FORMAT

1. EXCELLENCE

1.1 Quality and pertinence of the project's research and innovation objectives (and the extent to which they are ambitious, and go beyond the state-of-the-art).

According to the new EU forest strategy (EUFS) for 2030, one of the flagship initiatives of the European Green Deal, the quantity and quality of EU multi-functional forest must be improved. For this ambitious objective, the EUFS promotes lines of action that include implementing a sustainable forest bioeconomy and protecting the EU's last remaining old-growth forests (OGFs)[1]. Achieving the former relies on the type of forest management implemented. On the one hand, approaches such as e.g. rotation forest management (RFM) generate monospecific, even-aged forests with homogeneous forest structures, which may increase the future susceptibility to diseases and pests (e.g. bark beetles), especially under climate change scenarios[2]. On the other hand, management approaches such as uneven-aged continuous cover forestry (CCF) ensure the long-term environmental and socio-economic viability of forests, thereby retaining species present in mature forests to a greater extent than in RFM and conserving the structural, functional and compositional diversity[3]. CCF thus provides more ecosystem services than RFM. Regarding unmanaged systems, OGFs are among the richest forest ecosystems, storing significant carbon stocks and removing CO_2 emissions from the atmosphere[4], while being of paramount importance for biodiversity and the supply of critical ecosystem services[5]; also playing an important role in mitigating global warming at local scales[6]. The three states of development (RFM, CCF and OGF) form a gradient of maturity (i.e. degree of naturalness), thus defining a reference framework (Fig. 1) in the transition towards more resilient silviculture approaches to the natural forest ecosystem processes.

In the case of late stages of forest maturity, the EUFS clearly states that remains an immediate need to map OGFs based on reliable forest monitoring/data by using remote sensing techniques and geospatial data together with ground-based monitoring. The present proposal is thus in line with the state of the art in forestry monitoring, focusing on the need to map forest naturalness for a sustainable future[7]. However, monitoring forest maturity is complex, because of the multiple variables involved (often difficult to quantify), therefore measurable and reliable indicators, usually related to structural features, must be used[8].

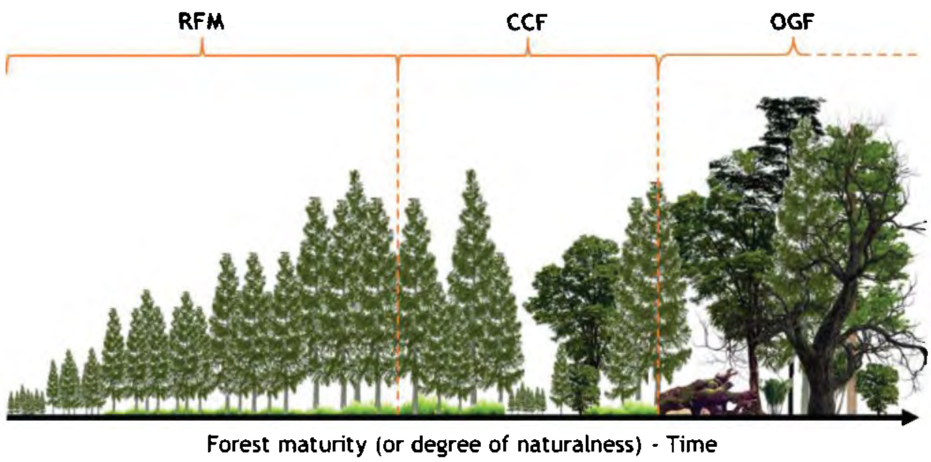

Fig. 1. Reference framework for forest maturity. Ranging from low (RFM, rotation forest management), intermediate (continuous cover forestry) and high (OGF, old-growth) degrees of maturity. RFM is represented by a complete cycle: seedlings - young – intermediate – optimal rotation ages.

[1] "A forest stand or area consisting of native tree species that have developed, predominantly through natural processes, structures and dynamics normally associated with late-seral developmental phases in primary or undisturbed forests of the same type. Signs of previous human activities may be visible, but they are gradually disappearing or are too limited to significantly disturb natural processes." (EUFS)

[2] Sommerfeld et al., (2021). Do bark beetle outbreaks amplify or dampen future bark beetle disturbances in Central Europe? *Journal of Ecology*

[3] Peura et al., (2018). Continuous cover forestry is a cost-efficient tool to increase multifunctionality boreal production forests Fennoscandia. *Biological Conservation*

[4] Luyssaert et al., (2008). Old-growth forests as global carbon sinks. *Nature*

[5] Wirth et al., (2009). *Old-growth forests: function, fate and value*. Springer Berlin, Heidelberg.

[6] Frey et al., (2016). Spatial models reveal microclimatic buffering capacity of old-growth forests. *Science advances*

[7] Chiarucci & Piovesan (2020). Need for a global map of forest naturalness for a sustainable future. *Conservation Biology*

[8] Blasi et al., (2010). Multi-taxon and forest structure sampling for identification of indicators and monitoring of old-growth forest. *Plant Biosystems*

These indicators, clearly defined in the Commission staff working document guidelines[9], are divided into main (native species, deadwood and old or large trees) and complementary (stand origin, structural complexity, habitat trees and indicator species) indicators. However, as maturity is not static, the performance of the indicators must be measured through quantifiable parameters along a maturity gradient (Fig. 2). Some of them can peak at earlier degrees of naturalness than OGF (e.g. biomass stock in beech-fir forests[10], represented by parameter A in Fig. 2), while others only peak at higher degrees of naturalness (e.g. structural parameters such as diameter differentiation[11], represented by parameter C in Fig 2, right). In addition, the peak values of parameters related to forest maturity may differ depending on site conditions (e.g. biomass production, Fig. 2 left), as well as different trends/trajectories, and they may even decrease after some degree of naturalness (represented by parameter B in Fig. 2 right).

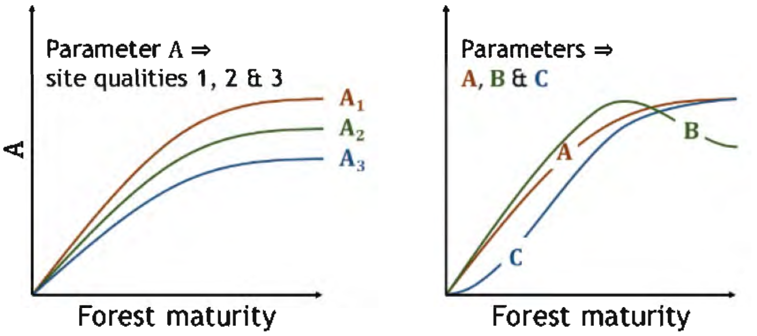

Fig. 2. Changes in hypothetical forest maturity parameters throughout the maturity gradient. Site quality can influence the maximum values of a given parameter (left), and different trends/trajectories in the parameters can be observed (right).

Monitoring forest maturity is crucial for guiding the conservation of forest areas with a high degree of naturalness and for providing information about the implementation of current and future strategies, policies and legislation. This can be done through outputs such as summary statistics and maturity maps. According to EUFS, methods of mapping OGF (and thus forest maturity) should be based on the previously mentioned definitions, criteria and indicators. Remote sensing data could be used in the first stage for pre-screening potential areas, in combination with *in-situ* data and modelling techniques. After identifying the target parameters to be estimated (e.g. those related to structural complexity indicators), the next challenge is to determine how to monitor them at different spatial and time scales. The correct approach is based on forest inventories (FIs), which have been greatly improved by new techniques, especially in the last few decades, since remote sensing emerged. While conventional FIs are costly and time-consuming, remote sensing can be very useful for increasing both spatial and temporal scales in monitoring without any proportional increases in costs. Many devices can be used to enhance FIs[12] and can play different roles regarding scale and precision requirements. For example, ground-based devices provide greater precision at the expense of the spatial scale, while spaceborne devices enhance spatial and time scales at the expense of precision. Nevertheless, the devices can also be used together in model-based inference approaches, in which the auxiliary information provided by remote sensing (e.g. sensors on board unmanned aerial vehicles -UAV) is used to fit predictive models developed with field data, obtained e.g. with ground-based devices[13]. Therefore, it is important to consider as wide a maturity gradient as possible to implement these inference methodologies using remote sensing, because the predictive potential will be enhanced by good representation of the range of values of the variable of interest (e.g. structural parameters). Unbiased estimates will then be obtained when the model is correct.

In this technological context, light detection and ranging (LiDAR) systems provide 3-dimensional point clouds, which are very useful for many forestry applications[14]. LiDAR enables mapping of vertical and horizontal forest structures through georeferenced points clouds and is operationally viable for estimating forest structure with LiDAR-based techniques such as terrestrial laser scanning (TLS)[15] and spaceborne laser scanning (SLS)[16]. However, SLS

[9] Commission Guidelines for Defining, Mapping, Monitoring and Strictly Protecting EU Primary and Old-Growth Forests, SWD(2023) 62 final
[10] Molina-Valero et al., (2021). Mature forests hold maximum live biomass stocks. *Forest Ecology and Management*
[11] Põldveer et al., (2020). Assessment spatial stand structure hemiboreal conifer dominated forests according different levels naturalness. *Eco. Indicators*
[12] White et al., (2016). Remote sensing technologies for enhancing forest inventories: A review. *Canadian Journal of Remote Sensing*
[13] Luck et al., (2023). Reduced model complexity for efficient characterisation of savanna woodland structure using terrestrial laser scanning.
[14] Dubayah & Drake, (2000). Lidar remote sensing for forestry. *Journal of Forestry*
[15] Watt & Donoghue, (2005). Measuring forest structure with terrestrial laser scanning. *International Journal of Remote Sensing*
[16] Mandl et al., (2023). Spaceborne LiDAR for characterizing forest structure across scales in the European Alps. *Remote Sensing Ecology Conservation*

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Central Bohemia Region

missions (e.g. GEDI) do not use continuous imaging instrumentation, and therefore techniques providing continuous mapping, such as spaceborne imaging radar (SIR), are necessary to capture sub-km variations in forest structure. This technology has been shown to be viable for estimating biomass under many different conditions[17], and new research is focusing on attributes such as forest structure. For example, SIR data have been used to estimate variables related to forest height in Mediterranean forests by means of Interferometric Synthetic Aperture Radar (InSAR) techniques[18]. However, although SIR can perform well, the use of ancillary topography derived from ALS or SLS can provide more accurate estimates[19]. In addition, integration of SIR and spaceborne optical images (SOI) appears promising for estimation of more complex forest structure variables (Gini coefficient, fractional cover, etc.) by using trending artificial intelligence (AI) deep learning techniques[20]. Moreover, upcoming SAR missions (ESA BIOMASS and NISAR) will be better able to penetrate the forest canopy by using longer wavelengths, thus heralding a new era of active remote sensing, with greater potential for estimating forest structure parameters.

In light of the above, the objective of the proposed research is to further improve methods for large-scale monitoring of forest maturity. The method development will be applied to the Norway spruce (*P. abies* L.) forests in the Central Bohemian Region (Czech Republic) and based on parameters related to biodiversity, deadwood and structural complexity indicators. The approach requires linking detailed measurements on *in-situ* data (ground truth) and continuous mapping data (predictors for upscaling). Ground-based LiDAR mobile laser scanning (MLS) devices calibrated with subsamples of conventional field data and spaceborne platforms (SIR supported by SOI when needed) will be used to estimate maturity parameters. ALS and SLS data may be used to improve estimates, calibrate models or validate outputs. Hence, the specific objectives of the proposal are addressed in the following research questions:

1. How can forest maturity be accurately estimated (detailed measurements of *in-situ* data)? → Estimation of forest maturity according to tree species, deadwood and structural indicators with detailed *in-situ* measurements based on field and MLS measurements. The sub-objectives of this objective are as follows:
   1.1. Classification of main tree species using MLS and AI techniques.
   1.2. Detection and characterization of deadwood (standing and lying) using MLS and AI techniques.
   1.3. Characterization of forest maturity according to structural complexity parameters, using MLS.
2. How can forest maturity be monitored from an operational point of view (continuous mapping data)? → Upscaling forest maturity estimation to regional scale (Central Bohemia) with SIR and SOI data. The sub-objectives of this objective are as follows:
   2.1. Exploration of the most suitable and available SIR and SOI products for estimating forest maturity parameters according to the inference approaches.
   2.2. Upscaling forest maturity parameters estimated using MLS technologies in objective 1 with SIR and SOI data, and model-based inference techniques.
   2.3. Generation of spatially continuous heat maps with associated estimates of forest maturity parameters.

The present project goes beyond the state-of-the-art techniques for monitoring forest maturity, one of the current challenges in forest strategies, policies and legislation. It is also in line with today's complex applications of active remote sensing for ecology and conservation[21]. Thus, the use of cutting-edge technologies such as MLS and SIR, together with the implementation of AI techniques and digitalization of the outcomes through open-source software, make this ambitious proposal relevant to the RIS3 Strategy for the Central Bohemian Region. In addition, working with spruce forests is particularly important as these are widely distributed in the study area, representing one of the most economically important species in the Central Bohemian Region and across the whole of the Czech Republic. Therefore, estimating forest maturity will help decision-making regarding this type of forests at both regional and national scales, e.g. for trying to maximize ecosystem services related to higher degrees of naturalness, controlling bark beetle outbreaks

[17] Mitchard et al., (2009). Using satellite radar backscatter to predict above-ground woody biomass: A consistent relationship across four different African landscapes.
[18] Gómez et al., (2021). Canopy height estimation Mediterranean forests Spain with TanDEM-X. *J. Selected Topics Applied Earth Obs. Remote Sensing.*
[19] Qi & Dubayah (2016). Combining Tandem-X InSAR and simulated GEDI lidar observations for forest structure mapping. *Remote Sensing Environme.*
[20] Gazzea et al., (2023). High-resolution mapping forest structure from SAR and optical images using enhanced U-net method. *Science Remote Sensing*
[21] Lafiti et al., (2023). Towards complex applications of active remote sensing for ecology and conservation. *Methods in Ecology and Evolution*

as mature spruce forests are assumed to be more resilient to these events and climate change scenarios[22].

1.2 Soundness of the proposed methodology (including interdisciplinary approaches, consideration of the gender dimension and other diversity aspects if relevant for the research project).

The experimental design will be applied to Norway spruce (*Picea abies* L.) forests, in three main study areas (each about 1 ha), one per reference state of maturity (RFM, CCF and OGF, Fig. 1). Those sites would be represented by the following: a) Brdy Highland forest, in which the researcher is already involved by an ongoing project[23] (**RFM**); b) **CCF** in western Slovakia through local foresters already contacted; and c) Žofín virgin forest in south Czech Republic (**OGF**). In addition, a pilot area in Amálie (located in the Central Bohemian Region) is available through the Host organization (HO) *Spatial Sciences in Ecology and Environment Lab* of the *Czech University of Life Sciences* (CZU) will be considered as a supersite for testing methods. This pilot area was promoted by the CZU (project number: CZ-ENVIRONMENT-0124) and focused on the implementation of selected innovative measures representing an active, innovative approach using many disciplines to solve the challenges associated with climate change. The long-time series of data available for this pilot area, obtained with different sensors (optical/LiDAR-UAV, dendrometers, etc.) and RADAR corner reflectors, may be useful for calibrating/validating SIR data. Optionally, new sites could be considered to improve the representation of the maturity gradient if necessary (floating plots). The location of additional sites would be based on knowledge of local experts (HO), as well as Czech National Forest Inventory (CNFI) data, provided in collaboration with the Faculty of Forestry and Wood Sciences through the Professor Surový (considered as a CZU partner in this proposal), available maps, and auxiliary remote sensing data (e.g. SIR). The whole study area will be scanned by MLS, and conventional field measurement will be conducted in subsampling areas (about 25% of the total area). The field data obtained will be used to calibrate/validate MLS estimates and training models.

The concept behind objective 1 is that ground-based LiDAR techniques provide more detailed data about near-ground vegetation than farther away remote sensing techniques. Thus, they can estimate maturity parameters (species mingling, tree size differentiation, etc.) with greater precision and accuracy. In this respect, sub-objective 1.1 will be based on classifying the main tree species present in the study forests (*P. abies*, *Acer* spp., *Betula* spp., etc.). The most common supervised machine learning (ML) algorithms currently in use for classification (neuronal networks, random forest, etc.) will be evaluated. Tree geometric features extracted from point clouds corresponding to specific parts of the trees (bark, crown, etc.) will be used as predictors, as done in other studies[24]. Models will be fitted with 70% of the data and validated with the remaining 30%. The main challenge will be implementing ML algorithms, which will be overcome by the specific knowledge acquired by the researcher during the *Statistical learning* subject in the MSc course in Statistical techniques (academic course 2023/2024, see CV). Sub-objective 1.2 will be conducted in a similar manner to the previous sub-objective. The response variables standing and lying deadwood will be classified (Table), and the volume will then be estimated. For sub-objective 1.3, measurements carried out in the study areas (RFM, CCF and OGF) will be characterized by different structural complexity parameters (Table) to explore how they vary across a degree of naturalness (Fig. 2). Species and deadwood parameters will be analyzed using the results of sub-objectives 1.1 and 1.2. For the other parameters mainly tree position, diameters and heights data will be necessary and can be obtained automatically using the R package FORTLS developed by the researcher[25]. The main challenge here will be implementing the statistical approaches (Table). Although the researcher's background covers some of these approaches, he will also take the *Spatial statistics* subject included in the aforementioned MSc course. In any case, all of these statistical approaches will not necessarily have to be applied, only the most common in the literature are mentioned here to explore the available methodologies. The best models resulting from this objective will be included in the R package FORTLS as new functions for classification of tree species and deadwood and estimation of structural complexity parameters. Although FORTLS will be the main type of software used to process and analyze the MLS data, the researcher may also contemplate using others such as CloudCompare and the FSCT python library, if necessary.

[22] Sommerfeld et al., (2021). Do bark beetle outbreaks amplify or dampen future bark beetle disturbances in Central Europe? *Journal of Ecology*
[23] LIFE21-CCA-CZ-LIFE-Adapt-Brdy/101074426. Faculty of Forestry and Wood Sciences (CZU) as participant
[24] Terry et al., (2020). Tree species classification using structural features derived from TLS. *ISPRS Journal of Photogrammetry and Remote Sensing*
[25] Molina-Valero et al., (2022). Operationalizing the use of TLS in forest inventories: The R package FORTLS. *Environmental Modelling & Software*

Indicator		Features (parameters)	Statistical approach
Main	Native species	Species (species composition, etc.)	Tree species classification (supervised ML)
	Deadwood	Standing (standing deadwood volume, etc.)	Deadwood classification (supervised ML)
		Lying (lying deadwood volume, etc.)	
Complementary	Structural complexity	Multi-layer canopy	Nearest neighbor statistics
		Horizontal structural diversity (tree arrangements, tree species mingling, tree size differentiation, etc.)	Second order statistics
			Kriging and cokriging

The idea behind objective 2 is that information about total cover is needed to generate wall-to-wall maps for large-scale monitoring of forest maturity. SIR is one of the most promising active remote sensing techniques[26] for this purpose, as it produces high temporal frequency data (every 12 days in the case of Sentinel-1), is not influenced by weather conditions and often yields full earth coverage. However, specific research skills are needed to process and analyze the data. This represents the greatest challenge for the researcher, who has only basic experience with RADAR data. Thus, the core part of this objective would be developed in the secondment organization (SO), the University of Edinburgh (UE), where the researcher's co-supervisor (Steven Hancock) and colleagues from the School of Geosciences will teach the researcher the skills required to handle SIR data. Moreover, an assistant professor in the HO (David Moravec) is currently working with SIR data and can support the researcher throughout the fellowship. In a first step (sub-objective 2.1), the most suitable and available SIR products (some only available through proposal submission procedures) for estimating forest maturity parameters will be evaluated. This will be performed under the supervision of the co-supervisor. The same will be done with SOI data (under the guidance of the HO supervisor) in cases where they may be complementary to SIR. For sub-objective 2.2, several inference approaches will be evaluated for upscaling forest maturity parameters derived from MLS calibrated with field data (ground truth), depending on the available SIR data. On the one hand, InSAR techniques are preferable for estimating height-related parameters in the case of twin satellites flying in close formation, as in the TanDEM-X mission. On the other hand, approaches integrating SIR and SOI data with deep learning AI techniques are more appropriate for more complex forest structure parameters, especially SAR missions using longer wavelengths (e.g. forthcoming ESA BIOMASS), as they will be better able to penetrate the forest canopy and thus capture the forest structure more efficiently. In addition, ancillary information such as SLS (e.g. GEDI mission) may be used to calibrate models and improve estimates. Finally, sub-objective 2.3 will involve generating spatially continuous maps for the forest maturity parameters estimated in sub-objective 2.2. Forest typology distribution maps already available will be used to clip the spruce forest area in Czech Republic. The output will enable the maturity of spruce forests in the Central Bohemian Region (in particular) and in the Czech Republic (in general) to be estimated on the basis of the parameters that work well in the previous sub-objectives. Uncertainty maps, a key issue in the current considerations of remote sensing in forestry[27], will be assessed.

The interdisciplinary aspect of the proposed research is depicted in Fig. 3. The research mainly includes a combination of the following disciplines: 1) **environmental studies and forestry** within the branch of the applied sciences (environmental management and silviculture); **formal science** (computer science and mathematics); and **earth sciences** within the branch of natural sciences (geosciences, spatial sciences in ecology and environment). These are integrated in a common methodology based on forest monitoring with **remote sensing techniques**, which is the common link. Forest measurements with ground-based LiDAR techniques can be upscaled using other remote sensing techniques that are more appropriate for environmental studies, such as large-scale estimation of forest maturity. Processing and analyzing remote sensing data requires the involvement of transverse disciplines such as computer science (e.g.

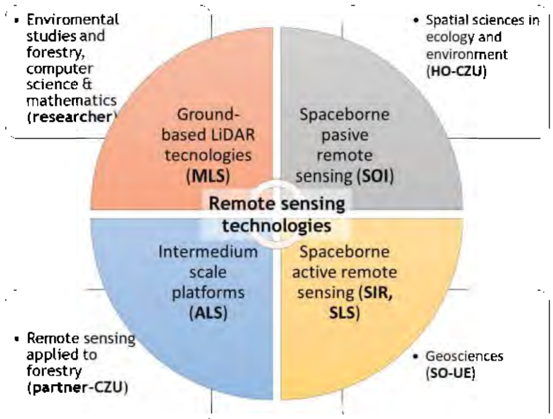


Fig. 3. Interdisciplinarity. All parties are represented: researcher, Host organization (HO), Secondment organization (SO), Faculty of Forestry (partner-CZU).

[26] Qi & Dubayah (2016). Combining Tandem-X InSAR and simulated GEDI lidar observations for forest structure mapping. *Remote Sensing Environme.*
[27] Fassnacht et al., (2023). Remote sensing in forestry: current challenges, considerations and directions. *Forestry: International Journal Forest Researc.*

digitalization, AI) and mathematics (e.g. statistics). Similarly, the outputs of forest monitoring must be evaluated using those disciplines. This action examines an issue that is not gender specific. Additionally, it has no gender discrimination, as indicated by the balance of genders between the researcher and the supervisors; two males (the researcher and the SO co-supervisor Hancock) and one female (HO supervisor Petra Šímová).

Open science practices, based on open cooperative work and systematic sharing of knowledge and tools as early on and widely as possible in the process, will be implemented. The researcher will implement early and open sharing of research by systematically publishing pre-prints of papers in the ResearchGate open access repository. Nevertheless, other practices such as registering reports will be considered for the scientific objectives with the most demanding methodology used to help science limit biases and increase transparency through early peer review of the study design. This will also help to ensure the reproducibility of the research output, together with publication of all scientific papers in open access platforms. Extensive, important parts of the methodology will be included in supplementary material. Regarding software, algorithms and workflows resulting from this proposal, some will be provided in cloud-based Git repositories such as GitHub or the Comprehensive R Archive Network (CRAN) in the case of s. Proof of this is the R package FORTLS developed by the researcher, which is available for users in both CRAN and GitHub (beta version). In fact, all the algorithms developed in the proposed research in terms of ground-based LiDAR technologies will be included in open-source R package FORTLS. Data and other research outputs derived from this action will be managed in accordance with the FAIR principles. According to the **findability** principle, data will be described with rich metadata and registered in trusted repositories (e.g. Yoda) assigning them a persistent identifier. This will also ensure compliance with the principle of **accessibility** for humans and machines. However, downloadable metadata will be publicly available while data will be available upon request. Regarding the **interoperability** principle, all data will be provided in well-known and preferably open formats and software, and a README file (.txt) and the programming scripts used to analyze them will be attached when necessary. Finally, the **reusable** principle will be fulfilled by well-documented support to proper data interpretation and accessible licences recommended in Horizon Europe, such as Creative Commons.

1.3 Quality of the two-way transfer of knowledge between the researcher and the host.

Three objectives are expected to be fulfilled by the researcher's training programme at the HO. The training objectives will be achieved in parallel with the scientific objectives and are considered indispensable for acquiring new knowledge that will allow the researcher to attain a position of professional maturity. Regarding achieving the training objectives, the researcher will be strongly supported by the supervisors and their research teams through coordination meetings and submission of progress reports every 6 months. The ***first training objective*** is to enhance the researcher's competency in the following core and advanced research skills: 1) processing and analyzing remote sensing data in general terms (HO); 2) processing and analyzing SIR data (SO); 3) generation of large-scale forest maturity maps (HO); and 4) learning state-of-the-art statistical techniques by part-time attendance of an online MSc in Statistical techniques (Galician public universities). Accomplishment of the first training objective will mainly focus on training in core skills by the supervisors and their research teams through personalized multidisciplinary training and training-through-research in the context of the research objectives. The personalized training will focus on knowledge that will serve to widen the researcher's competency in the discipline of spatial sciences in ecology and environment by utilizing remote sensing & earth observation and AI in the following topics: 1) detection of natural and near-natural habitats; and 2) biodiversity indicators/proxies across spatial scales. All of these are areas in which the supervisor and her research team are internationally renowned. These activities will be accomplished by direct mentoring by the supervisor (HO) and co-supervisor (SO) (scheduled for the beginning of the fellowship), as well as through internal presentations and interactions in the host research team. The training will be complemented with exercises in programming through courses and self-learning. Following the Horizon Europe's open research initiative, the goals of the present application include the priority use of open-source tools: Python and R for data and statistical analysis, and QGIS for spatial data analysis and geographical information management. The ***second training objective*** is to enhance the researcher's competency in transferable skills, which will mainly be acquired during the sessions organized by the Central Bohemian Innovation Center (SIC) and delivered by experts in their filed. The researcher will participate in at least four relevant training sessions (32 h): open science practices (Open Science/Open Access seminar); preparing scientific proposals and scientific and economic management of projects (funding opportunities/Grant writing workshop); how to crowdfund scientific research (crowdfunding workshop); and work-balance and sustainable career path (leadership skills workshop). The researcher's contribution at conferences and workshop organization related to his topic will be useful for developing transferable skills. The ***third training objective*** will be to enhance the researcher's lecturing skills by the assignment of lecturing duties. In addition, the researcher will also co-supervise bachelor's/master's students on the topic of the present proposal. The soft skills acquired in lecturing will improve the researcher's professional practice in academia. The lecturing/supervising activities of the researcher will serve as a two-way transfer of knowledge: the researcher will acquire additional experience in lecturing, and the HO will benefit from his knowledge on ground-based LiDAR devices apply to forest monitoring and the new research skills acquired during this project, as well as imparting seminars/workshops on the R package FORTLS. The international expertise and networks of the researcher will serve to increase the international mobility of MSc and PhD students to and from the HO. Transfer of knowledge to the local institution will be done through the following: 1) the lecturing assignments of the researcher; 2) contributions made in the HO's internal presentations; and 3) training-through-research activities by accomplishing the research objectives.

1.4 Quality and appropriateness of the researcher's professional experience, competences and skills.

The researcher was awarded a PhD in Forestry in October 2022 and received a prize from the Spanish Society of Forestry Sciences for the best doctoral thesis on forestry in Spain. He has been conducting post-doctoral research at the Faculty of Forestry and Wood Sciences (CZU) since November 2022. The researcher has an H index of 4 and has published 9 papers in scientific journals ranked by their impact factor in the first quantile of the Journal Citation Reports and has made 15 contributions at conferences (7 internationals). The researcher has also published an R package, considered one of the most remarkable outputs of his PhD and relevant to the proposed research. The researcher was granted for his PhD studies and for international mobility, granted with a competitive PhD fellowship for university teacher training from the Spanish Ministry of Education and Science (FPU-MEC). He was recently awarded a one-year postdoctoral fellowship by the *Ramón Areces* foundation to continue his research at the CZU. He has collaborated in the scientific implementation of 6 research projects in Spain and Czech Republic and is currently collaborating with the NS University (USA) and has participated in the organization of 2 conferences, demonstrating his leadership and management skills. He has more than 4 years of experience in lecturing at the USC (Spain), ULE (Spain) and CZU (Czech Republic). The researcher's main areas of expertise are forest inventory, statistical sampling, forest modelling, remote sensing, R programing and the development of algorithms for processing ground-based LiDAR data. The researcher's previous experience is therefore appropriate for integration in the HO, complementing existing lines of research with ground-based LiDAR devices. Estimation of forest maturity is relevant to the HO's research, and the proposed research is also expected to have an impact on the HO, as the researcher will share the experience acquired during his PhD stage in ground-based LiDAR scanning and its application to forest monitoring, areas in which the HO does not yet have any established experts. The researcher will facilitate contacts between the HO and researchers from other institutions.

2. IMPACT

2.1 Credibility of the measures to enhance the career perspectives and employability of the researcher and contribution to his skills development.

This fellowship represents a unique opportunity for the researcher to obtain valuable experience of being involved in cutting-edge academic and industrial forestry innovation, helping him to develop a successful research and development career. During the research and training programmes, the researcher will gain new knowledge, competency and skills both within and beyond his main area of study. Through secondment and collaboration with the project partners, the researcher will learn how to communicate effectively with partners, while enhancing his leadership and team working skills, which are essential for leading positions in academia and industry. These skills are complementary to the researcher's current qualifications and will significantly enhance his scientific career prospects. The researcher aspires, in the medium-term, to obtaining a tenure-track fellowship, while his long-term goal is to obtain a permanent position in academia or in a research institution. These prospects will be greatly enhanced by the present proposal, as the expected outcomes are major aspects considered in the evaluation of candidates. Thus, as a consequence of the fellowship, the researcher is expected to 1) improve his **writing and presentation skills** through high impact scientific publications and participation in conferences; 2) enhance his **transferable skills** by training sessions provided by the SIC; 3) acquire experience in **project management**; 4) increase his experience and **skills in lecturing**; and 5) extend **networking**.

The competency of the researcher in the field of forest modelling and ground-based LiDAR devices in forest monitoring will be extended through newly acquired theoretical and practical knowledge. In this respect, CZU will train the researcher in various aspects of remote sensing and earth observation, with the SO covering SIR technology. The methodological improvements expected to be implemented in relation to monitoring forest maturity will enhance the researcher's ability to deal with innovative concepts, such as that considered in the proposal. Studies in the field of programming and data analysis will broaden the researcher's ability to deal with complex studies. Accomplishment of the research tasks, on the other hand, will enhance the researcher's skills in sharing and exchanging ideas, methods and approaches with scientists working on different research topics and from different backgrounds. He will take advantage of the scientific contacts of the HO with other European scientists, thus providing opportunities for negotiating cooperative scientific projects and initiatives.

The fact that forest maturity monitoring remains a challenge in the international context is a favourable point regarding the researcher's career prospects, as the skills and experience gained within the framework of the fellowship will place the researcher in a leading situation in the international context of this topic. The objective of the present application is to enable the candidate to continue his demonstrated ability by conducting research on a highly relevant topic in an international context, while complementing and enhancing his current skills. The achievements of the researcher during the early stage of his career demonstrate his capacity for independent thinking, leadership and management, and indicate that he will make good use of this fellowship to acquire additional knowledge and experience that will help him to acquire an independent, senior position. Implementation of the training objectives under the guidance of the supervisors and the scientific interaction with their research teams will broaden the researcher's expertise in advanced methods and the use of cutting-edge technologies in forest monitoring. The knowledge and skills that the researcher will acquire, as well as the expected outcomes of the fellowship in terms of scientific publications, software and networks, will increase his chances of obtaining a good position in either academia or technology-based companies.

2.2 Suitability and quality of the measures to maximise expected outcomes and impacts, as set out in the dissemination and exploitation plan, including communication activities.

The main method of disseminating the results of the present application in the scientific community will be by publication of open-access scientific papers. Four papers are expected to be submitted for publication, with the following tentative titles: **P1**) "Classification of tree species in Norway spruce forests using ground-based LiDAR and artificial intelligence techniques"; **P2**) "Detection and characterization of deadwood using ground-based LiDAR and artificial intelligence techniques"; **P3**) "Estimating forest structure from SAR and optical images with machine learning algorithms"; **P4**) "Mapping forest maturity from integrated SAR and optical images with machine learning algorithms". The topics of the papers correspond to the research objectives, and the journals to which the manuscripts will tentatively be submitted are *ISPRS Journal of Photogrammetry and Remote Sensing* (P1-2) and *Remote Sensing of Environment* (P3-4). Results of the present research will also be presented at scientific conferences on the topic under study. Thus, the researcher is expected to present the research results at the most important international conferences on the application of spatial analysis techniques in forestry "ForestSAT 2024" (**Co1**, Rotorua, New Zealand, 9-13.09.2024), LiDAR technologies in forestry "SilviLaser2025" (**Co2**, 09.2025) and the International Geoscience and Remote Sensing Symposium "IGARSS 2026" (**Co3**, Washington DC, 19-24.07.2026). The researcher will participate in the regular scientific departmental meetings organized by the HO. As scientists are not the only potential users or beneficiaries of the expected outcomes, the researcher will also consider creating a workshop (**Wo**) just after finishing the fellowship in collaboration with the HO and open to all interested parties (researchers, students, technicians, etc.).

The aims of this proposal include broadcasting the research results and promoting the research profession both in society in general and specifically in the non-scientific community. The researcher will undertake three main activities in this respect: **C1**) outreach activities in (or organized by) the HO such as summer schools, **C2**) outreach activities organized jointly with the European Commission, and **C3**) communication activities. Regarding **C2**, the researcher will participate in the European Researchers' Night, held every year in September. The goal of this activity is to promote the research activities of researchers to a wider audience. Regarding **C3**, the researcher will contribute with interviews to the Welcome Centre of the CZU, in which he will present a simplified overview of the research approach and will explain the overall aims and objectives of the proposed research. These activities highlight the ongoing research activities of academia, and the target audience is the general public interested in science. In C1, C2 and C3, the use of everyday language and simplifications are important to allow non-academic audiences and academics from different areas to understand the ongoing research activities. The researcher will also create a personal website during the first year of the fellowship in order to publicize the project outputs.

The HO, in accordance with the "European Charter for Researchers", confirms that the researcher will secure the benefits of the exploitation (if any) of R&D results through legal protection and, in particular, through appropriate protection of Intellectual Property Rights, including copyrights. Some of the methods resulting from the present proposal are expected to be implemented in open-source software with a General Public Licence v3.0. This will simplify implementation of the methods developed in the present proposal.

2.3 Sustainability of the candidates' research project in the Region. Opportunities to continue the research through regional/international collaboration with relevant industry or academic sectors.

The project results are expected to have a positive impact at regional level in many sectors of society. Firstly, in the scientific sector, by generating new methodologies for large-scale estimation of forest maturity, which will have an impact on decision-making related to environmental aspects of spruce forests. This will enhance forest planning, which can also improve economics aspects for society. The strategy for connecting this project with relevant international academic sectors will be performed by the planned secondment at the UE. All of the dissemination tasks will help to connect this project with different sectors. In addition, this research will be sustained in the region by further funding, for example by means of ERC grants which support projects carried out by talented early-career scientists who have already produced excellent supervised work. These grants will bring investment to the Central Bohemian Region.

3. IMPLEMENTATION

3.1 Quality and effectiveness of the work plan and assessment of risks.

3.1.1. Work package description: To achieve the proposed objectives, the following work packages (WPs) are defined. Each WP is described by the specific tasks (T) and objectives to which it refers, and the resources and the data to be used for its successful execution. The progress of the project will be monitored with the Gantt chart shown below.

WP1: *Project management*. T.1.1 Career Development Plan (CDP); T1.2 Coordination meetings with the Supervisor; T1.3 progress reports; T1.4 management of financial issues; and T1.5 contingency planning (see 3.2.2).

WP2: *Training and career development*. T2.1 training in core and advanced research skills; T2.2 Training in transferable skills; and T2.3 training in lecturing skills. T2.2 will be carried out according to SIC organization after defining CDP.

WP3: *Dissemination and public engagement*. T3.1 Dissemination among the scientific community; T3.2 dissemination among end users of the research results; and T3.3 communication and public engagement with society in general. T3.1 refers to activities P1-P4 and Co1-Co3 (see 2.2.2); T3.2 to activity Wo; and T3.3 to activities C1-C3.

WP4: *Estimation of the degree of forest naturalness according to maturity indicators with detailed in-situ measurements based on ground-based LiDAR data* (objective 1). T4.1 data acquisition and processing; T4.2 classification of main tree species using ground-based LiDAR techniques and AI techniques; T4.3 detection and characterization of deadwood using ground-based LiDAR and AI techniques; T4.4 characterization of forest maturity according to structural attributes.

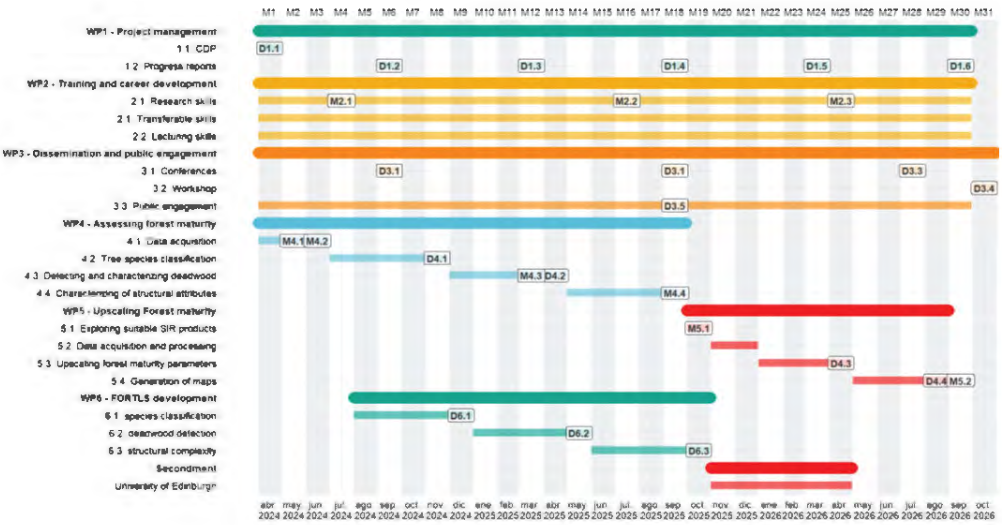
WP5: *Upscaling forest maturity estimation to regional scale with spaceborne imaging radar (SIR) techniques* (objective 2). T5.1 Exploring the most suitable SIR products for estimating forest maturity attributes; T5.2 SIR data acquisition and processing; T5.3 upscaling forest maturity parameters measured in-situ by using model-based inference approaches with SIR data; T5.4 Creation of forest maturity maps and assessment of its uncertainty.

WP6: *Implementation of results previously found in FORTLS*. This WP will be parallel to the whole project proposed here. This will consist of improving and adding new functionalities to the R package FORTLS, which will be an essential tool for achieving the proposed objectives. These functions will be T6.1 species.classification; T6.2 deadwood.detection; and T6.3 structural.complexity.

3.1.2. List of major deliverables. The main expected deliverables (D) for the project management are CDP (D1.1) and the progress reports (D1.2-D1.6). Five deliverables are expected regarding dissemination and public engagement: D3.1-D3.3 correspond to the three conferences which the candidate is expected to attend (Co1-Co3); D.3.4 correspond to the workshop imparted after the end of the project (Wo); and D3.5 corresponds to the outreach and dissemination activity C2 described in 2.2. Regarding the scientific objectives, four scientific papers are expected to be produced (D4.1-D4.2, D5.1-D5.2). Finally, three functions are expected to be implemented in the R package (D6.1-D6-3).

3.1.3. List of major milestones. In the case of the training objectives, three milestones are expected, two at the end of academic courses 2023/24 and 2024/25, related to the MSc in Statistical techniques (M2.1-M2.2); and another at the end of the secondment (M2.3), when the researcher is expected to have gained strong skills in processing SIR data. In addition, another milestone will be reached when the dataset is acquired for use in WP4 (M4.2). A further milestone (M4.4) will be reached when the objectives for WP4 are met, allowing the next WP to begin. The same for WP5 (M5.2).

3.1.4. Contingency plan. The risk management plan will be formulated in cooperation with the supervisors. For the research objectives, an endangering factor is the availability of a sufficient number of plots to accurately represent the level of forest maturity. Nonetheless, all the data corresponding to the lowest levels of maturity (RFM) will be available from the beginning of the project. At milestone M4.1, a decision will be made about whether some levels of maturity should be avoided, or study areas reduced. Regarding WP4, if the second sub-objective, which is considered the most complicated in this WP, proves too difficult and threatens to hamper achieving the overall project objectives, it may be removed. A decision will be reached at milestone M4.3. Another milestone will be considered after exploring SIR products (M5.1), which will be decisive for planning suitable SIR approaches. Situations not considered in this contingency plan will be resolved as part of the project management.



3.2. Relevance, feasibility and benefit for the research project objectives of the planned secondments. Quality of the secondments choice in terms of at least one of the following principles: intersectorality, interdisciplinarity or international mobility.

The secondment of 6 months at the University of Edinburgh is consistent with the second scientific objectives of this project. This objective is to upscale forest maturity estimation to regional scale with SIR and SIO techniques (the latter when necessary). For this purpose, the SO is considered one of the most prestigious universities in the world regarding SIR data. Proof of this is the remarkable book "Introduction to Microwave Remote Sensing" written by the professor Iain Woodhouse (Personal Chair in Applied Earth Observation). Moreover, the co-supervisor at the SO, Steven Hancock, also has an outstanding professional career in this topic. He has an H index of 31 and has led several projects and papers in collaboration with Professor Woodhouse and other departmental colleagues. He is therefore the perfect candidate to co-supervise the researcher in this secondment, providing significant added value learning in the latest techniques in the processing and analysis of SIR technologies. This collaboration will not only give added value to the HO through publication of high quality scientific articles together with EU, but will also reinforce new collaborations (PhD, Postdoc, etc.) between the two institutions. This secondment represents a good example of **international mobility**, providing the aforementioned professional skills and also others such as social and intercultural skills. This project is also considered **interdisciplinary**, as different technologies of remote sensing and methodologies will be used.

Zápis z jednání Steering Committee MERIT ze dne 11.12.2023

Přítomni:

- XXXXX– předsedající Steering Committee
- XXXXX– člen Steering Committee
- XXXXX– člen Steering Committee
- XXXXX– členka Steering Committee
- XXXXX– Programová manažerka MERIT
- XXXXX– Finanční manažerka MERIT

Omluvena:

- XXXXX– členka Steering Committee

Agenda:

1. Zahájení, schválení programu schůze

Program schůze:

- **Rekapitulace stavu úkolů z minulého jednání**
- **Představení výběrového procesu**
- **Schvalování předložených projektů**
- **Termíny následujících jednání + zamyšlení nad informacemi potřebnými pro monitoring vědeckých projektů**

Návrh usnesení:

Řídicí komise MERIT bere na vědomí program jednání.

Výsledky hlasování

Pro: 4; Proti: 0

Přijaté usnesení:

Řídicí komise MERIT bere na vědomí program jednání.

2. Úkoly z minulého jednání

- Vytvořeno sdílené úložiště pro členy SC v prostředí Microsoft 365
- Aktualizovaný jednací řád a seznam zúčastněných partnerských institucí programu MERIT poslán členům SC
- Připravena Dohoda o mlčenlivosti (Non-disclosure agreement) kvůli zajištění důvěrnosti informací členů Steering Committee, podepsána všemi členy (přílohy tvořily ještě prohlášení v AJ: Prohlášení o důvěrnosti, neexistenci střetu zájmů a nediskriminaci, kvůli splnění podmínek projektu vůči EU)

Návrh usnesení:

Řídicí komise MERIT bere na vědomí stav úkolů z minulého jednání.

Výsledky hlasování

Pro: 4; Proti: 0

Přijaté usnesení: *Řídicí komise MERIT bere na vědomí stav úkolů z minulého jednání.*

3. Stručné představení výběrového procesu

- PPT prezentace Programové manažerky

Návrh usnesení:

Řídicí komise MERIT bere na vědomí informaci o průběhu výběrového procesu první výzvy programu MERIT.

Výsledky hlasování

Pro: 4; Proti: 0

Přijaté usnesení: *Řídicí komise MERIT bere na vědomí informaci o průběhu výběrového procesu první výzvy programu MERIT.*

4. Schvalování předložených projektů

- Členům komise byla předem sdílena tabulka s přehledem kandidátů, jejich umístění, včetně navrhovaných secondmentů, stručné abstrakty řešených projektů, a dále kompletní projektové návrhy a hodnotící reporty z obou kol hodnocení
- Všechny projekty prošly hodnocením v mezinárodním transparentním výběrovém řízení v souladu s pravidly programu MERIT.

Návrh usnesení:

Řídicí komise schvaluje celkem 23 projektů předložených do první výzvy programu MERIT, z nichž 15 projektů, které získaly v hodnocení nejvyšší skóre, budou podpořeny, a 8 rezervních projektů může být podpořeno v případě, že některý z podpořených projektů nebude realizován.

Výsledky hlasování

Pro:4 ; Proti: 0

Přijaté usnesení – *Řídicí komise schvaluje celkem 23 projektů předložených do první výzvy programu MERIT, z nichž 15 projektů, které získaly v hodnocení nejvyšší skóre, budou podpořeny, a 8 rezervních projektů může být podpořeno v případě, že některý z podpořených projektů nebude realizován.*

Řídící komise zároveň navrhuje prověřit zejména ruské žadatele a žadatele z třetích zemích z důvodu bezpečnostního rizika realizace jejich projektů (BIS).

5. Plán pro druhou výzvu a termíny následujících setkání

- ČERVENEC 2024 – monitoring po prvním reportovacím období (zprávy o průběhu realizace projektů, komunikační a diseminační aktivity vědců, účast vědců na akcích SIC apod.)
- ZÁŘÍ 2024 – schvalování projektů vybraných v druhé výzvě programu

- LEDEN 2025 – monitoring po druhém reportovacím období (zprávy o průběhu realizace projektů, komunikační a diseminační aktivity vědců, účast vědců na akcích SIC apod.)

Návrh usnesení:

Řídicí komise MERIT bere na vědomí plán pro druhou výzvu programu a termíny následujících jednání.

Výsledky hlasování

Pro:4; Proti: 0

Přijaté usnesení

Řídicí komise MERIT bere na vědomí plán pro druhou výzvu programu a termíny následujících jednání. Řídíce komise stanovila termín na příští setkání k prvnímu reportovacímu období dne 25.7.2024.

6. **Zamyšlení nad informacemi potřebnými pro monitoring projektů**

- Monitoring bude probíhat jednou za 6 měsíců, informace budou pravidelně poskytovány ze strany výzkumných organizací (supervizor + vybraný stážista)

Návrh usnesení:

Řídicí komise MERIT bere na vědomí obsah monitorovacího reportu a schvalují navržené změny.

Výsledky hlasování

Pro:4.; Proti:0

Přijaté usnesení

Řídicí komise MERIT bere na vědomí obsah monitorovacího reportu a schvaluje navržené následující změny, které budou vloženy do monitorovacího reportu:

- neúspěchy a případné změny projektu,

- informace, zda je projekt v souladu s harmonogramem,

- informace o tom, v jakém stavu se projekt nachází,

- milníky projektu.

Monitorovací Report bude upraven a poslán Řídicí komisi k odsouhlasení.

Zapsala:
XXXXX
Programová manažerka MERIT

Zápis ověřil:
XXXXX
Předsedající Steering Committee

Příloha: Seznam schválených projektů

Seznam 15 kandidátů s nejvyšším skóre

Name of the candidate	Host organisation	Final score
Bláha, Pavel	ELI Beamlines Facility - The Extreme Light Infrastructure ERIC	95,8
Trifonov, Vladimir	Institute of Animal Physiology and Genetics of the Czech Academy of Sciences	95,7
Moudra, Alena	National Institute of Mental Health	94,7
Grossschedl, Josefa	Astronomical Institute of the Czech Academy of Sciences	89,9
Gormaz-Matamala, Alex	Astronomical Institute of the Czech Academy of Sciences	89,7
Stojak, Joanna	Institute of Animal Physiology and Genetics of the Czech Academy of Sciences	87,8
Owolabi, Bayode	Institute of Thermomechanics of the Czech Academy of Sciences	85,6
Pavlik, Vaclav	Astronomical Institute of the Czech Academy of Sciences	84,1
Filippov, Evgeny	ELI Beamlines Facility - The Extreme Light Infrastructure ERIC	83,3
Molina Valero, Juan Alberto	Czech University of Life Sciences Prague	82,3
Paul, Nitish	Institute of Physics of the Czech Academy of Sciences / HiLASE	81,5
de Campos Souza, Paulo Vitor	Czech Technical University in Prague, Czech Institute of Informatics, Robotics, and Cybernetics	81,4
Zajdel, Radoslaw	Research Institute of Geodesy, Topography and Cartography	81,1
Koshiba, Yuya	Institute of Physics of the Czech Academy of Sciences / HiLASE	80,1
salehipour, fatemeh	UCEEB Czech Technical University in Prague, University Centre for Energy Efficient Buildings	78,9

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Central Bohemia Region

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Seznam 8 rezervních kandidátů

Name of the candidate	Host organisation	Final score
Henegariu, Octavian	National Institute of Mental Health	76,8
Ullah, Najeeb	Institute of Microbiology of the Czech Academy of Sciences	76,1
Khoptar, Alina	Research Institute of Geodesy, Topography and Cartography	76,1
Popov, Sergey	Astronomical Institute of the Czech Academy of Sciences	74,7
Abouaiana, Ahmed	UCEEB Czech Technical University in Prague, University Centre for Energy Efficient Buildings	74,6
Jeevanandam, Jaison	National Institute of Mental Health	74,5
Haque, Md. Mozzammel	Institute of Animal Physiology and Genetics of the Czech Academy of Sciences	73,8
Munoz, Patricio	ELI Beamlines Facility - The Extreme Light Infrastructure ERIC	73,6