Bilateral cooperation - Fostering the ability of native European beech and sessile oak forests in the border region against the impacts of climate change

Erik Szamosvári[‡], László Nagy[§], Heino Konrad[‡], Norbert Móricz[§], Lambert Weißenbacher[‡], Anita Bálint[|], Anikó Neuvirthné Bilics[|], Marcela van Loo[‡]

‡ Austrian Research Centre for Forests (BFW), Vienna, Austria
§ Forest Research Institute – University of Sopron (SOE ERTI), Sárvár, Hungary
| Vas County Government Office (VVÖH), Szombathely, Hungary

Corresponding author: Erik Szamosvári (erik.szamosvari@bfw.gv.at)

Abstract

Adequate adaptions and actions to combat anthropogenic climate change (CC) are significant challenges of the 21st century. In Europe, according to the European Environmental Agency, warming of around 2°C is expected under the moderate climate scenario (RCP 4.5) by the end of the century, but the pessimistic RCP 8.5 scenario project an increase of up to 6°C. In addition to the rise in temperature, changes in precipitation and increased frequency of extreme weather events are predicted. New environmental conditions affect tree species and habitats differently; thus, forest biodiversity and local tree species compositions probably will be altered in many regions in the future. The effects may be manifold: some tree species may persist, locally adapt and migrate, while others may disappear from given regions and be replaced by native or non-native species. The native forests of the Austrian-Hungarian border region are particularly affected by the climate change. To mitigate the consequences of anthropogenic climate change to preserve forest biodiversity for future generations and to enable their use, deliberate and planned human interventions and actions are essential. These require transnational or even global efforts since nature and climate do not recognise man-made borders.

The REIN-Forest project (Interreg V-A Austria-Hungary Programme - ATHU150), a bilateral project between Austria and Hungary, aimed to establish harmonised protection measures for the conservation of native forests in Northern, Central and Southern Burgenland, Vienna, Vienna Umland-South, Lower Austria South, Graz and Eastern Styria, Győr-Moson-Sopron, Vas and Zala counties (the so-called programme area). In the scope of this project, international cooperation between three project partners: the Austrian Research Centre for Forests (BFW, Austria), the Forest Research Institute – University of Sopron (SOE ERTI, Hungary) and the Vas County Government Office (VVÖH, Hungary) was

established. Previous results and outputs of the SUSTREE project (Interreg Central Europe CE614), such as: a) Transnational delineation model of conservation and forest seed transfer zones in climate change, b) Report of intraspecific response function and derivation of climate transfer limits, SusSelect data, recommendations and c) Application of the species distribution models for the delineation of seed transfer zones/models in Central Europe, were put into practice during the project, focusing on two native deciduous forest tree species of the Austrian-Hungarian border region: European beech (*Fagus sylvatica* L.) and sessile oak (*Quercus petraea* (Matt.) Liebl.).

During the REIN-Forest project, the following joint documents were prepared and several activities were implemented:

1. Model-based document on the current state and future perspectives of European beech and sessile oak forests;

2. Bilateral strategy for the transfer of forest reproductive material (FRM) and its use in the Austrian-Hungarian border region;

3. Establishment of altogether six demonstration sites (three in each country) with local and climate-adapted FRM of European beech and sessile oak for long-term monitoring;

4. Management and monitoring plan of the demonstration sites;

5. Joint bilingual communication strategy, which included informative programmes and meetings with professionals, locals and schools and also education material for further use.

REIN-Forest focused on using scientific results and outputs in the field of applied forestry and awareness-raising. Besides strategies, recommendations and reports that would facilitate forest managers' decisions for the future in the border region, events and workshops were offered for forestry practitioners, school pupils and the public and a short film and educational materials were published.

Keywords

assisted-migration, climate change, experimental trial, *Fagus sylvatica*, Provenance research, *Quercus petraea*

Translation of the Abstract

Deutsch (German)

Geeignete Anpassungen und Maßnahmen zur Bekämpfung des anthropogenen Klimawandels (CC) sind eine große Herausforderung des 21. Jahrhunderts. In Europa wird nach Angaben der Europäischen Umweltagentur bis zum Ende des Jahrhunderts eine Erwärmung um etwa 2 °C im moderaten Klimaszenario (RCP 4.5) erwartet, während im pessimistischen RCP 8.5-Szenario ein Anstieg um bis zu 6 °C prognostiziert wird. Neben

dem Temperaturanstieg werden auch Veränderungen bei den Niederschlägen und eine größere Häufigkeit extremer Wetterphänomene vorhergesagt. Die neuen Umweltbedingungen wirken sich unterschiedlich auf Baumarten und Lebensräume aus; daher werden sich die biologische Vielfalt der Wälder und die Zusammensetzung der lokalen Baumarten in Zukunft wahrscheinlich in vielen Regionen verändern. Die Auswirkungen können vielfältig sein: Einige Baumarten können persistieren, sich lokal anpassen und einwandern, während andere aus bestimmten Regionen verschwinden und durch heimische oder nicht-heimische Arten ersetzt werden können. Die heimischen Wälder der österreichisch-ungarischen Grenzregion sind besonders betroffen. Um die Folgen des anthropogenen Klimawandels abzumildern, die biologische Vielfalt der Wälder für künftige Generationen zu erhalten und ihre Nutzung zu ermöglichen, sind bewusste und geplante menschliche Eingriffe und Maßnahmen unerlässlich. Diese müssen international sein, denn Natur und Klima kennen keine von Menschen gemachten Grenzen. Das REIN-Forest Projekt (Interreg V-A Österreich-Ungarn Programm - ATHU150), ein bilaterales Projekt zwischen Österreich und Ungarn, hatte zum Ziel, harmonisierte Schutzmaßnahmen zur Erhaltung der heimischen Wälder im Nord-, Mittel- und Südburgenland, Wien, Wien Umland-Süd, Niederösterreich-Süd, Graz und Oststeiermark, in den Komitaten Györ-Moson-Sopron, Vas und Zala (das sogenannte Programmgebiet) zu etablieren. Im Rahmen dieses Projekts wurde eine internationale Kooperation zwischen drei Projektpartnern eingerichtet: dem Bundesforschungs- und Ausbildungszentrum für Wald, Naturgefahren und Landschaft (BFW, Österreich), dem Forstlichen Forschungsinstitut - Universität Sopron (SOE ERTI, Ungarn) und dem Amt der Selbstverwaltung des Komitates Vas (VVÖH, Ungarn). Frühere Ergebnisse und Outputs des SUSTREE-Projekts (Interreg Central Europe CE614), wie z.B. a) Transnationales Abgrenzungsmodell von Schutz- und Waldsamen-Transferzonen im Klimawandel, b) Bericht über die intraspezifische Reaktionsfunktion und Ableitung von Klima-Transfergrenzen, SusSelect-Daten, Empfehlungen und c) Anwendung der Artenverteilungsmodelle für die Abgrenzung von Saatgutübertragungszonen/ Modellen in Zentraleuropa, wurden innerhalb des Projektes praktisch umgesetzt, wobei der Schwerpunkt auf zwei heimischen Laubbaumarten der österreichisch-ungarischen Grenzregion lag: Rotbuche (*Fagus sylvatica* L.) und Traubeneiche (*Quercus petraea* (Matt.) Liebl.).

Im Rahmen des REIN-Forest-Projekts wurden die folgenden gemeinsamen Dokumente erstellt und mehrere Aktivitäten durchgeführt:

1. Modellbasiertes Dokument über den aktuellen Zustand und die Zukunftsperspektiven der europäischen Buchen- und Traubeneichenwälder;

2. Bilaterale Strategie für den Transfer von forstlichem Vermehrungsgut (FVG) und dessen Nutzung in der österreichisch-ungarischen Grenzregion;

3. Einrichtung von insgesamt sechs Demonstrationsflächen (drei in jedem Land) mit standortgerechtem und klimaangepasstem FVG von Rotbuche und Traubeneiche für ein langfristiges Monitoring;

4. Management- und Monitoringplan für die Demonstrationsflächen;

5. Gemeinsame zweisprachige Kommunikationsstrategie, die Informationsprogramme und Treffen mit Fachleuten, mit der Bevölkerung und mit Schulen sowie Bildungsmaterial zur weiteren Verwendung umfasst.

REIN-Forest konzentrierte sich auf die Nutzung wissenschaftlicher Ergebnisse und Resultate im Bereich der angewandten Forstwirtschaft und der Bewusstseinsbildung. Neben Strategien, Empfehlungen und Berichten, die den Forstmanagern in der Grenzregion künftige Entscheidungen erleichtern sollen, wurden Veranstaltungen und Workshops für Forstfachleute, Schüler und die breite Öffentlichkeit angeboten sowie ein Kurzfilm und Lehrmaterial veröffentlicht.

Magyar (Hungarian)

Az antropogén eredetű éghajlatváltozáshoz való megfelelő alkalmazkodás és az azzal kapcsolatos intézkedések a 21. század jelentős kihívásai közé tartoznak. Az Európai Környezetvédelmi Ügynökség jelentése alapján Európában a mérsékelt éghajlati szcenárió (RCP 4.5) szerint az évszázad végére 2 °C körüli felmelegedés várható, a pesszimista RCP 8.5 forgatókönyv szerint azonban akár 6 °C-os növekedés elképzelhető. A hőmérséklet emelkedése mellett a csapadék változását és a szélsőséges időjárási események gyakoribbá válását is prognosztizálják. Az új környezeti feltételek eltérő módon hatnak a fafajokra és az élőhelyekre, így az erdők biológiai diverzitása és a helyi fafajösszetétel a jövőben valószínűleg számos régióban átalakul. A hatások sokrétűek lehetnek: egyes fafajok fennmaradhatnak, helyileg alkalmazkodhatnak és elvándorolhatnak, míg mások eltűnhetnek az adott régiókból, és helyüket őshonos vagy idegenhonos fajok veszik át. Az osztrák-magyar határvidék őshonos erdei különösen érintettek. Az antropogén éghajlatváltozás következményeinek enyhítése, az erdők biológiai sokféleségének a jövő nemzedékek számára történő megőrzése és használatuk lehetővé tétele érdekében elengedhetetlenek a tudatos és tervezett emberi beavatkozások és intézkedések. Ezeknek nemzetközi szintűnek kell lenniük, mivel a természet és az éghajlat nem ismeri az ember által létrehozott határokat.

A REIN-Forest projekt (Interreg V-A Ausztria-Magyarország Program - ATHU150), egy bilaterális projekt Ausztria és Magyarország között, az őshonos erdők megőrzését szolgáló összehangolt védelmi intézkedések létrehozását tűzte ki célul Észak-, Közép- és Dél-Burgenland, Bécs, Bécs Umland-Dél, Alsó-Ausztria Dél, Graz és Kelet-Stájerország, Győr-Moson-Sopron, Vas és Zala vármegye (az úgynevezett programterület) területén. A projekt keretében nemzetközi együttműködés jött létre három projektpartner között: a Szövetségi Erdészeti, Környezetvédelmi és Tájvédelmi Kutatási és Képzési Központ (BFW, Ausztria), az Erdészeti Kutatóintézet - Soproni Egyetem (SOE ERTI, Magyarország) és a Vas Vármegyei Önkormányzati Hivatal (VVÖH, Magyarország) között. A SUSTREE projekt (Interreg Central Europe CE614) korábbi eredményei és kimenetei, mint például a) A természetvédelmi és erdei magtranszferzónák transznacionális lehatárolási modellje az éghajlatváltozásban, b) Jelentés az intraspecifikus válaszfunkcióról és az éghajlati transzferhatárok levezetése, SusSelect adatok, ajánlások és c) A fajeloszlási modellek alkalmazása a magtranszferzónák/modellek lehatárolására a CE-ben, a projekt során a gyakorlatban is alkalmazásra kerültek, az osztrák-magyar határvidék két őshonos

lombhullató erdei fafajára összpontosítva: Az európai bükkre (*Fagus sylvatica* L.) és a kocsánytalan tölgyre (*Quercus petraea* (Matt.) Liebl.).

A REIN-Forest projekt során a következő közös dokumentumok lettek elkészítve, és számos tevékenységet is megvalósításra került:

1. Modellalapú dokumentum az európai bükk- és kocsányos tölgyerdők jelenlegi állapotáról és jövőbeli kilátásairól;

2. Kétoldalú stratégia az erdészeti szaporítóanyag transzferére és felhasználására az osztrák-magyar határrégióban;

3. Összesen hat demonstrációs helyszín létrehozása (országonként három) helyi és az éghajlathoz alkalmazkodott európai bükk és kocsányos tölgy szaporítóanyaggal hosszú távú megfigyelés céljából;

4. A demonstrációs területek kezelési és monitoring terve;

5. Közös kétnyelvű kommunikációs stratégia, amely tájékoztató programokat, valamint szakemberekkel, a lakossággal és az iskolákkal való előadássorozatot, továbbá további felhasználásra szánt oktatási anyagokat is tartalmazott.

A REIN-Forest a tudományos eredmények és kimenetek felhasználására összpontosított az alkalmazott erdőgazdálkodás és a figyelemfelkeltés területén. Az erdészeti szakemberek, az iskolai tanulók és a nyilvánosság számára szervezett rendezvények és workshopok mellett olyan stratégiák, ajánlások és jelentések is készültek, amelyek elősegítik a határ menti régió erdőgazdálkodói számára a jövőre vonatkozó döntéseket, valamint egy rövidfilmet és oktatási anyagokat is közzé lett téve.

Background and introduction of the project

Projected climate change (CC) scenarios (European Environment Agency 2023) for the remainder of the 21st century indicate a range of significant impacts on forests, including severe droughts, extended heatwaves, unpredictable rainfall patterns, increased storm activity (Gálos et al. 2007, Bednar-Friedl et al. 2022), as well as new pathogens, pests and invasive species. These impacts are anticipated to bring about remarkable transformations in certain forest ecosystems (Buras and Menzel 2019). Addressing these adverse climatic consequences necessitates inevitable human intervention and proactive measures. Foresters, stakeholders and policy-makers are compelled to minimise both the environmental and financial risks associated with climate change, as the ecological implications are deeply concerning, while the economic repercussions are notably significant. To mitigate the effects of climate change, forest managers must proactively embrace alternative and innovative management approaches, starting at the present time.

One of the possible approaches and solutions to keep the present forest cover and to preserve biodiversity and economic benefits for the future is to select suitable, resilient and

potentially adapted provenances and seed sources or even new tree species for the future (Sousa-Silva et al. 2018). This approach has been termed assisted migration, which is a human-supported relocation of species or genotypes within or beyond their natural distribution range to new locations that are going to be more suitable under future climate conditions (Benito-Garzon and Fernandez 2015). The re- and translocation must be based on scientific evidence, such as future climate data, vulnerability maps, the projected probability of occurrence and species distribution modelling and must take local site conditions into account. Social, political, economic and ecological issues must be considered in any case of assisted migration. This human-altered migration may be of critical importance already in the present day, as tree species and their populations are unable to cope with rapid CC due to their slow natural migration pace, geographic barriers and the fragmentation of the forest cover due to anthropogenic impact. During the application of assisted migration, depending on the projected climate, different genotypes or new provenances of the same species should be considered as the first replacement (Chakraborty et al. 2019). If it is not possible, other native species should be used for reforestation. The final option is the utilisation of non-native species for reforestation. An indispensable prerequisite for their use is sufficient knowledge about their long-term performance, potential species-specific diseases and invasiveness (Chakraborty et al. 2019). Keeping this order of forest reproductive material (FRM) selection, the risk of invasion or hybridisation may be avoidable or minimised.

Almost half of Austria and about one-fifth of Hungary are covered with forests (www.fao.org). In both countries, the warming climate will likely affect forest growth, productivity, tree vitality and species composition in the long term (Spathelf et al. 2014). In the common border region of both countries, deciduous forests are mainly dominated by European beech or oak species. In Burgenland (one of the federal states in Austria), for example, these tree species account for more than one-quarter of the total forest area according to the Austrian Forest Inventory (Bundesforschungs- und Ausbildungszentrum für Wald, Naturgefahren und Landschaft 2022). Assuming a limited natural migration capacity and local adaptation caused by the warming climate, many species are expected to face significant loss of suitable habitats and, therefore, decreased distribution in the future (Dyderski et al. 2018, Illés and Móricz 2022).

The REIN-Forest project aimed to foster the resilience and stability of the forest cover in the Austrian-Hungarian border region by developing a local strategy for transferring reproductive material for European beech and sessile oak. One of the main outputs was the establishment of demonstration sites to assess, monitor and validate the benefits of assisted migration. During the implementation of the project, we applied previous FRM recommendations for the future to test how feasible it is to acquire climate-adapted FRM in a short period in practice. Next to the recommended sources, local material was also used in the establishment of the demonstration sites for later comparison purposes.

Project objectives and outputs

Model-based document on the current state and future perspectives of European beech and sessile oak forests

In order to establish a solid technical platform for the development of seed transfer recommendations, existing approaches in REIN-Forest, knowledge and continental scale models developed within the framework of the preceding SUSTREE project (Chakraborty et al. 2021) were downscaled and applied to ascertain the status and future prospects of forests in the Interreg AT-HU programme area. The regional species distribution models (SDMs) provided input for REIN-Forest activities, the development of a regional seed transfer strategy and the selection of the demonstration sites. During modelling, a recent European forest cover map (Copernicus Land Monitoring Service and European Environment Agency 2020) was obtained from the Copernicus Land Monitoring Service, which provides public geographical information on land cover and its changes, land use and vegetation state. The forest cover density map was clipped, focusing only on the Interreg AT-HU programme area. To exclude minor tree groups, amenity plantings and forest strips, pixels with more than 50% density were selected and later only 1 km grids with more than 75% forest coverage were considered as closed forest stands for the local application of SDMs. Distribution of the forest areas by probability classes (in 10% intervals) was computed for the two species for both climate scenarios and three timeframes, 2041-2060, 2061-2080 and 2081-2100. Vulnerability maps were developed using the occurrence maps of the RCP 8.5 scenario (Fig. 1). The results show notable shifts in species composition of natural forests as projected by the SDMs. Both model species will face habitat loss or at least demographic losses throughout their occurrences in the majority of the modelled area by the end of the century.

Bilateral strategy for the transfer of forest reproductive material (FRM) and its use in the Austrian-Hungarian border region

We published the bilateral strategy for the border region to assist and support stakeholders and forest managers. This strategy aimed to promote assisted migration initiatives to improve the resilience of the local forests to climate change by reviewing national legislations and official procedures related to FRM production, transfer and use, summarising the future perspectives of beech and sessile oak forests, based on the vulnerability assessment, formalising recommendations on the FRM transfer in the programme area. The review of the legislation and official procedures of the two countries suggests that both national regulations comply with the framework and minimum requirements of the Council Directive 1999/105/EC and the OECD Forest Seed and Plant Scheme. Next to this, we also collected information on the species covered by the schemes and regulations, regions of provenance, categories of FRM and the legal background of FRM transfer amongst EU and third countries. One of the bilateral strategy outcomes is the recommendation for FRM transfer in the programme area, which is based on the vulnerability assessment results and three vulnerability classes. The first class, marked with green colour on the map (Fig. 1), where a relative decrease in the projected

probability of occurrence between the present state and the period 2081-2100 is lower than 15%, is called the non-vulnerable class. In the second, moderately vulnerable class (orange colour on the map) decrease is projected between 15-50%. The last class is the so-called severely or highly vulnerable class, which marks areas (red colour on the map), where a relative decrease in the probability of occurrence is more than 50% at the end of the 21st century. The recommendations of the strategy highlight that the principle of "native species and local provenances should be preferred where appropriate" (MCPFE 1993) will not be 100% valid everywhere in the future. The use of different genotypes in the future is a key element. Artificial regeneration and assisted migration facilitated via systematic transfer of FRM have been identified as a unique opportunity and valuable option to enhance the climatic adaptation of future forests (Kowalczyk et al. 2015).

Establishment of six demonstration sites with local and climate-adapted FRM of European beech and sessile oak for long-term monitoring

The project REIN-Forest aims to evaluate and validate the benefits of climatically adapted reproduction material for the future on six sites (three in Austria and three in Hungary) to test assisted migration in practice. In April 2021, the lead- and project partners posted online a joint, bilateral open call, which targeted forest owners and managers to find suitable areas for the establishment of demonstration sites. To establish these experimental trial areas with local and future climate-adapted provenances, we used the previously developed model-based information background and vulnerability maps on the current and future perspectives of the European beech and sessile oak forests in the programme area and the following recommendation systems: SusSelect (from the SUSTREE project), Forest Vulnerability and Seed Transfer Tool (www.seed4forest.org), Baumartenampel of the BFW: www.klimafitterwald.at/baumarten/. These tools and systems helped us to obtain the information regarding which provenances would fit according to the RCP 4.5 and 8.5 future CC scenarios. The research institutes were responsible for purchasing the “local” and “the best-fitted future climate-adapted” FRM. One of the early results, which was later also presented to a broad audience, was the difficulties during the procurement of the right FRM. Especially, the procurement of the “adapted” FRM proved to be very challenging. The main problem was the unavailability of the required provenances because the suggested seed stands were not harvested that year (seeds of both species can only be stored for a relatively short time). As the project is science-based, but practice-orientated, we focused on searching for available seed or seedling sources also from other future climate-adapted provenances. Some of the seed stands were parts of clusters that were defined as most probably best fitted for the future according to the SUSTREE recommendation system, based on modelling. In addition to these, we also used FRM from different clusters, which were recommended for the area according to the more optimistic CC scenario. In the end, FRM from 21 seed stands, eight local and thirteen future climate-adapted, was purchased on the Austrian side, considering the recommendation systems and criteria, such as FRM from seed stands from dry and warm sites. A randomised experimental trial design (Suppl. materials 1, 2, 3) was used in Austria according to the properties of the demonstration sites, consisting of three repetitions of each provenance per site, except for two provenances where the germination rate was low. The sizes of trial

sites ranged between 1.2 and 1.3 hectares and were based on the different spatial tree spacing depending on the tree species (European beech: 1.5 m x 1 m, sessile oak: 2.5 m x 1.5 m and 2 m x 1.5 m). Before planting the seedlings with the help of a professional company, the exact locations of the individual trees were measured out and marked at all three sites in the Austrian trial areas. In the autumn and winter of 2022, one site in each country was reforested with local and adapted sessile oak provenances, another with local and adapted European beech provenances and the third site with local European beech and adapted sessile oak provenances because, in this area, beech is predicted to lose its dominance in the future.

Management and monitoring plan of the demonstration sites

In provenance research and forest plant breeding, the maintenance and monitoring of demonstration sites are central elements of long-term experiments in addition to their establishment. Measures and surveys on these sites provide forestry science with data at stand, species, provenance and individual tree levels through repetition at different sites and over different periods. Responsible and continuous management and maintenance guarantee that these experimental trials permanently meet their objectives. Regular controls and planned activities on the experimental sites allow for a timely response to changes. In the future, both institutions, ERTI and BFW, will coordinate with the landowners and forest managers of the demonstration sites on the necessary forest protection and management measures. During the duration of the trials, in this case at least 15 years, regular measures and controls will be carried out to guarantee their success and data collection. These measures, which are based on local forest management practices applied in the border region, are as follows: care and protection of trees/seedlings, control of the condition of the protective fence and necessary silvicultural steps that include forest protection aspects. These are to be carried out at least annually and/or after extreme weather conditions, such as heavy snowfall or storms. The loss of plants in the first year will be corrected by a one-time supplemental planting with the same age group from the identical provenance during the first monitoring activity. For typical monitoring characteristics (Liesebach et al. 2017), we will observe phenology (bud burst/ shoot termination), abiotic and biotic damage, quality characteristics and growth characteristics in the first, second/ third, fifth, tenth and in the fifteenth year after the establishment of the demonstration sites. Next to these also a genetic monitoring approach is an option, which focuses on tracking temporal changes in the genetic variation and structure of tree populations and is the only way to verify how well genetic diversity is maintained over time and how this diversity is shaped by climate change and management practices (Hansen et al. 2012Aravanopoulos et al. 2015). Forest owners and forest managers were and are responsible for tasks resulting from the management and monitoring plan. In the 15 years following planting, all trial sites will be monitored and the performance of the different seed sources/origins will be compared to feedback and validate the FRM transfer system and assisted migration of future climate-adapted provenances according to the recommendation systems.

Joint bilingual communication strategy, which included informative programmes and meetings with professionals, locals and schools and also education material for further use

In addition to practical work based on scientific data, the project emphasised public relations and public awareness. As described in our bilateral communication strategy, altogether 20 events were organised in both countries for a broad audience. In both Austria and Hungary, four workshops were held for experts and researchers in nature conservation and forestry and, in total, eight events were offered to the general public. Besides these, a bilateral two-day forestry study tour with 27 participants was held for the target groups. Topics such as assisted migration, the role of biodiversity in forest management under climate change and future forest- and land use in anticipation of environmental change were presented and discussed during these events. To raise awareness amongst the younger generation, educational days about forests and nature in nature parks and arboretums were offered to pupils between 7 and 14 years old. On the Austrian side, more than 375 people took part in these events; in Hungary the number of participants was 369. In addition, a joint educational film in German and Hungarian with English subtitles (https://www.youtube.com/watch?v=KGUpMoTJ4mE&t=3s), an educational kit and a bilateral, German and Hungarian activity booklet were published as part of the project.

Acknowledgements

The project REIN-Forest (No. ATHU150) is funded within the framework of the programme INTERREG V-A Austria-Hungary through the support of the European Funds for regional development. The authors thank the forest owners and managers who participated in this project and also the colleagues who worked on the implementation of the activities and outputs.

Funding program

The bilateral project REIN-Forest (Nr. ATHU150) is implemented in the programme INTERREG V-A Austria-Hungary, co-financed by the European Regional Development Fund.

Total budget:

ERDF: €489,600 and national contributions: €86,400.

Duration of the project:

27 months (01.10.2020-31.12.2022)

Grant title

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

Hosting institution

Lead Partner:

Vas County Government Office (Vas Vármegyei Önkormányzati Hivatal).

Project partners:

Forest Research Institute – University of Sopron (Erdészeti Tudományos Intézet – Soproni Egyetem).

Austrian Research Centre for Forests BFW (Bundesforschungs- und Ausbildungszentrum für Wald, Naturgefahren und Landschaft).

Strategic partners:

Szombathely Forestry Corporation (Szombathelyi Erdészeti Zrt.).

Provincial Government of Lower Austria - Department for Forestry (Amt der Niederösterreichischen Landesregierung - Abteilung Forstwirtschaft).

Őrség National Park Directorate (Őrségi Nemzeti Park Igazgatóság).

Educational District Centre of Szombathely (Szombathelyi Tankerületi Központ).

Educational District Centre of Sárvár (Sárvári Tankerületi Központ).

Author contributions

All authors and project partners were contributing during the proposal and the implementation of the project.

Conflicts of interest

The authors have declared that no competing interests exist.

References

- Aravanopoulos FA, Tollefsrud MM, Graudal L, Koskela J, Kätzel R, Soto A, Nagy L, Pilipovic˘ A, Zhelev P, Božic˘ G, Bozzano M (2015) Genetic monitoring methods for genetic conservation units of forest trees in Europe. EUFORGEN.
- Bednar-Friedl B, Biesbroek R, Schmidt DN, Alexander P, Børsheim KY, Carnicer J, Georgopoulou E, Haasnoot M, Le Cozannet G, Lionello P, Lipka O, Möllmann C, Muccione V, Mustonen T, Piepenburg D, Whitmarsh L (2022) Chapter 13. In: Pörtner H-, et al. (Ed.) Climate Change 2022: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the IPCC Sixth Assessment Report. Cambridge University Press https://doi.org/10.1017/9781009325844.015.
- Benito-Garzon M, Fernandez J (2015) Testing scenarios for assisted migration of forest trees in Europe. New Forests 46 https://doi.org/10.1007/s11056-015-9481-9
- Bundesforschungs- und Ausbildungszentrum für Wald, Naturgefahren und Landschaft (2022) Österreichische Waldinventur 2016-2021. www.waldinventur.at
- Buras A, Menzel A (2019) Projecting Tree Species Composition Changes of European Forests for 2061-2090 Under RCP 4.5 and RCP 8.5 Scenarios. Frontiers in Plant Science 9 https://doi.org/10.3389/fpls.2018.01986
- Chakraborty D, Gaviria J, Bolte A, Bouissou C, Buchacher R, Hazarika R, Henning L, Kowalczyk J, Longauer R, Lstibůrek M, Nagy L, Schnabel G, Stejskal J, Tomášková I, Schueler S (2019) Implementing assisted migration. SUSTREE Policy Brief No. 2 (2). https://doi.org/10.3220/DATA20191016132031
- Chakraborty D, Móricz N, Rasztovits E, Dobor L, Schueler S (2021) Provisioning forest and conservation science with high-resolution maps of potential distribution of major European tree species under climate change. Annals of Forest Science 78 https://doi.org/10.1007/s13595-021-01029-4
- Copernicus Land Monitoring Service, European Environment Agency (2020) High Resolution Layer: Tree Cover Density (TCD) 2018.
- Dyderski M, Paź-Dyderska S, Frelich L, Jagodziński A (2018) How much does climate change threaten European forest tree species distributions? Global Change Biology 24: 1150-1163. https://doi.org/10.1111/gcb.13925
- European Environment Agency (2023) Observed annual mean temperature change from 1960 to 2019 (left panel) and projected change under different emissions scenarios (right panels) in Europe. https://www.eea.europa.eu/data-and-maps/figures/trends-in-annual-temperature-across-2
- Gálos B, Lorenz P, Jacob D (2007) Will dry events occur more often in Hungary in the future? Environmental Research Letters 2 https://doi.org/10.1088/1748-9326/2/3/034006
- Hansen M, Olivieri I, Waller D, Nielsen E (2012) Monitoring adaptive genetic responses to climate change. Molecular ecology 21: 1311-29. https://doi.org/10.1111/j.1365-294X.2011.05463.x
- Illés G, Móricz N (2022) Climate envelope analyses suggests significant rearrangements in the distribution ranges of Central European tree species. Annals of Forest Science 79 (1). https://doi.org/10.1186/s13595-022-01154-8

- Kowalczyk J, Konnert M, Fady B, Gömöry D, A'Hara S, Wolter F, Ducci F, Koskela J, Bozzano M, Maaten T (2015) Use and transfer of forest reproductive material in Europe in the context of climate change. European Forest Genetic Resources Programme (EUFORGEN), Bioversity International
- Liesebach M, Ahrenhövel W, Janßen A (2017) Planung, Anlage und Betreuung von Versuchsflächen der Forstpflanzenzüchtung : Handbuch für die Versuchsanstellung. Johann Heinrich von Thünen-Institut, DE. https://doi.org/10.3220/REP1496222427000
- MCPFE (1993) RESOLUTION H1 General Guidelines for the Sustainable Management of Forests in Europe. In: Ministerial Conference on the Protection of Forests in Europe (Ed.) Helsinki Process. Second Ministerial Conference on the Protection of Forests in Europe, Helsinki/Finland, 16-17 June 1993.
- Sousa-Silva R, Verbist B, Lomba Â, Valent P, Suškevičs M, Picard O, Hoogstra-Klein M, Cosofret C, Bouriaud L, Ponette Q, Verheyen K, Muys B (2018) Adapting forest management to climate change in Europe: Linking perceptions to adaptive responses. Forest Policy and Economics 90 https://doi.org/10.1016/j.forpol.2018.01.004
- Spathelf P, van der Maaten E, van der Maaten-Theunissen M, Campioli M, Dobrowolska D (2014) Climate change impacts in European forests: The expert views of local observers. Annals of Forest Science 71: 131-137. https://doi.org/10.1007/s13595-013-0280-1

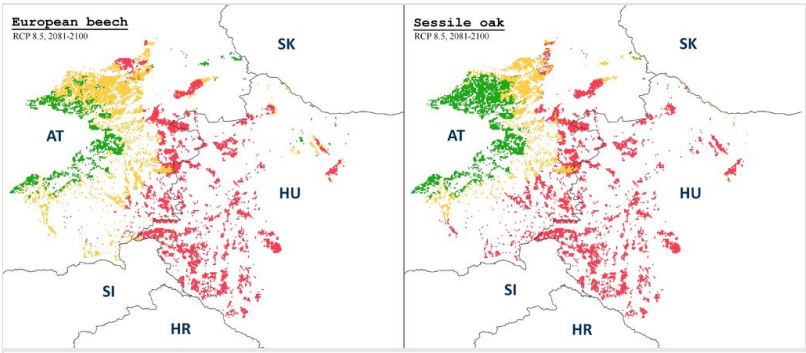

Figure 1.

Figure 1. Projected changes in the probability of occurrence of European beech (*Fagus sylvatica*) and sessile oak (*Quercus petraea*) in the Austrian-Hungarian border region according to the RCP 8.5 CC scenario in the period of 2081-2100 (L. Nagy & N. Móricz; SOE).

Supplementary materials

Suppl. material 1: Experimental trial design near Mannersdorf am Leithagebirge, NÖ, AT.

Authors: Erik Szamosvari
Data type: Trial design
Brief description: The document includes the design of the trials and also information about the plot structure, the exact coordinates of the trial, the provenance and origin of the seedlings, the tree species as well as the number of seedlings and the other details, which are essential for monitoring activities.
Download file (477.26 kb)

Suppl. material 2: Experimental trial design near Reichenau an der Rax, NÖ, AT

Authors: Erik Szamosvari
Data type: Trial design
Brief description: The document includes the design of the trials and also information about the plot structure, the exact coordinates of the trial, the provenance and origin of the seedlings, the tree species as well as the number of seedlings and the other details, which are essential for monitoring activities.
Download file (319.61 kb)

Suppl. material 3: Experimental trial design near Sparbach, NÖ, AT

Authors: Erik Szamosvari
Data type: Trial design
Brief description: The document includes the design of the trials and also information about the plot structure, the exact coordinates of the trial, the provenance and origin of the seedlings, the tree species as well as the number of seedlings and the other details, which are essential for monitoring activities.
Download file (350.30 kb)