PROJECT INFORMATION

Project title:	**Interaction between *Viscum album* ssp. *austriacum* and *Pinus sylvestris* on different spatial and temporal scales**
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PROJECT DESCRIPTION

Scots pine (*Pinus sylvestris* L.) is probably the most important – both ecologically and economically – tree species due to wood technical properties and wide distribution in Eurasia. Based on three climate change scenarios and using the three Global Circulation Models (GCMs) Dyderski et al. (2018) indicated *P. sylvestris* L. (as well as *Picea abies* L. and *Larix decidua* Mill.) is going to detract from the west, central and east parts of Europe to find optimal growth conditions to the north. Although, scenarios presented in the study by Dyderski et al. (2018) are not taking into account the high impact of other abiotic conditions (soil types for instance), the genetic variability of Scots pine, and biotic factors. It is certainly not a mistake – we have no comprehensive knowledge about genetics (provenance experiments are still under investigation) and biotic factors – like insect outbreaks, which are almost unpredictable from a long-time perspective. Certainly, climate change has an impact not only on tree species but also on their environment (it's both biotic and abiotic parts) making predictive modelling a challenge. Although mistletoe is a plant not able to move sensu stricto – it can spread in the manner plants do by seeds and hence allowing standard modelling and prediction of plant species distribution.

Xylem-tapping mistletoes, like *Visum album* ssp. *austriacum* (Wiesb.) Vollm. which is specific for Scots pine, strikes their haustoria into aboveground water transporting tissues of the host to obtain water and solutes (2). It is great from their point of view because of savings of energy from the costly, and not always profitable for standardly soil anchored plants, root system. Mistletoe maintains much lower water potential in comparison with the host and keeps a high transpiration rate and in the case of water mistletoes are not thrifty – mistletoe-to-host transpiration ratio is growing with the increase of photosynthetic photon flux density and vapour pressure deficit (3). A higher transpiration rate of mistletoe in comparison with the host was indicated early – at the beginning of the XX c. (4). The hypothesis assuming this phenomenon is related to nitrogen demand was stated by Schulze et al. (1984), who suggested this element is the potentially most limiting for mistletoes (referred to as nitrogen-parasitism hypothesis). In the study by Scalon & Wright (2015) authors indicated mistletoes are responding to environmental conditions similar to their hosts – WUE was inversely proportional to the level of annual precipitation. Recent findings of Camarero et al., (2019) concerning the impact of mistletoe on trees water relations from the southeast part of *P. sylvestris* distribution speak for the results of Scalon & Wright (2015) indicating greater WUE of host tree in a dry site in comparison with the wet site. Hence, I might deduce and state hypothesis: site quality (soil+climate sensu lato) is a limiting factor for both mistletoe and host. However, we know the distribution of both doesn't coincide and the question is: Does it only matter of time?

Trees defence mechanism against water loss due to mistletoe transpiration is similar to response against drought, i.e. hosts are closing their stomata (8). This phenomenon is driven by an increase in the concentration of abscisic acid in hosts tissues as was shown in a study by Hu et al. (2017). During that time, basic metabolic regulation may rely on the storage, but to what extent it drives the carbon starvation is planned to be investigated in collaboration with Max Planck Institute for Biogeochemistry (partially funded by Polish National Science Centre, grant No 2020/04/X/NZ9/01094). Drought is the factor that primarily negatively influences growth. That is written in tree ring sequences. The same has been observed as the effect of infestation by mistletoe (10, 11). However, from the study by Bigler et al. (2006) we know even prolonged drought periods may not be the direct cause of trees mortality, but to a great extend is weakening trees condition. Hence it is easy to predict that additional water leaks caused by mistletoe could be the factor increasing the probability of trees dying out. If, however, we should observe a greater mortality rate in stands infested by mistletoe. Based on data from National Forest Inventory plots Lech et al. (2020) indicated a growing trend (across 2008-2018) of injuries caused by mistletoe on *P. sylvestris* in the last two decades in the area of Poland. The cited study presents few simple statistical characteristics and has shown some trends when different explanatory variables are used, like site fertility, water availability, elevation class, tree social position, diameter and degree of defoliation. The abovementioned trends in growth, the impact of nitrogen (and potentially other macroelements), growing temperature and changes in quantity and quality of precipitation together with tree and stand characteristics are the points of departure for screening study of the interaction between *P. sylvestris* and mistletoe.

To understand processes, one must start by answering a crucial question: what are the sources of variation driving investigated phenomenon? That is at least partially covered by the arguments put forward. Now, to what extent do individual variance components explain observed variability? Permanent observational plots are probably the most important source of information when inference on a large-area level (microregion, country, continent) is going to be done. To date, one study gave us cues about the spreading dynamics of the mistletoes with the use of such data (13). Although, it is still hard to draw any conclusion for the future. In other words, the current state is known, but we want to know why we observe this state? Then we might be able to create norms to answer the question: how to act?

Briefly, data from Level I and II monitoring plots are going to be integrated with:

1) bioclimatic variables and elevation model (WorldClim): https://www.worldclim.org/,
2) "Land Cover Map of Europe 2017" (the result of S2GLC project): http://s2glc.cbk.waw.pl/,
3) data from Forest Data Bank for the area of Poland: https://www.bdl.lasy.gov.pl/portal/,
4) among data from different UNECE ICP Forests programmes listed in the application form,

to conduct screening study concerning the unanswered questions about distribution and spreading dynamics of mistletoe. Integration is going to be done with the use of QGIS software (14). Hereunder I provide an extended description of specific objectives listed in the application form.

1. Determination of linkage between the mistletoe distribution and bioclimatic variables for the area of Europe. The first analysis to be conducted is aimed to find a link between observed mistletoe occurrence (binomial variable) and chosen bioclimatic variables. Variables indicating warm are, among others, main candidates for an explanation of mistletoe distribution. Firstly, from a recent study (15) we can predict the probability of germination as a function of the lowest temperature. Hence, variables like 'minimal temperature of the coldest month' or 'mean temperature of coldest quarter' are supposed to be most indicative for mistletoe distribution. Although, birds are the main vector of seeds and other temperature-based variables might explain also observed variability, as it is possible, that dynamic shifts in mistletoe distribution are a synergic effect of its dynamic and changes in the ecology of birds. Here I'm going to use stepwise regression to obtain a generalised linear model.

2. Assessment of mistletoe distribution and degree of infestation as a function of site conditions (soil+climate). This issue is to some extent covered by results published in a study by Lech et al. (2020). Frequencies of trees with detected mistletoe were compared with stand age class, site moisture and fertility, and others not mentioned here for the area of Poland. It is evident that together with growing height probability of infestation by mistletoe is higher. That is because both variables are related to time and more time will pass more probable is that birds will bring the seed able to germinate (1) as well as the preference of birds – they probably feel safer on taller trees (at least hypothetically). Although, we are still unable to model and indicate the probability of infestation with the mixture of site conditions. Here I will try to model mistletoe occurrence (generalised linear model) or level of infestation (ordinal logistic model) as a function of abiotic conditions and infested tree (as well as stand) characteristics. Additionally, detailed stand characteristics from data obtained from Forest Data Bank will be employed, but those are limited only to the area of Poland. Again stepwise regression will be employed as an attempt to identify variables explaining the observed variability to model the probability of infestation (or infestation level). At this point, I would like to introduce to model information about nitrogen deposition from Level II plots. The issue of integration data between Level I and II plots will be solved by modelling the latter with inverse distance weighting interpolation and attribution of modelled value to the Level I plots coordinates.

3. Modelling mistletoe spreading dynamics. The basic concept is to use previously constructed models (as described in points 1. & 2.), spatiotemporal variability from inventories, land cover maps and climate change projections to estimate the probability of infestation by mistletoe on the areas currently not occupied. The most difficulty in achieving that goal is the incompleteness of information for the area of whole Europe, i.e. areas not covered by Level I or II plots. That is especially for the determination of species composition of the stand. Hence, the basic factor to be included – if whole Europe to be modelled – is the localisation of

Scots pine stands, as it is not the same as a distribution. Using distribution instead would be some kind of simplification also possible. To make such a map, information from inventories plus elevation models will be used to assess the probability of coniferous forest (indicated on "Land Cover Map of Europe 2017") to be a Scots pine stand. Depending on the accuracy of such a map, the possibility of "Mistletoe spreading dynamics model" development will be determined. Evaluation is planned to be made in the area of Poland where detailed information is available directly from Forest Data Bank. That would be a starting point if we want to model predicting mistletoe spreading dynamics.

References

1. M. K. Dyderski, S. Paź, L. E. Frelich, A. M. Jagodziński, Glob. Chang. Biol. 24, 1150–1163 (2018).

2. S. Yoshida, S. Cui, Y. Ichihashi, K. Shirasu, Annu. Rev. Plant Biol. 67, 643–667 (2016).

3. D. Yang et al., Tree Physiol. 37, 501–510 (2017).

4. Z. Kamerling, Ber. Dtsch. Bot. Ges. 32, 17–24 (1913).

5. E.-D. Schulze, N. C. Turner, G. Glatzel, Plant, Cell Environ. 7, 293–299 (1984).

6. M. C. Scalon, I. J. Wright, Funct. Ecol. 29, 1114–1124 (2015).

7. J. J. Camarero, E. González de Andrés, G. Sangüesa-Barreda, A. Rita, M. Colangelo, Dendrochronologia. 56, 125598 (2019).

8. R. Zweifel, S. Bangerter, A. Rigling, F. J. Sterck, J. Exp. Bot. 63, 2565–2578 (2012).

9. B. Hu et al., Tree Physiol. 37, 676–691 (2017).

10. G. Sangüesa-Barreda, J. C. Linares, J. J. Camarero, Tree Physiol. 32, 585–598 (2012).

11. S. Pilichowski et al., Sylwan. 162, 452–459 (2018).

12. C. Bigler, O. U. Bräker, H. Bugmann, M. Dobbertin, A. Rigling, Ecosystems. 9, 330–343 (2006).

13. P. Lech, A. Żółciak, R. Hildebrand, Forests. 11, 83 (2020).

14. QGIS.org, QGIS Geographic Information System. QGIS Association. (2021).

15. O. P. Tikkanen et al., For. Ecol. Manage. 482 (2021), doi:10.1016/j.foreco.2020.118806.

16. T. Hengl, A Practical Guide to Geostatistical Mapping of Environmental Variables (Office for Official Publications of the European Communities, Luxenbourg (Luxenbourg), 2007)