original scientific article
received: 2017-11-20

DOI 10.19233/ASHN.2017.12

POTENTIAL DISTRIBUTION OF SILVER FIR (*ABIES ALBA*) IN SOUTH-EASTERN ALPINE AND DINARIC PHYTOGEOGRAPHIC REGIONS OF SLOVENIA AND CROATIA IN THE LIGHT OF CLIMATE CHANGE

Aljaž KOŽUH
Pševo 9, Pševo, 4000 Kranj
e-mail: aljazeko@gmail.com

Mitja KALIGARIČ
Department of Biology, Faculty of Natural Sciences and Mathematics and Faculty of Agriculture and Life Sciences, University of Maribor, Koroška 160, Maribor, Slovenia
e-mail: mitja.kaligaric@um.si

Danijel IVAJNŠIČ
Department of Biology, Faculty of Natural Sciences and Mathematics, University of Maribor, Koroška 160, Maribor, Slovenia
e-mail: dani.ivajnsic@um.si

ABSTRACT

*We studied the potential distribution of silver fir (*Abies alba *Miller) in the Alpine and Dinaric phytogeographic regions of Slovenia and Croatia in the light of climate change. A decline of silver fir in southern Europe due to summer droughts and heat has already been observed, along with the spread of its range towards the north-east in continental Europe due to a warmer climate with milder winters. In this study, we modelled habitat suitability for the silver fir in regard to the most probable climate change scenarios. No major changes in habitat suitability were found in either region. Habitat suitability should slightly increase in the central and western parts of the Alpine region in more optimistic scenarios and on Pohorje and in the Dinaric region in more pessimistic scenarios. A more distinctive change of habitat suitability would probably be suppressed by weather extremes, such as summer drought and heat, a cold winter period, and extreme weather phenomena.*

Key words: global warming, ecological modelling, habitat suitability, RCP, silver fir, species range change

DISTRIBUZIONE POTENZIALE DELL'ABETE BIANCO (*ABIES ALBA*) NELLE REGIONI FITOGEOGRAFICHE ALPINA SUD-ORIENTALE E DINARICA IN SLOVENIA E CROAZIA IN RELAZIONE AI CAMBIAMENTI CLIMATICI

SINTESI

*Gli autori hanno studiato la distribuzione potenziale dell'abete bianco (*Abies alba *Miller) nelle regioni fitogeografiche alpina e dinarica della Slovenia e della Croazia in relazione ai cambiamenti climatici. Una diminuzione dell'abete bianco nell'Europa meridionale, dovuta alla siccità e al caldo estivi, era già stata osservata, insieme all'espansione del suo areale verso nord-est nell'Europa continentale. In questo studio gli autori hanno modellato l'idoneità dell'habitat per l'abete bianco in relazione agli scenari più probabili di cambiamento climatico. Non è risultato alcun cambiamento importante nell'idoneità dell'habitat in nessuna delle due regioni. Secondo scenari più ottimistici, l'adeguatezza dell'habitat dovrebbe aumentare leggermente nelle parti centrale e occidentale della regione alpina, mentre secondo scenari più pessimistici dovrebbe ingrandirsi sul Pohorje e nella regione dinarica. Un cambiamento più distintivo dell'idoneità dell'habitat verrebbe probabilmente soppresso da condizioni meteorologiche estreme, quali la siccità estiva e il caldo, un freddo periodo invernale e fenomeni meteorologici estremi.*

Parole chiave: riscaldamento globale, modellistica ecologica, idoneità dell'habitat, RCP, abete bianco, cambiamenti dell'areale della specie

INTRODUCTION

Recently, the spatial distributions of many plant species, among them trees, including the silver fir (*Abies alba*), have been noted to be much different from their natural distributions owing to several anthropogenic factors and influences. With this research we aimed to reveal the potential distribution of silver fir without anthropogenic influences in the Alpine and Dinaric phytogeographic regions of Slovenia and Croatia. Furthermore, we also aimed to determine differences between the two areas. Primarily, we tested the present natural habitat suitability for the silver fir of those two study areas by considering environmental variables and ecological modelling techniques. Finally, we examined future potential spatial distributions of the silver fir based on the four most likely future climate scenarios grounded on four representative concentration pathways (RCP) of greenhouse gases.

The silver fir (*Abies alba*) grows up to 50 m high and 2.5 m thick, an evergreen tree with coniform to oviform crown, flat branches, flat needles with white lines and upright cones. It blossoms from April to June (Brus & Robič, 2002). Its main growth period is around 50 to 60 days from May to July (Aussenac, 2002). The silver fir is mainly a European tree species (Brus & Robič, 2002). Its natural habitat is located mostly in the mountain regions of eastern, western, southern and central Europe (Anić *et al*., 2009). It grows in the Alps, Vosges and Jura, on the Balkan Peninsula and in the Carpathians. There are also some isolated ranges on the Apennine Peninsula, Corsica, in the Massif Central and Pyrenees (Brus & Robič, 2002). Its range spreads between 40° and 52° in latitude (between Poland and northern Greece) and between 5° and 27° in longitude (between the western Alps and the Carpathians) (Anić *et al*., 2009). In the Alpine and Dinaric regions it prospers between 400 and 1200 meters above sea level (Brus & Robič, 2002) in humid habitats with more than 1000 mm annual rainfall, and in the Mediterranean with average annual temperatures between 7 and 13 °C (Aussenac, 2002). It prefers fresh, deep and nutrient rich soils and is not sensitive to geological bedrock: it grows on carbonate or non-carbonate substrates (Brus & Robič, 2002) despite water accessibility being lower on carbonate (Ficko *et al*., 2011). The silver fir grows at late succession phases, mostly in a community with the common beech (*Fagus sylvatica*) and the spruce (*Picea abies*) (Brus & Robič, 2002). However, it is a rather weak competitor and as such prospers only in a narrow gradient of environmental conditions. In most of the favourable areas for the silver fir, the beech is more successful in less and spruce in more extreme conditions (Ellenberg, 1988). Nevertheless, the silver fir is more competitive in shady forests with slower growth during the spring compared to the beech (Diaci *et al*., 2010). It does not tolerate extreme winter cold and summer drought and heath (Gazol *et al*., 2015; Koprowski, 2013). In the Mediterranean, its growth is limited mostly by low precipitation and water accessibility in spring and summer, while in central Europe its growth is limited due to low temperatures in late winter and early spring (Gazol *et al*., 2015). Forest managers gave preference to coniferous rather than to deciduous trees (Ellenberg, 1988; Ficko *et al*., 2011). The silver fir is more common and widespread in the Dinaric region than in the Alpine (Slovenian Forest Service, 2010). Young specimens of fir are frequently consumed and damaged by deer (Brus & Robič, 2002). It is therefore no surprise that the silver fir population size is negatively correlated with deer population size (Diaci *et al*., 2010).

The global increase of greenhouse gas concentration and mean temperature is currently well documented (Ogrin, 2004). The CO_2 concentration has risen from 280 to over 400 ppm since 1750 (Anić *et al*., 2009). Without anthropogenic emissions, it only rose by 20 ppm between the years 8000 and 2000 B.C. (Anić *et al*., 2009). In the study area, the increase of average annual temperature and decrease of annual rainfall was recorded during the 20th century (Ogrin, 2004; ARSO, 2016). Similar trends are expected in the 21st century. Average annual temperature increased by 1 to 1.5 °C over the 20th century (Ogrin, 2004; Gazol *et al.,* 2015) and it should increase additionally by 1.5 to 6 °C according to different scenarios during the 21st century (Ogrin, 2004). The variability in precipitation patterns are even higher (Ogrin, 2004). During the summer, the precipitation amount is expected to decrease by 20% followed then by a 30% increase during the winter (Kutner & Kobler, 2011). However, on the annual scale, a 10% decrease of precipitation is expected (Anić *et al*., 2009). It should be emphasized that extreme weather events (heat and cold waves, droughts, fires, irregular precipitation, etc.) are more and more frequent and intensive (Kutner & Kobler, 2011; ARSO, 2016) and significantly affect the silver fir populations.

The silver fir population in the Mediterranean is expected to decrease due to more intensive summer droughts, heat waves and fires (Gazol *et al*., 2015). The beech-fir forests in the Dinaric region are expected to be gradually replaced by thermophile forests (Kutner & Kobler, 2011). In central Europe, the silver fir range extension towards the northeast is expected because of less extreme cold conditions in late winter and early spring, as well as its present range stability despite the possible competition with thermophile tree species (Ruosch *et al*., 2016).

We presumed that altitude, annual mean air temperature and precipitation variables represent the most important natural determinants of the silver fir´s spatial distribution. Climate change should affect silver fir populations and its distribution in the study area especially in the lowlands. On the other hand, it is not expected that silver fir will spread to altitudes higher than its up-per limit, because winter cold is still too severe in the high mountains (ARSO, 2016; Ogrin, 2004). From that perspective, we focused on three hypotheses: 1. there are more potentially suitable silver fir habitats in the Dinaric than in the Alpine region; 2. its range will move towards higher altitudes and will be narrower along this gradient; 3. Potential silver fir range will decrease especially in the Dinaric region because it also occupies mountain peaks.

MATERIALS AND METHODS

Study area

The Alpine phytogeographic region of Slovenia and the Dinaric phytogeographic region of Slovenia and Croatia were chosen as the study area (Fig. 1). The Alpine region of Slovenia contains Alpine geographic region of Slovenia with Julian Alps, Kamnik-Savinja Alps and the Karawanks (they also contain several mountain plateaus – Pokljuka, Jelovica, Menina, Velika Planina and Dobrovlje), which are a part of the Southern Limestone Alps; and Pohorje and Kozjak as part of the Central Alps. The Dinaric region of Slovenia contains mostly the Dinaric geographic region of Slovenia with poljes and Dinaric plateaus (Senegačnik, 2012). The north-western border are the plateaus of Banjšice and Trnovski gozd. At the border with Croatia it stretches from Snežnik at the west across Kočevski Rog to the mountain edge of Bela Krajina at the east. In Croatia we marked off the Dinaric region from the Slovenian border with Gorski Kotar at the north across the Velebit and its continental hinterland with poljes to the southern edge of Velebit at the south.

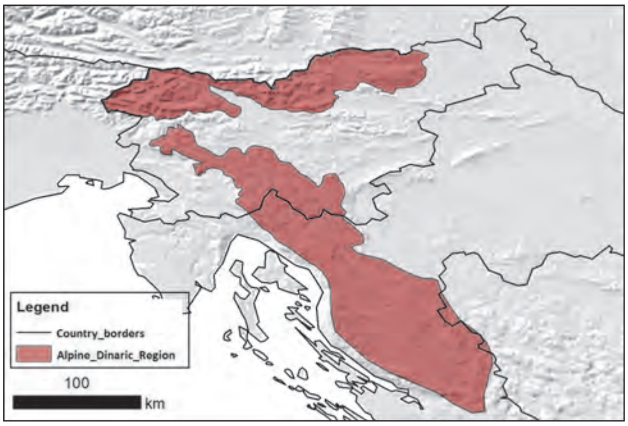

Fig. 1: The chosen study area.
Sl. 1: Izbrano območje raziskave.

Tab. 1: Bioclimatic variables from the Worldclim database.
Tab. 1: Bioklimatske spremenljivke podatkovne baze Worldclim.

Symbol	Description
BIO1	Annual mean temperature
BIO2	Mean Diurnal Range (mean of monthly (max temp – min temp))
BIO3	Isothermality (BIO2/BIO7) (*100)
BIO4	Temperature Seasonality (standard deviation *100)
BIO5	Max Temperature of Warmest Month
BIO6	Min Temperature of Coldest Month
BIO7	Temperature Annual Range (BIO5-BIO6)
BIO8	Mean Temperature of Wettest Quarter
BIO9	Mean Temperature of Driest Quarter
BIO10	Mean Temperature of Warmest Quarter
BIO11	Mean Temperature of Coldest Quarter
BIO12	Annual Precipitation
BIO13	Precipitation of Wettest Month
BIO14	Precipitation of Driest Month
BIO15	Precipitation Seasonality (Coefficient of Variation)
BIO16	Precipitation of Wettest Quarter
BIO17	Precipitation of Driest Quarter
BIO18	Precipitation of Warmest Quarter
BIO19	Precipitation of Coldest Quarter

Alpine valleys stretch between 500 and 1000 m a.s.l., relief plateaus from 1000 to 1600 m a.s.l.; whereas the tree line extends up to 1900 m a.s.l., with the highest peaks reaching up to 1000 m above it. In the Dinaric region, poljes are distributed between 400 and 800 m a.s.l., plateaus between 800 and 1500 m a.s.l., and the highest peaks up to 1800 m a.s.l., thus stretching just above the tree line (Požar & Novak, 2005; Senegačnik, 2012). The average annual temperature of alpine plateaus is 2 to 6 °C, whereas on the Dinaric plateaus average temperatures are significantly higher and range from 4 to 7 °C. Annual rainfall on both considered regions reaches 1500 to 3000 mm (Zaninović *et al.*, 2008; ARSO, 2016).

Collection of spatial data

Initially, silver fir spatial distribution data for the two phytogeographical regions in Slovenia and Croatia were gathered from the Slovenia Forest Service (Slovenia Forest Service, 2010; url: http://www.zgs.si/slo/gozdovi_slovenije/o_gozdovih_slovenije/karte/index.html) and the Flora Croatica database (Nikolić, 2015), which was established by the Faculty of Science in Zagreb (Url: https://hirc.botanic.hr/fcd/). Thereafter,

Tab. 2: The considered future climate scenarios (RCP2.6, RCP4.5, RCP6.0, RCP8.5) according to CCSM global climate model.
Tab. 2: Upoštevani podnebni scenariji (RCP2.6, RCP4.5, RCP6.0, RCP8.5) po globalnem podnebnem modelu CCSM.

Scenario	Solar radiation change (W/m²)	Increase of global annual temperature by year 2100 (°C) (variability)
RCP2.6	2.6	1.0 (0.3 to 1.7)
RCP4.5	4.5	1.8 (1.1 to 2.6)
RCP6.0	6.0	2.2 (1.4 to 3.1)
RCP8.5	8.5	3.7 (2.6 to 4.8)

bioclimatic (Worldclim 1.4; Hijmans *et al.*, 2005) and elevation data were considered as major contributions to potential future distribution of the silver fir under the selected climate change model (CCSM4) and four representative concentration pathways greenhouse gas scenarios (RCP2.6, RCP4.5, RCP6.0, RCP8.5 [Tab. 2]) until the end of the century (2070) (Tab. 1). The horizontal resolution of these geospatial datasets corresponds to 30 arc seconds (approximately 1 km² in mid latitudes).

The considered greenhouse gas (GHG) scenarios are named after possible changes of radiative forcing in the year 2100 relative to the preindustrial age (Meinshausen *et al.*, 2011). Scenario RCP2.6 anticipates a recent peak of emissions of GHG (between years 2010 and 2020); scenario RCP4.5 anticipates the GHG peak around 2040; scenario RCP6.0 around 2080; and finally, scenario RCP8.5 a continuous increase of GHG emissions until the end of the 21st century (Weyant *et al.*, 2009). Consequently, a global annual temperature increase is inevitable (Stocker et al., 2013) (Tab. 2).

Spatial data processing and ecological modelling

The acquired spatial databases of silver fir distribution in the study area were unified (by leaning on the WGS84 coordinate system) and spatially filtered with ArcGIS software (ESRI, 2016). Selected environmental variables (bioclimatic and altitude) were extracted by using a background bias file (Barbet-Massin *et al.*, 2014). Additionally, all 19 bioclimatic variables were PCA transformed in order to avoid possible correlation of explanatory variables. The resulting first three components (BioPCA), explaining 87.5% of variability, together with altitude were considered using the habitat suitability modelling procedure.

In that light, the Mahalonobis Typicality species distribution modelling (SDM) approach within Idrisi Selva software (Clark Labs, 2015) was selected. This method is less sensitive to spatially auto-correlated occurrence data and is frequently being used to model plant distribution from the climate change perspective (Clark Labs, 2015). After completing the present scenario, the accuracy and reliability of the produced habitat suitability map was verified with ROC analysis and the resulting AUC value. The final processing of future environmental conditions, captured in future BioPCA components, gave us five habitat maps (present, and four future, RCP scenarios) for the silver fir in the study area. However, the continuous maps were simplified for easier interpretation into four suitability maps by applying the following thresholds: 1 = 0 – 25%, 2 = 25 – 50%, 3 = 50 – 75% and 4 = 75 – 100%. Finally, a comparative table summarizing the proportions of each suitability class within both phytogeographic regions was produced (Tab. 3)

RESULTS

The ROC analysis results and the corresponding AUC value for the silver fir suitability in the study area by applying the Mahalonobis typicality model are shown

Table 3: The proportion of potential habitat area for the silver fir in each phytogeographic region by considering four suitability thresholds and climate scenarios.
Tabela 3: Delež potencialnega habitata jelke po upoštevanih razredih ustreznosti in podnebnih napovedih na obravnavanih fitogeografskih območjih.

Model	Alpine phytogeographic region				Dinaric phytogeographic region				Both regions together			
	Habitat suitability (%)				Habitat suitability (%)				Habitat suitability (%)			
	0-25	25-50	50-75	75-100	0-25	25-50	50-75	75-100	0-25	25-50	50-75	75-100
Present	40	26	22	11	53	24	13	10	49	25	16	10
RCP2.6	40	23	24	13	54	25	15	7	50	24	18	9
RCP4.5	41	27	17	14	49	24	19	7	47	25	19	9
RCP6.0	39	26	21	14	40	27	26	8	39	27	24	9
RCP8.5	36	25	26	13	71	6	12	11	60	12	16	12

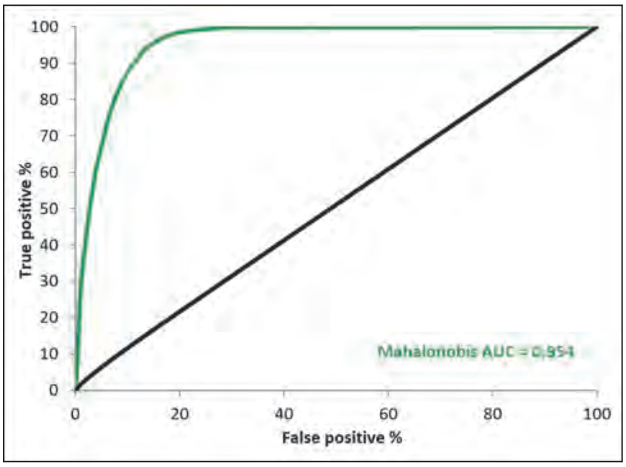

Fig. 2: ROC analysis curve and the corresponding AUC value.
Sl. 2: Krivulja ROC analize in pripadajoča AUC vrednost.

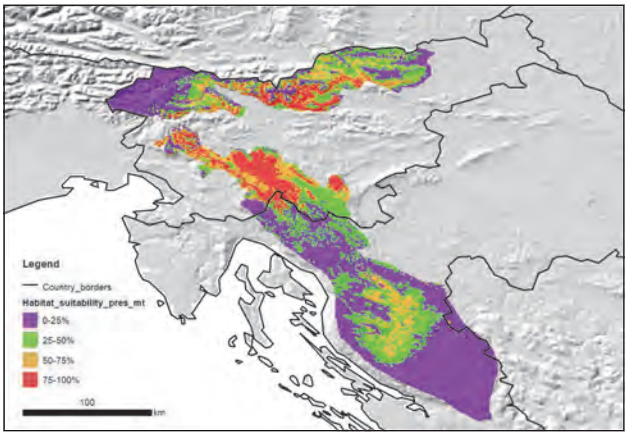

Fig. 3: Recent habitat suitability for the silver fir** (Abies alba) **in the chosen Alpine and Dinaric phytogeographic regions.
Sl 3: Aktualna primernost jelke** (Abies alba) **v izbrani alpski in dinarski fitogeografski regiji.

in Fig. 2. The curve for the model is steep and flattens quickly (Fig. 2), the AUC value is close to 1 (0.954) thus indicating a satisfactory level of agreement between occurrence data and predicted suitability.

Figure 3 shows the present silver fir´s (*Abies alba*) habitat suitability in the chosen Alpine and Dinaric phytogeographic regions, and figure 4 its future (year 2070) potential suitability according to considered GHG scenarios (RCP 2.6, 4.5, 6.0, 8.5) and the CCSM4 global climate model.

The present habitat suitability is the highest in Dinaric plateaus of Slovenia and Alpine plateaus and the middle mountain zone (Kamnik-Savinja Alps and the surrounding plateaus) (Fig. 3). Low suitability is detected in the western Julian Alps and in the Dinaric region of Croatia (Fig. 3). Quite distinctive contrasts are evident on both sides of the border (Fig. 3). The lowest suitability can be identified in the high mountains. The alpine valleys, the peak of Pohorje and several surrounding poljes exhibit low suitability as well (Fig. 3).

All future scenarios show common spatial features of the silver fir's potential habitat but differ in a few details (Fig. 4). They all show lower habitat suitability in the western Julian Alps and the southern part of the Dinaric region in Croatia (Fig. 4). The first scenario RCP2.6 is similar to the present one. The difference is noticeable in a somewhat lower habitat suitability on the Dinaric plateaus of Slovenia and higher on western Alpine plateaus of Slovenia (Pokljuka, Jelovica). The RCP4.5 scenario is the most similar to the present one. The only difference is a bit higher habitat suitability in the central Karawanks and a bit lower in the Trnovski gozd area. In comparison with RCP2.6 there is a bit higher silver fir habitat suitability on the Dinaric plateaus of Slovenia and a bit lower on Pokljuka and Jelovica (Fig. 4). The RCP6.0 scenario is similar to the present one and to RCP4.5. There is a bit lower suitability in the central part of the Dinaric region of Slovenia, whereas in Trnovski gozd it is similar to the present one. A noticeable difference of silver fir habitat suitability is in the eastern part of the Alpine region of Slovenia (eastern Karawanks, Pohorje) compared to other scenarios. There is a bit higher habitat suitability in the central part of the Dinaric region in Croatia as well (Fig. 4). The RCP8.5 scenario predicts the best conditions by the end of the century for the considered species mostly in Slovenia except in the western part of the Alpine region (Pokljuka, Jelovica, central Karawanks, western Kamnik-Savinja Alps) resulting in the highest habitat suitability. On the other hand, it is simultaneously the worst scenario for the Dinaric region of Croatia where there is very low habitat suitability almost throughout the whole region. This scenario assumes the highest contrast on both sides of the border (Fig. 4). Future scenarios also show a little tendency of potential habitat optimum shift from west to east in the Alpine region of Slovenia from less (RCP2.6) to the warmest scenario (RCP8.5) (Fig. 4).

The proportions of potential silver fir habitat area for each of the applied thresholds and considered regions separately and together are shown in Tab. 3. In the Alpine region, the proportions of the suitable area are similar considering all thresholds and RCP scenarios. However, in the 4th quartile of the potential habitat suitability a clear positive trend towards warmer climate conditions can be identified. In the Dinaric Region the largest potential habitat in the fourth class is predicted in the case of scenario RCP8.5. If climate scenarios RCP2.6, 4.5 or 6.0 are realized, the Dinaric region could be

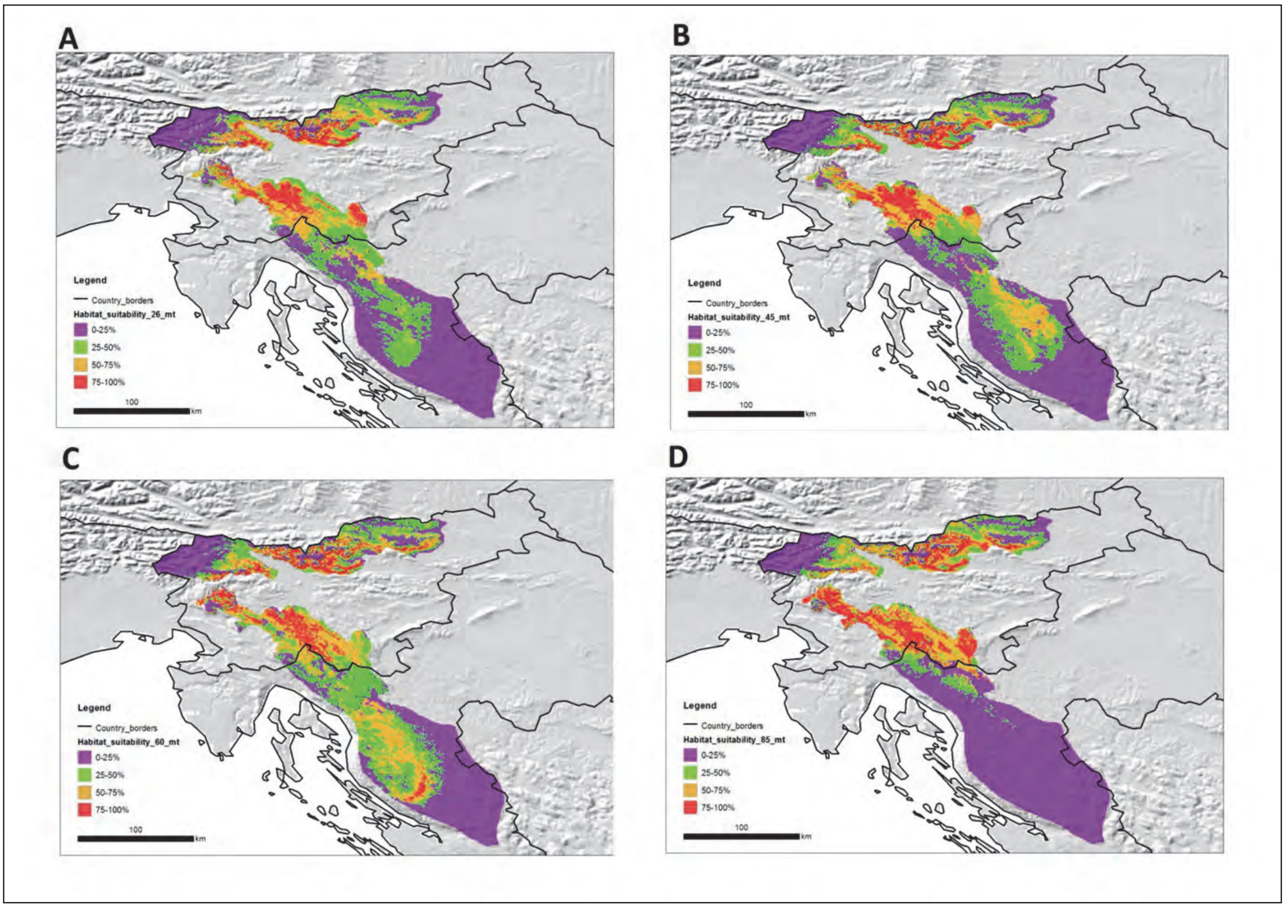

Fig. 4: Potential habitat suitability for silver fir** (Abies alba) **for the year 2070 by four future climate scenarios (RCP2.6 [A], RCP4.5 [B], RCP6.0 [C], and RCP8.5 [D]) in the chosen Alpine and Dinaric phytogeographic regions.
Sl. 4: Primernost habitata jelke** (Abies alba) **leta 2070 po štirih prihodnjih klimatskih scenarijih (RCP2.6 [A], RCP4.5 [B], RCP6.0 [C], and RCP8.5 [D]) v izbrani alpski in dinarski fitogeografski regiji.

occupied with less silver fir. Overall, high variability in silver fir potential habitat in the study area is assured in both - more optimistic and more pessimistic - thresholds considered.

DISCUSSION

The influence of climate change on silver fir populations across Europe was already studied by Gazol *et al.* (2015). They outlined that in southwestern Europe, silver fir populations could decrease owing to increased aridity, but increase in the Continental temperate zone of central Europe due to climate warming. Ruosch *et al.* (2016) draw similar conclusions, predicting that silver fir range should decrease in southern Europe and spread northeast toward central Europe in future. They also predict that the present range should remain stable despite possible competition with thermophilous tree species. Kutner & Kobler (2011) tried to predict the change of forest vegetation in Slovenia by considering different climate scenarios with the use of ecological modelling. They calculated that the share of beech-fir forests will substantially decrease by the year 2100 and could be mostly replaced by thermophile forests. The coniferous forests with prevalent spruce and fir are expected to be replaced mostly by broadleaf forests. Koprowski (2013) tried to determine the response of silver fir growing outside its natural range concerning spring extreme weather phenomena in Poland. The higher March temperatures should stimulate silver fir growth especially in the western part of the study area, at the edge of continental plains with less spring frost and where colder winter periods are less pronounced. Anić *et al.* (2009) tried to reveal the influence of climate change on silver fir´s ecological niche in Croatia and proposed that the niche will gradually decrease in the 21st century because of temperature rise. Ficko *et al.* (2011) found that silver fir's range in Slovenia shifted towards cooler and more humid habitats over the last 40 years and slightly expanded.

Based on our results, none of the hypotheses can be completely proven. The first hypothesis about higher portion of suitable habitats in the Dinaric region can be at least partly proven, because the model, especially in Slovenia, shows more optimal potential habitats in the Dinaric compared to the Alpine region by applying the 4th quartile suitability threshold (75-100%) for the Mahalonobis probability distribution. Surprisingly, though the environment in Gorski Kotar is very similar to that on the Slovenian side of the border (Čavlović *et al.,* 2006; Kutnar & Kobler, 2011), the results show there much lower habitat suitability for the silver fir. However, the spatial pattern of the silver fir is heterogeneous; the tree grows in places like the Velebit and in its surroundings despite less favourable condition (Nikolić, 2015). The second hypothesis can neither be proven nor rejected because the model does not show any distinctive change in the Alpine region or the results are not distinctive enough to draw proper conclusions. In this case, a more accurate scale would be needed to adequately test this research question. The third hypothesis can be completely rejected, because the silver fir´s range will probably not decrease in the Dinaric region and could even increase, especially in the most pessimistic scenario, RCP8.5.

The results confirm the fact that silver fir is most common in the middle altitude (mountain) zone (Brus & Robič, 2002). Lower habitat suitability in the western and central Julian Alps might be the consequence of Mediterranean influence in the Soča valley (Ogrin, 2004). Thermophilic vegetation is also present there and could displace the silver fir (Kutner & Kobler, 2011), although all references do not confirm that (Ruosch *et al.*, 2016). However, climate conditions there are more variable; even though there are higher rates of precipitation and longer dry periods (ARSO, 2016). In the Dinaric region of Croatia the results show mostly low habitat suitability, but some scenarios (especially RCP6.0) still indicate better potential habitat suitability in the northern and central parts of the region. However, in the southern part all scenarios show mostly low potential habitat suitability. We could conclude that especially in Gorski Kotar, where the environment is currently similar to that on the Slovenian side of the border, potential habitat suitability is also similarly high. On the Velebit, especially its southern part and its continental hinterland, the habitats might actually be less suitable for silver fir today and still might be in the future. Maybe also the Mediterranean effect of summer droughts, heat and fires is and will be more distinctive there.

Future scenarios predict a lower share of optimal habitats in the Dinaric region in optimistic scenarios (RCP2.6 and RCP4.5) and higher in the most pessimistic (RCP8.5). In the Alpine region, all scenarios are similar; however, most of habitats of greater suitability are also shown by considering the RCP8.5 scenario. The Dinaric region could be placed in southern Europe and the Mediterranean, where the silver fir´s range should mostly decrease, especially because of hotter summers and more severe droughts (Aussenac, 2002; Kutnar & Kobler, 2011; Gazol *et al.*, 2015; Ruosch *et al.*, 2016). Such climate change consequences have already been spotted there (Anić *et al.,* 2009; Čavlović *et al.,* 2012; ARSO, 2016); but, surprisingly, our results do not confirm such a response of the silver fir. However, better potential habitat suitability for the silver fir in central Europe, where the Alpine region can be placed (Ruosch *et al.*, 2016), is confirmed but without significant change. That could be the consequence of a milder climate in the Alps, where more distinctive summer heat and droughts are not present yet (ARSO; 2016).

Finally, some restrictions and limitations regarding the research should be pointed out. We are aware that the bioclimatic variables of the *Worldclim* database are uncertain in some mountain areas, especially on geographically heterogeneous landscapes; this is why the results should be treated with some caution. Owing to more accurate data in Slovenia, the forecast of habitat suitability is probably much more representative. The exaggerated difference on both sides of the border, despite similar environmental conditions, is certainly not a representative result, but likely the consequence of unbiased spatial data or a highly variable spatial pattern of the considered species concerning the considered environmental predictors.

CONCLUSIONS

The expected climate change could not have any distinctive influence on the silver fir distribution range. In western and central parts of the Alpine region, the optimistic future climatic scenarios predict somewhat more favourable conditions for the silver fir; in contrast, in the eastern part of its current range, in the Dinaric region, the pessimistic climate scenario (RCP 8.5) results in a more potentially suitable habitat area. Such results could be the consequence of higher mean air temperatures, but their favourable effect should probably be partly suppressed by more common and intensive weather extremes. Because of some research restrictions and limitations, the results can deviate from the actual expected state in the future.

ACKNOWLEGMENTS

We thank the Croatian Botanical Society and prof. Toni Nikolić in particular, for allowing the use of spatial distribution data of silver fir in Croatia. The research for this paper was partly funded by the P1-0164 grant, provided by the Slovenian Research Agency.

POTENCIALNA RAZŠIRJENOST JELKE (*ABIES ALBA*) V JUGOVZHODNO-ALPSKEM IN DINARSKEM FITOGEOGRAFSKEM OBMOČJU SLOVENIJE IN HRVAŠKE V LUČI KLIMATSKIH SPREMEMB

Aljaž KOŽUH
Pševo 9, Pševo, 4000 Kranj
e-mail: aljazeko@gmail.com

Mitja KALIGARIČ
Department of Biology, Faculty of Natural Sciences and Mathematics and Faculty of Agriculture and Life Sciences, University of Maribor, Koroška 160, Maribor, Slovenia
e-mail: mitja.kaligaric@um.si

Danijel IVAJNŠIČ
Department of Biology, Faculty of Natural Sciences and Mathematics, University of Maribor, Koroška 160, Maribor, Slovenia
e-mail: dani.ivajnsic@um.si

POVZETEK

*Zaradi vse bolj izrazitega vpliva klimatskih sprememb na vegetacijo smo s to raziskavo želeli ugotoviti njihov vpliv na potencialno razširjenost jelke (*Abies alba *Miller) v alpski in dinarski fitogeografski regiji na območju Slovenije in Hrvaške. Že danes je opazno krčenje areala jelke na južnem območju razširjenosti zaradi vse intenzivnejših poletnih suš in vročine v Sredozemlju ter širjenje areala proti severovzhodu zaradi toplejše klime in milejših zim kontinentalne Evrope. Preverjali smo primernost habitata za jelko s pomočjo ekološkega modeliranja za sedanje stanje in štiri najbolj verjetne prihodnje scenarije. Rezultati niso pokazali večjih sprememb v primernosti habitata v obeh regijah. Primernost habitata naj bi se nekoliko povečala, v osrednjem in zahodnem delu alpske regije ob bolj optimističnih scenarijih, na Pohorju in v Dinarski regiji pa ob bolj pesimističnih scenarijih. Izrazitejše izboljšanje primernosti habitata pa bodo najbrž vseeno zavrli vse intenzivnejši vremenski ekstremi, kot so poletna suša in vročina, zimski mraz in vremenske ujme.*

Ključne besede: ekološko modeliranje, jelka, globalno segrevanje, primernost habitata, RCP, sprememba areala

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