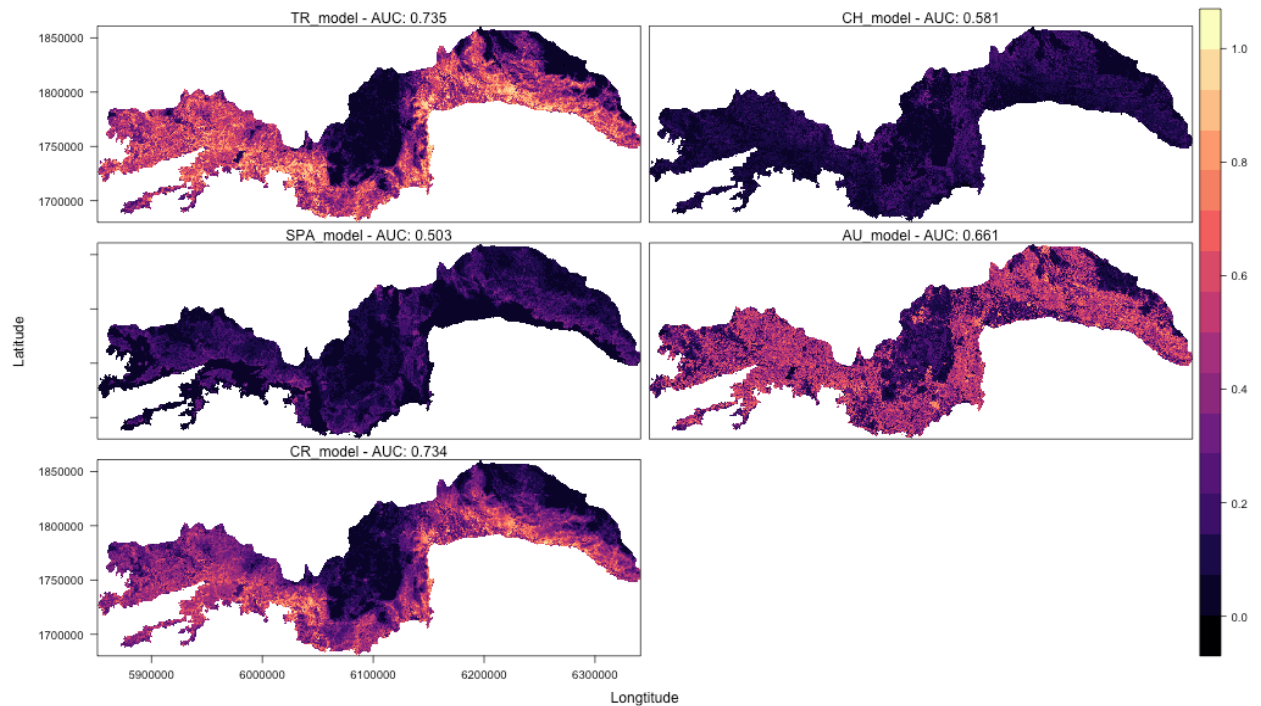


Fig. S15: Predicted fire occurrence maps for Southwestern Turkey using the fine resolution models of the other regions.

References

- <other>**Atalay İ (2014)** Ecoregions of Turkey, General Directorate of Forestry [In Turkish]</other>
- <bok>**Bekar İ (2016)** Akdeniz ekosistemlerinde günümüz yangın rejimlerinin şekillenmesinde doğal ve antropojen faktörlerin rolü. Translated title: The role of anthropogenic and natural factors in shaping recent fire regimes in Mediterranean ecosystems. M.Sc. Thesis, Hacettepe University, Ankara, Turkey. [In Turkish] Available at <http://www.openaccess.hacettepe.edu.tr/8080/servlet/handle/11655/4914> [Verified March 2020]</bok>
- <jrn>**De Angelis A, Ricotta C, Conedera M, Pezzatti GB (2015)** Modelling the meteorological forest fire niche in heterogeneous pyrologic conditions. *PLoS One* **10**, e0116875 [doi:10.1371/journal.pone.0116875](https://doi.org/10.1371/journal.pone.0116875).</jrn>
- <eref>**Grima N (2011)** Forest fire hazard mapping in Carinthia (Southern Austria). M.Sc. Thesis, University of Natural Resources and Applied Life Sciences (BOKU), Vienna. Available at <http://bit.ly/2EwTET6> [Verified March 2020]</eref>
- <jrn>**Pausas JG (2004)** Changes in fire and climate in the eastern Iberian Peninsula (Mediterranean Basin). *Climatic Change* **63**, 337–350 [doi:10.1023/B:CLIM.000018508.94901.9c](https://doi.org/10.1023/B:CLIM.000018508.94901.9c).</jrn>

<jrn>Pausas JG, Fernández-Muñoz S (2012) Fire regime changes in the western Mediterranean Basin: from fuel-limited to drought-driven fire regime. *Climatic Change* **110**, 215–226 [doi:10.1007/s10584-011-0060-4](https://doi.org/10.1007/s10584-011-0060-4).</jrn>

<jrn>Pezzatti GB, Reinhard M, Conedera M (2010) Swissfire: die neue schweizerische Waldbranddatenbank | Swissfire: the new Swiss forest fire database. *Schweizerische Zeitschrift für Forstwesen* **161**, 465–469. [doi:10.3188/szf.2010.0465](https://doi.org/10.3188/szf.2010.0465) [In German]</jrn>

<jrn>Vacik H, Arndt N, Arpacı A, Koch V, Müller M, Gossow H (2011) Characterisation of forest fires in Austria. *Austrian Journal of Forest Science* **128**, 1–32.</jrn>

<jrn>Zumbrunnen T, Menéndez P, Bugmann H, Conedera M, Gimmi U, Bürgi M (2012) Human impacts on fire occurrence: a case study of hundred years of forest fires in a dry alpine valley in Switzerland. *Regional Environmental Change* **12**, 935–949 [doi:10.1007/s10113-012-0307-4](https://doi.org/10.1007/s10113-012-0307-4).</jrn>