Trilateral Partnerships - Cooperation Projects between Scholars and Scientists from Ukraine, Russia and Germany
– VolkswagenStiftung –

Project title

The past development, present status and likely futures of Norway spruce in Western Ukraine, Northwest Russia and Southwest Germany - A scenario-based projection of forest resources and wood supply to support transition to green economies - SURGE-Pro

Partners

- **Partner 1:**

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Zusammenfassung (German)

In den letzten Jahrhunderten wurde in vielen Ländern Mittel-, Nord- und Osteuropas bei der Wiederbewaldung und Waldrestaurierung die Rotfichte (*Picea abies* [L.] Karst.) bevorzugt. Die Fichte ist leicht zu etablieren und zu bewirtschaften, hat schnelle Wachstumsraten und lässt hohe wirtschaftliche Erträge erwarten. Heute wird das Verbreitungsgebiet der von der Fichte dominierten Wälder weitgehend durch frühere Bewirtschaftungspraktiken und nicht durch natürliche Faktoren bestimmt. Während in Nordwestrussland der größte Teil der Fichte in ihrem natürlichen Verbreitungsgebiet vorkommt, reicht sie in der Westukraine und noch mehr in Südwestdeutschland weit über das angenommene natürliche Verbreitungsgebiet hinaus. Aufgrund von Umweltveränderungen und Änderungen der Bewirtschaftungsziele ändert sich die Zusammensetzung der Waldbaumarten bereits heute. Diese Veränderungen werden Auswirkungen auf die Holzproduktion sowie auf die Kohlenstoffbindung, den Nährstoffkreislauf, die Artenvielfalt und die Resistenz gegenüber abiotischen und biotischen Störungen haben. Die damit verbundenen Veränderungen der Zusammensetzung, Struktur und Funktion der Wälder wirken sich auf nahezu alle Produkte und Dienstleistungen aus, einschließlich der sekundären Auswirkungen auf das Einkommen der Waldbesitzer und auf das Klimaschutzpotenzial dieser Wälder.

In Mittel- und Osteuropa ist die Fichte derzeit einer beispiellosen Bedrohung durch mehrere abiotische und biotische Stressfaktoren ausgesetzt. Die gegenwärtige Waldgesundheitskrise weist auf die geringe Widerstandsfähigkeit und Anpassungsfähigkeit der Fichte an den Klimawandel hin, und untermauert ihre Anfälligkeit für die Klimaerwärmung. Dies gibt Anlass, die Größe des Klimaschutzpotenzials der zukünftigen Wälder in Frage zu stellen.

In dem vorgeschlagenen Forschungsprojekt werden wir die frühere Entwicklung und den gegenwärtigen Zustand der Fichte in den drei Partnerregionen (Westukraine, Nordwestrussland und Südwestdeutschland) analysieren und mittelfristige klimasensitive Szenarien erstellen, die Prognosen zur Versorgung mit Fichtenholz mit besonderem Schwerpunkt auf dem Übergang zu einer klimaneutralen grünen Wirtschaftsweise liefern. Die erwarteten Ergebnisse werden einmalige und zeitnahe Informationen über die künftige Verfügbarkeit von Fichtenholz (insbesondere Stammholz) in den drei Modellregionen in Europa sein. Diese Informationen werden für den Forst- und Holzsektor sowie für die politische Entwicklung im Hinblick auf den Übergang zu Green Economies in Europa von hoher Relevanz sein.

Summary (English)

During recent centuries Norway spruce (*Picea abies* [L.] Karst.) was often favored in forest restoration activities in many Central, Northern and Eastern European countries; it was easy to establish and manage, had fast growth rates and was expected to provide high economic returns. Today, the range of Norway spruce dominated forests is largely determined by former management practices rather than by natural factors. While in Northwest Russia most of Norway spruce occurs within its natural range, in Western Ukraine and even more in Southwest Germany it reaches far beyond its assumed range. Due to environmental changes and changes in management aims, forest tree species composition is already changing. These changes will have an impact on wood production as well as on carbon sequestration, nutrient cycling, biodiversity, and resistance against storm, snow, drought, fires, insects and fungi. Associated compositional, structural and functional changes of forests will affect almost all goods and services provided by forests including secondary effects on income of forest owners and on the climate change mitigation potential of these forests.

In Central and Eastern Europe Norway spruce is currently facing unprecedented severe threats by multiple abiotic and biotic stressors. The current forest health crisis points to the low resilience and adaptability of Norway spruce to climate change, and underpins its vulnerability to climate warming, hence, giving reason to question the size of the climate change mitigation potential of the future forests.

In the suggested research study, we will analyze the past development and present status of Norway spruce in the three partner regions (Western Ukraine, Northwest Russia and Southwest Germany) and provide climate sensitive scenario-based mid-term projections of Norway spruce wood supply with special focus on the transition to carbon-neutral green economies.

The expected results will be unique and timely information on future availability of Norway spruce wood (particularly timber) in the three model regions in Europe. This information will be of high relevance for the forestry-wood sector and for the policy development towards transition to green economy in Europe.

Project description

State of the art

For centuries, forests in European countries have been affected by misuse, resulting in forest loss and causing devastation and soil degradation. Applying great efforts to eliminate severe wood shortages in the past, countermeasures were taken by planting and tending highly productive forests. Norway spruce (*Picea abies* [L.] Karst.) was often favored because it was easy to establish and manage, had fast growth rates and was expected to provide high economic returns. Its robustness and high competitiveness made it the preferred species for forest restoration in many Central, Northern and Eastern European countries over the last two centuries (Spiecker et al. 2004). The use of ordinary silvicultural methods, low cost of planting (including repair planting) and relatively little damage by browsing also promoted the expansion of coniferous forests. Today, the range of Norway spruce forests is largely determined by former management practices rather than by natural factors.

Contemporary forest management needs to address and optimize the production of various goods and provision of services to meet changing demands claimed by an increasing number of stakeholders (Douglas & Simula 2010). In Europe, societies request sustainable forestry with emphasis on biodiversity and close-to-nature forest management, simultaneously producing timber, as well as providing water and soil protection, carbon sequestration, local climate regulation, opportunities for recreation, and preservation of cultural heritage. As there are extensive secondary Norway spruce forests in many European countries, several countries are faced with the question whether these forests will continue to fulfill society’s needs under changing environmental conditions in an efficient way.

At present, Norway spruce forests are distributed far beyond their assumed natural range in many parts of Europe. While in Northwest Russia most of Norway spruce occurs within its natural range, in Western Ukraine and even more in Southwest Germany it reaches far beyond its assumed range. Due to environmental changes and changes in management aims, forest tree species composition is already changing. These changes will have an impact on wood production as well as on carbon sequestration, nutrient cycling, biodiversity, and resistance against storm, snow, drought, fires, insects and fungi (Spiecker et al. 2000). Associated compositional, structural and functional changes of forests will affect almost all goods and services provided by forests including secondary effects on income of forest owners and on the climate change mitigation potential of these forests.

In Central and Eastern Europe Norway spruce is currently facing unprecedented severe threats by multiple abiotic and biotic stressors (Dyderski et al. 2018). The current forest health crisis points to the low resilience and adaptability of Norway spruce to climate change (Frank et al. 2017), and underpins its vulnerability to climate warming, hence, giving reason to question the size of the climate change mitigation potential of the future forests (Hasenauer et al. 2017). In the suggested research study, we will analyze the past development and present status of Norway spruce in the three partner regions (Western Ukraine, Northwest Russia and Southwest Germany) and provide climate sensitive scenario-based mid-term (30 years) projections of Norway spruce wood supply with special focus on the transition to carbon-neutral green economies.

Preliminary results from the existing cooperation

The suggested project is based on the successful partnership and results of the trilateral partnership project SURGE – *“Strengthening the Adaptive Potential of the Forests of Western Ukraine, Northwest Russia and Southwest Germany to Changing Environmental Conditions and Societal Needs”* (mobility project, March 2016 to June 2018). The SURGE-project served as a precursor to the SURGE-Pro research proposal.

The core achievements of the SURGE-project were:

(i) the lessons learnt from a SWOT analysis in which we assessed and evaluated the strengths, weaknesses, opportunities and threats involved in managing the forest resources in each model region (Western Ukraine, Northwest Russia and Southwest Germany),
(ii) the project allowed us to establish demonstration plots at the Ukrainian and Russian partner institution for educational, training and research purposes,
(iii) the project enabled setting-up of tree-ring measurement stations at the two partner institutions supported by training workshops in laboratory tree-ring measurement and dendroecological analyses as measures of sustained capacity building in silvicultural techniques, production ecology and forest growth research, as well as,
(iv) the consolidation of a successful, active and trustful cooperation between the partners from Ukraine, Russia and Germany.

The trilateral partnership program gave young, second and third level as well as senior forest scientists, scholars and forestry practitioners from Ukraine, Russia and Germany the possibility to openly discuss in a harmless environment issues of forest-based land-use management in the context of contrasting social, economic and political concepts in the different regions. The project stimulated visionary thinking about possible forest futures in each partner region (Fig. 1) and motivated young scientists to be more intensively involved in developing the respective scientific background and strengthening the trilateral partnership in the future.

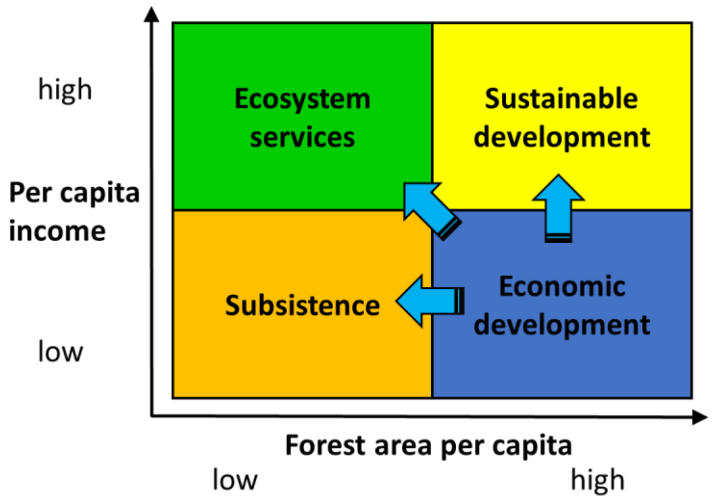

Figure 1: Trajectories of the societal importance of forests depending on forest area and income per capita.

Rationale and objectives

The overall objective of the cooperative SURGE-Pro research proposal is the consistent assessment of the potential future role of Norway spruce in the three model regions. The primary aim is to provide reliable estimates of the future supply of Norway spruce wood as a renewable resource to facilitate and support the transition to green economy. Building on the past development and present status, we will at the same time assess and evaluate the implications of the Norway spruce-based scenarios for the provision of other forest ecosystem services like regulating, social and supporting services. The proposed study serves as the platform to intensify the existing partnership by focusing the collaboration on these highly relevant topics.

The addressed topics are mutually highly relevant because:

(i) Norway spruce covers substantial forest areas in Western Ukraine (approx. 0.7 x 10^6 ha, Lavnyy & Spiecker 2007), Northwest Russia (1.6 x 10^6 ha, Lioubimow et al. 1998), and in Southwest Germany (0.5 x 10^6 ha, Kändler & Cullmann 2014),

(ii) Norway spruce is among the forest tree species with the highest productivity in terms of wood volume production (m^3/ha/yr), and it stands out due to its ability to sequester large amounts of carbon (t C/ha/yr) (Kändler & Cullmann 2014),

(iii) Norway spruce dominated forests are among the forest types with the largest growing stock (standing wooden biomass, m^3/ha) (Kändler & Cullmann 2014), why these forests store large amounts of carbon, and are of significant importance for the terrestrial carbon pools,

(iv) Norway spruce is increasingly facing severe threats by multiple abiotic and biotic stressors, why mortality is currently boosting in many Central European forests (Etzold et al. 2019) and,

(v) due to its excellent technical wood properties and its large share of timber yield Norway spruce is considered to be among the timber tree species with the highest substitution potential, strengthening the role of forests in climate change mitigation (Sathre & O'Connor 2010).

The planned outreach activities will support transfer of the newly generated information and scientific knowledge into forest-based land-use planning (Lavnyy & Spathelf 2016) and will guide decision makers on strategic, tactical and operational levels through the active participation of actors in the dissemination of project results.

Hypotheses

We hypothesize,

(i) that current trends in growth and productivity, and in mortality and regeneration of Norway spruce in Western Ukraine and Southwest Germany are indicative of a non-sustainable development

(ii) that gains in Norway spruce growth and productivity in the boreal forests of Northwest Russia can partially compensate for losses in the other regions.

Methods

We developed our research plan along three data streams: forest inventory data, forest growth data, and satellite data (Fig. 2). The three data streams are closely interlinked through the forest growth simulator.

Forest inventory data

Data from National Forest Inventories (NFI) provide precise, accurate and spatially representative data on the forest resources. The theories and concepts of NFIs are well developed (Tomppo et al. 2009). Whereas NFI data are publicly available for Germany (https://www.bundeswaldinventur.de/), no such systematically surveyed current data are at disposal for Ukrainian and Russian forests. Here data from stand-wise forest management planning need to be processed, compiled and scaled-up to achieve comparable representativity and statistical power (Alekseev 2019, Alekseev et al. 2019b). We aim at covering a 30-year observation period with spatially representative data on the forest resources (ca. 1985-2015). Our model regions are Lviv, Ivano-Frankivs'k, Chernivtsi, and Sakarpatska (Transcarpathia) in Western Ukraine, Leningrad, Novgorod, and Pskov region in Northwest Russia, and Baden-Württemberg in Southwest Germany. The project will make use of results from former studies (Alekseev 2018, 2019, Alekseev et al. 2019b, FAO 2012, Kändler & Cullmann 2014, Lavnyy & Spiecker 2007, Lioubimow et al. 1998, Päivinen et al. 1999). The forest survey data will provide the basic input for the forest growth simulation (Fig. 2).

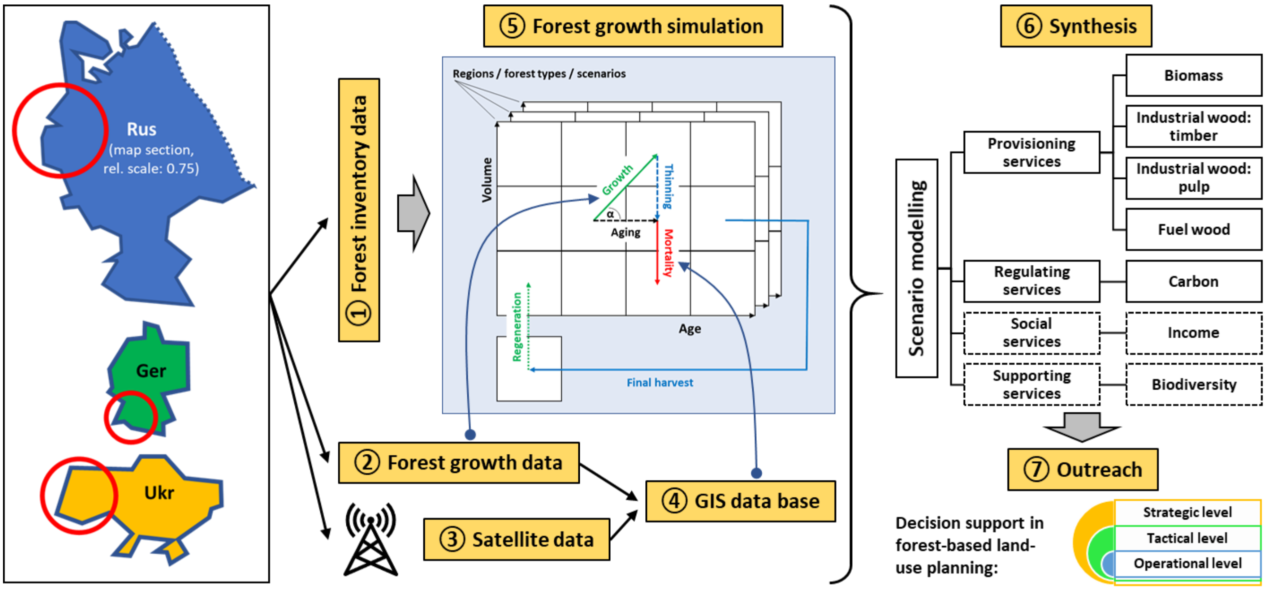

Figure 2: Process diagram indicating the partner regions, data streams, work flows and type as well as sequence of work packages (WP ① to ⑦). Solid dark blue arrows indicate that outputs from WP2 (updated growth data) and WP4 (updated mortality data) provide input to WP5. Dashed contour lines in the vertical box-list on the right-hand side indicate, that due to capacity limitations within the framework of the project these items will only be dealt with at lower level of detail.

Forest growth data

Through the measurement of increment cores and the analysis of the tree-ring data it is possible to achieve a quantitative retrospective view into the growth dynamics of trees. The sampling will be designed in a way that in combination with proper data analysis and modelling, scaling-up the growth data to the stand-level will be possible. We aim at covering a period of several decades with data on tree growth including most recent years. The primary aim of the retrospective analysis of the data on forest growth is to parameterize regional-specific updated forest growth functions to be implemented in the forest growth simulator (Fig. 2). Together with the satellite data, the data on forest growth serve as well as input for the GIS data base (Fig. 2), where remotely sensed information on tree and stand vitality and mortality rates will be spatially and temporally linked to the forest growth data.

Satellite data

Increased availability of remotely sensed data (e.g., satellite data) on the state of forests on large spatial extents and on timely basis offers new possibilities for the use of these data in forest-based land-use management. Applications of satellite data include, assessment of land forest cover, of forest land use, of forest resources, of forest health, as well as forest mapping (e.g., Masek et al. 2008, Soenen et al. 2010, Ivits et al. 2014, Hasenauer et al. 2017). Prerequisites to these applications are, (i) the availability and accessibility of respective digital data, (ii) the possibility to manage the data in a relational database, and, (iii) the availability of efficient software tools to screen and analyze the data. Relevant multi-temporary satellite data (from the 1980ies up to most recent) are publicly available, can be freely downloaded and used for research purposes (e.g., USGS Earthexplorer, https://earthexplorer.usgs.gov/). A satellite database with data sets of different spatial resolutions and temporal extents, and with varying spectral and radiometric resolutions will be compiled in the course of the project. Suitable image interpretation software allowing different approaches of image analysis (e.g., supervised, unsupervised, knowledge-based, segmentation etc.) is already in use at the partner institution (P2).

In the past, the most popular satellite images for land cover/land-use interpretation have been Landsat images which cover the time period from the 1980ies up to now. These data have been used for multi-temporal investigations of forest cover changes (Zhang & Zhang 2007, Wulder et al. 2008, Tokar et al. 2019), forest health monitoring and research into forest disturbances (Masek et al. 2008, Schmidt et al. 2015, Datta et al. 2018). More recently MODIS satellite images have been used for regional and large-scale studies (Hasenauer et al. 2017), and since 2015 high-resolution Sentinel-2 images are available for regional and local studies. Several recent studies made intensive use of the NDVI-approach (Normalized Difference Vegetation Index) to detect extent and severity of abiotic and biotic stresses on forest vegetation and subsequent forest tree mortality due to drought, insect infestations, windstorms, forest fires etc. (Wang et al. 2004, Wessels et al. 2012, Ivits et al. 2014, Keersmaecker et al. 2014, Datta et al. 2018, Seftigen et al. 2018). A recent modification of the NDVI is the EVI (Enhanced Vegetation Index) which has successfully been used by Ma et al. (2013), Walker et al. (2014), Watts & Laffan (2014), and White et al. (2014) for similar purposes.

For our investigations we will use different kinds of digital satellite images (Landsat, MODIS, Sentinel-2) to screen the crown vitality of forest stands in our model regions, to identify putative stressors, and, together with field data, to assess subsequent extent and severity of tree mortality. Existing images for our areas of interest are maintained and directly accessible at USGS-Earthexplorer, https://earthexplorer.usgs.gov/. Together with data on forest growth, the satellite data serve as input for the GIS database (Fig. 2).

Forest growth simulation

The forest resources projections will be developed through the parametrization of an existing forest growth simulator to the model regions (EFISCEN, Sallnäs, 1990, Verkerk et al. 2016). The model-based assessment of future trends in resource availability will follow scenarios of anticipated changes in the forest composition and growth, legal frameworks, wood trade rules and trends in management practices (Oehmichen et al. 2017, Kilham et al. 2018 and 2019). Forest futures scenarios of NGOs, like the Forest Vision of Greenpeace (Böttcher et al. 2018), will be considered as well.

EFISCEN was particularly designed to accommodate different data sources about forest conditions. For each region it has to be adapted to the available data, be it from sample based national forest inventories (like in Baden-Württemberg), or be it from forest management databases (like in Western Ukraine and Northwest Russia). The EFISCEN-based assessment of forest development and timber supply in the three regions will provide consistent and comparable results. On the one hand growth modelling and management practices have to be adapted to each region, as they represent different site conditions and silvicultural regimes; on the other hand, a common understanding and harmonized scenarios will be developed jointly by the involved partners. Accounting for the effect of climate change on growth will most probably show different developments between the regions.

Expected outcomes

The expected results will be unique and timely information on future availability of Norway spruce wood (particularly timber) in the three model regions in Europe. This information will be of high relevance for the forestry-wood sector and for the policy development towards transition to green economy in Europe.

The results obtained on future supply of Norway spruce timber are not only relevant for the respective forest enterprises and wood industries, but are also of great interest from a scientific perspective as methodological issues will be addressed as well: for the Baden-Württemberg region the results provided by the EFISCEN-based approach will be compared with timber supply assessments generated by the WEHAM-model, the simulation model used in the analysis of the German National Forest Inventory data regarding future forest development and timber supply projections (Kändler & Riemer 2017, Oehmichen et al. 2017, Kilham et al. 2018 and 2019). This comparison will allow a validation of the results obtained by EFISCEN and will help to improve timber supply projections as well as to assess uncertainty of the results.

Based on the updated growth functions for Norway spruce in the three model regions we will provide for the first-time comparative results of the environmental control of Norway spruce growth under temperate-continental (Western Ukraine), boreal (Northwest Russia) and temperate-atlantic climatic conditions (Southwestern Germany) using most up-to-date data. The combined analysis of field growth data and remotely sensed data will produce results relevant for the development of large-scale real-time forest monitoring systems, e.g., for the detection of early warning signals of environmental stresses on trees and forests (Keersmaecker et al. 2014).

The methodology developed for and applied in the project can be used for other tree species and has large potential to be applied to other regions in the partner countries.

Beside advances in science, the project will actively support education and training of young scientists. The participation of young scientists, PhD and postdoctoral students in the project will offer them a possibility to become familiar with modern multidisciplinary researches as well as to obtain experiences in working in international teams. Further on, the project activities will help to establish closer links between the participating universities, that can be strengthened and developed in the future for facilitation of more in-depth tri-lateral cooperation.

Time and work schedule

The project will take three years (36 months). The proposed start date is 1st of January, 2020 (proposed project period: 01.2020-12.2022). We have identified seven work packages (WP1-WP7) (see Fig. 2), plus the coordination work package (WP0). The tasks and work packages are balanced among the partners. For each work package we have defined a work package leader who is responsible for the implementation of the respective research work (see work package milestones), including the timely provision of the work package results and deliverables. The other project partners support the work package leader, contribute to the work package tasks and to the success of the whole research project as a team achievement. The start, duration and sequence of project activities is illustrated in Fig. 3.

<u>Work package WP0: Project coordination - WP-Leader P1.1 ALU-FR (Germany)</u>

Task description (keywords): Project coordination, incl. administration, budgeting, reporting, public relations/project website (English, Ukrainian, Russian, German), time schedule development and control, meetings.

Work package milestones (MS):
- MS 0-1 Project website (duration: 4 months, due: month 4)
- MS 0-1 Project workshop (WS, hosted by P3, duration: 1 week, due: month 9)
- MS 0-3 Project symposium (SY, hosted by P2, duration: 1 week, due: month 32)
- MS 0-4 Research stays of P2 and P3 at P1 (duration: 1 month, due: in 2021).

Work package deliverables (DE):
- DE 0-1 Project website online (due: month 4, regularly updated)
- DE 0-2 Workshop minutes (due: month 9)
- DE 0-3 First year report (due: month 12)

• DE 0-4 Second year report (due: month 24)
• DE 0-5 Symposium minutes (due: month 32)
• DE 0-6 Final report (due: month 36).

Work package WP1: Forest inventory database - WP-Leader P3 SFTU-SP (Russia)

Task description (keywords): Compilation of a forest inventory database, incl. collection of data, data quality control, data preprocessing, preparation for EFISCEN format.
Task description: Development of the common template for all project partners for data collection and conducting of data collection which includes information about Norway spruce forest for the agreed regions in Western Ukraine (administrative units: Lviv, Ivano-Frankivs'k, Chernivtsi, Sakarpatska), Northwest Russia (administrative units: Leningrad region, Novgorod region, Pskov region) and Southwest Germany (administrative unit: Baden-Württemberg) in respect of area, growing stock, productivity, distribution of the area and growing stock over age classes (e.g., young, middle aged, premature, mature and over mature), increment (total and mean), allowable and real cuttings as well as damaging factors (incl. mortality). The official forest statistics will be used as the main source of information to guarantee the data quality and respective references. The collected data will serve as the data basis to implement and run the EFISCEN model for scenario modeling of Norway spruce forest development in the future.

Work package milestones (MS):
• MS 1-1 Common template for data collection development (duration: 2 months, due: month 2)
• MS 1-2 Inventory data collection (duration: 6 months, due: month 8)
• MS 1-3 Data quality control, validation and verification (duration: 1 month, due: month 9)
• MS 1-4 Data transformation for EFISCEN model implementation (duration: 2 months, due: month 12).

Work package deliverables (DE):
• DE 1-1 Universal data collection form (due: month 2)
• DE 1-2 Verified database on Norway spruce forest inventory data (due: month 9)
• DE 1-3 Reliable input data for EFISCEN model (due: month 12).

Work package WP2: Growth database - WP-Leader P2 UNFU-LV (Ukraine)

Task description (keywords): Growth database, incl. collection of field data, data quality control, data preprocessing, compilation of database.
Task description: Selection of sample sites according to different age groups of Norway spruce (age classes - <40 years; 41-80 years and more than 80). Additionally, the sample sites will be stratified according to (i) altitude, (ii) slope aspects, (iii) forest site types, (iv) types of geographical positions, for all model regions in Western Ukraine, Northwest Russia and Southwest Germany. Increment cores will be taken from sample trees. Tree-ring width will be measured on increment cores using the existing measurement stations at partner institutions. Growth data will be quality checked and cross-dated according to the principles applied in dendroecological and growth and yield studies. The growth data will be preprocessed to same conditions for the compilation of the common growth database.

Work package milestones (MS):
• MS 2-1 Developing methodology of field work with definition of sampling design including number of sample plots and sample trees for increment core sampling in the different regions (duration: 4 months, due: month 6)
• MS 2-2 Collection of growth data from all participants and for all regions of investigation (duration: 6 months, due: month 16)
• MS 2-3 Growth data quality control (duration: 2 months, due: month 18)

• MS 2-4 Compilation of database of growth data, including sample plots and tree-ring measurements (duration: 2 months, due: month 20)
• MS 2-5 Data preprocessing (duration: 2 months, due: month 22)
• MS 2-6 Compilation of elaborated database (duration: 4 months, due: month 24).

Work package deliverables (DE):
• DE 2-1 Developed methodology of field work (due: month 6)
• DE 2-2 Formed database of field work with preprocessed quality controls for all regions of investigation (due: month 24)
• DE 2-3 Growth functions for spruce stands in different regions (due month 24).
• DE 2-4 Detected relations between main inventory indexes on sample plots and tree-ring increment using database and inventory data (due month 28)

Work package WP3: Satellite database - WP-Leader P2 UNFU-LV (Ukraine)

Task description (keywords): Satellite database (collection of data, data quality, data preprocessing, compilation of database).
Task description: Collection of satellite images from different sensors (MODIS, Landsat and Sentinel-2) according to areas of interests of different regions of investigation (Western Ukraine, Northwest Russia and Southwest Germany). All available satellite data from the beginning of surveying (for example for Landsat from the 1980ies, MODIS from 2000 and Sentinel-2 from 2015) without cloud cover (less than 10%) within 5-years periods will be collected. For these images pre-processing algorithms (atmospheric corrections, stacking images, etc.) and database will be developed. For the images NDVI-indexes will be calculated for detecting relations with growth data. For all three model regions the dynamics of coniferous wood cover will be estimated in 5-year periods.

Work package milestones (MS):
• MS 3.1-1 Monitoring of existing images from different satellites (Landsat, MODIS and Sentinel-2) on USGS Earthexplorer Hub for 5-year periods and download of files according to their quality for all regions (duration: 4 months, due: month 10)
• MS 3.1-2 Quality assessment of images (duration: 2 months, due: month 12)
• MS 3.1-3 Preprocessing images (layer stacking, atmospheric correction etc.) depending on satellite features and relief (duration: 4 months, due: month 16)
• MS 3.1-4 Forming of NDVI (EVI) images (duration: 2 months, due: month 18)
• MS 3.1-5 Interpretation of images using available algorithms for spruce stands detection using field sample plots (duration: 4 months, due: month 22)
• MS 3.1-6 Change detection on thematic maps for 5-year periods (duration: 2 months, due: month 24).

Work package deliverables (DE):
• DE 3.1-1 Downloaded satellite images (Landsat, MODIS and Sentinel-2) for available 5-years periods for area of interests of all regions (Western Ukraine, Northwest Russia and Southwest Germany) with their quality assessment (due: month 16)
• DE 3.1-2 Formed images for analyzing, additionally including NDVI (and EVI) images for areas of interest (due: month 18)
• DE 3.1-3 Creation of thematic maps as a result of image interpretation for detection forest cover, including spruce stands (due: month 22)
• DE 3.1-4 Change detection of spruce stands on thematic maps for 5-year periods (due: month 24).

Work package WP4: GIS database - WP-Leader P3 SFPU-SP (Russia)

Task description (keywords): GIS database and analysis.
Task description: Development of the structure of specialized multilayer GIS database with the aim to combine and analyze the remote sensing (satellite images) and ground true (tree rings) georeferenced data on Norway spruce for the agreed areas in Western Ukraine, Northwest Russia and Southwest Germany. Implementation of freely accessible GIS-software with sufficient facilities for spatial and temporal statistical analyses of the data should be considered as preferable. Retrospective analysis of Norway spruce tree growth on North-South for Northwest Russia and elevation above sea level incl. temperature gradient for Western Ukraine and Southwest Germany.

Work package milestones (MS):
• MS 4-1 Architecture of multilayer GIS development (duration: 2 months, due: month 10)
• MS 4-2 Gathering, validation and control of the remote sensing and ground base georeferenced data (duration: 2 months, due: month 20)
• MS 4-3 Retrospective data analysis on temperature gradients (duration: 3 months, due: month 29)
• MS 4-4 Extrapolations and projections (duration: 3 months, due: month 32).

Work package deliverables (DE):
• DE 4-1 Specialized GIS ready for georeferenced data analysis (due: month 20)
• DE 4-2 Relationships between Norway spruce tree stands growth and climatic factors (due: month 29)
• DE 4-3 Projections on Norway spruce growth for the future (due: month 32).

Work package WP5: Growth simulation - WP-Leader P1.2 FVA-FR (Germany)

Task description (keywords): Modification of the EFISCEN model, incl. regionalization, parameterization, modification of growth functions for Norway spruce, scenario development, model runs/projections). Model validation and model comparison (WEHAM).
Task description:
So far EFISCEN has not been used for the assessment of forest development and timber supply based on National Forest Inventory (NFI) data in Baden-Württemberg. The model will be run using the most recent NFI data from 2012. This data as well as those from Western Ukraine and Northwest Russia has to be prepared and specified according to the requirements of EFISCEN (in close cooperation with WP1). A major task will be to fit the growth functions for Norway spruce (in close cooperation with WP2 and WP4). Different scenarios will be developed together with the partners. The results obtained for the Baden-Württemberg region will be compared with the projections made by the German WEHAM-model for validation. The results of the EFISCEN results for the three regions will be analyzed and interpreted jointly with the partners.

Work package milestones (MS):
• MS 5-1 Compilation and preparation of data from the NFIs according to the requirements of EFISCEN (together with WP1) (duration: 4 months, due: month 12)
• MS 5-2 Calibration of EFISCEN growth model for Norway spruce in Baden-Württemberg (together with WP2) (duration: 4 months, due: month 24)
• MS 5-3 Joint scenario development (duration: 4 months, due: month 24)
• MS 5-4 Validation: comparison of EFISCEN results with WEHAM (duration: 4 months, due: month 24)
• MS 5-5 Joint analysis and interpretation of EFISCEN results in the three regions (duration: 4 months, month 28).

Work package deliverables (DE):
• DE 5-1 Database for EFISCEN runs (due: month 24)

• DE 5-2 Definition of harmonized scenarios (due: month 24)
• DE 5-3 Report on validation of EFISCEN for the Baden-Württemberg region (due: month 28)
• DE 5-4 Report on joint interpretation and conclusions about EFISCEN results (due: month 32).

Work package WP6: Synthesis - WP-Leader P1.1 ALU-FR (Germany)

Task description (keywords): Synthesis (results, conclusions, discussion, scientific data management, report, publications).
Task description: Based on the results from the forest growth simulation (WP5), the implications of the different scenarios on ecosystem services provided by the forests, like provisioning and regulating services, but also social and supporting services (see Fig. 2) will be discussed. We will use published functional relationships between ecosystem structures (as provided by the scenario modelling) and ecosystem functions to derive a synthesis assessment.

Work package milestones (MS):
• MS 6-1 Literature study on functional relationships between forest structures and forest functions (duration: 4 months, due: month 32)
• MS 6-2 Assessment of implications of scenario outputs on provisioning, regulating, social and supporting services (duration: 4 months, due: month 34).

Work package deliverables:
• DE 6-1 Synthesis report (due: month 36).

Work package WP7: Outreach - WP-Leader P2 UNFU-LV (Ukraine) and P3 SFPU-SP (Russia)

Task description (keywords): Outreach (knowledge transfer through stakeholder participation, vertical (transdisciplinary) integration, training, demonstration plots, leaflets).
Task description:
The planned outreach activities aim at transferring the newly generated information and scientific knowledge into forest-based land-use planning in order to guide decision makers on strategic, tactical and operational levels. This will be achieved through the active participation of actors in the dissemination of project results, including, (i) preparation of scientific material/publications based on the data and ideas developed and obtained during the projects' lifetime, (ii) development of teaching materials for the students on bachelor, master and PhD levels, such as thematic modules in the courses on sustainable forest management, (iii) using of project outcomes in refreshing teaching, (iv) reporting of the project results at scientific conferences, seminars, workshops, summer schools etc. as well as presenting them in mass media and for interested target groups such as forest authorities, forest managers, representatives of forest business, NGOs in nature protection etc., and (v) through the development of the project website (in close cooperation with WP0) and issue of thematic leaflets.

Work package milestones (MS):
• MS 7-1 Spreading results of project (seminars, conferences, publications etc.)
• MS 7-2 Preparation of educational modules (due: month 34)
• MS 7-3 Scientific trainings (attached to project workshop (month 9) and project symposium (month 32).

Work package deliverables (DE):
• DE 7-1 Thematic leaflets (due: month 36)
• DE 7-2 Teaching modules (due: month 24 and 36)
• DE 7-3 Scientific paper (manuscripts, due: month 36).

Project workpackages time schedule

The start, duration and sequence of project activities is illustrated in Fig. 3.

Activity (WP: workpackage)	Start	Duration
WP0: Project coordination	1	36
WP1: Forest inventory database	1	12
WP2: Growth database	2	27
WP3: Satellite database	6	25
WP4: GIS database	8	25
WP5: Growth simulation	8	25
WP6: Synthesis	28	9
WP7: Outreach	28	13

Figure 3: Project Gantt chart.

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(**authors in bold:** project participants)

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Kahle, H.P., Alekseev, A., Lavnyy, V. et al. 2019b. The relationships between tree-ring widths and intra-annual density profiles of Norway spruce (*Picea abies* L. Karst) and Scots pine (*Pinus sylvestris*) on selected sites in the temperate-atlantic, temperate-continental, and boreal climatic zone in Europe. To be submitted to Tree Physiology. In preparation.

Specification and justification of budget

During proposal preparation phase we have been informed by Dr. Nöllenburg, VolkswagenStiftung, that the maximum allowable share between partners is 140.000 Eur for the German partners, and 80.000 Eur each for the Ukrainian and Russian partner.

Table 1: Staff cost rates (data for Partner 2 and Partner 3 see enclosed statements).

	Euro/month			Costs (Index: costs P1=100%)		
	Partner 1	Partner 2	Partner 3	Partner 1	Partner 2	Partner 3
Professor	8675	600	2300	100	6,9	26,5
Assoc. Professor	7150	550	1900	100	7,7	26,6
Post Doc	5665	430	1900	100	7,6	33,5
PhD student	3682	280	300	100	7,6	8,1
Technician	4125	350	600	100	8,5	14,5
Administration staff	3713					
Student assistant	1320					

Table 2: Budget overview (specification of costs).

	Partner 1		Partner 2		Partner 3	
	months	Euro	months	Euro	months	Euro
Professor	0,0	0	3,0	1800	3,0	6900
Assoc. Professor	0,0	0	36,0	19800	12,0	22800
Post Doc	18,0	101961	36,0	15480	3,0	5700
PhD student	0,0	0	36,0	10080	36,0	10800
Technician	0,0	0	18,0	6300	12,0	7200
Administration staff	1,0	3713	0,0	0	0,0	0
Student assistant	20,0	26394	0,0	0	0,0	0
	units		units		units	
Travel (research stay)	0	0	2 Pers. x 2	10640	2 Pers. x 2	10640
Travel (works./conf.)	3 Pers. x 2	7050	5 Pers. x 1	5950	5 Pers. x 1	5950
Inclusion of add. scientists	0	0	1 Pers. x 1	1190	1 Pers. x 1	1190
Recurring non-personal		700	1	4000	1	4300
Non-recurrent		0		4760		4520
Sum		**139818**		**80000**		**80000**
Total sum (P1+P2+P3)		**299818**				

Table 3: Justification of costs.

	Description/justification		
	Partner 1	**Partner 2**	**Partner 3**
Professor		Vasyl Lavnyy: research, coordination	Alexander Alekseev: research, coordination
Assoc. Professor		Serhii Havryliuk, Petro Khomiuk, Serhii Kopiy: data compilation and analysis	Dmitri Tschernikowsky, Leonid Vetrov, Marcel Vagiza, Svetlana Tereschenko, Michael Gouriyanov: research, data base compilation, coordination
Post Doc	NN: Research + coordination (0.5 P1.1 ALU-FR, 0.5 P1.2 FVA-FR)	Volodymyr Savchyn, Natalia Pavliuk, Olga Krynytska: support in data compilation and analysis	Anna Michailova: support in data compilation and analysis
PhD student		NN: topic for PhD-study to be defined	NN: topic for PhD-study to be defined
Technician		NN: support of field work and laboratory work	Igor Tschernov: database compilation
Administration staff	NN: Administration + coordination		
Student assistant	NN: Inventory data and growth data compilation		
Travel (research stay)		2 Pers. x 2: Research stay at P1	2Px2: Research stay at P1
Travel (works./conf.)	3 Pers. x 2: Workshop/symposium participation	5 Pers. x 1: Workshop participation 2020	5Px1: Symposium participation 2022
Inclusion of add. scientists		1 Pers. x 1: Inclusion of scientist to project symposium 2022	1 Pers. x 1: Inclusion of Prof. Jan-Gert Nabuurs, Univ. Wageningen (to be confirmed) to project symposium 2022
Recurring non-personal	Consumables (lump sum)	Meeting costs: Project symposium Sep 2022 + consumables	Meeting costs: Project workshop Sep. 2020 + consumables
Non-recurrent		Equipment: Electric borer (Makita), increment borer, powerful computer (for satellite image interpretation), publication costs	Equipment: Electric borer (Makita), increment borer, powerful computer (for GIS), publication costs

Table 4: Overview on project meetings and research stays.

Year	**Organizer, host**		
	Partner 1	**Partner 2**	**Partner 3**
2020			Project workshop (WS) Sep 15-20, 2020
2021	Research stay of P2 and P3 at P1		
2022		Project symposium (PS) Sep 15-20, 2022	

Table 5: Overview on travel costs for attendance at project meetings (WS: workshop, SY: Symposium).

Activity	Person	Partner	Transportation costs (Euro)	Accommodation costs	Allowance	Other costs (Euro)	Total travel costs (Euro)
WS	Prof. Dr. Kahle	**P1**	Train: 120 Air: 400	7 days x 80 Euro = 560 Euro	7 days x 10 Euro/day = 70	Visa: 50	1200
WS	Dr. Kändler	**P1**	Train: 120 Air: 400	7 days x 80 Euro = 560 Euro	7 days x 10 Euro/day = 70	Visa: 50	1200
WS	NN (PostDoc)	**P1**	Train: 120 Air: 400	7 days x 80 Euro = 560 Euro	7 days x 10 Euro/day = 70	Visa: 50	1200
SY	Prof. Dr. Kahle	**P1**	Train: 120 Air: 400	7 days x 80 Euro = 560 Euro	7 days x 10 Euro/day = 70		1150
SY	Dr. Kändler	**P1**	Train: 120 Air: 400	7 days x 80 Euro = 560 Euro	7 days x 10 Euro/day = 70		1150
SY	NN (PostDoc)	**P1**	Train: 120 Air: 400	7 days x 80 Euro = 560 Euro	7 days x 10 Euro/day = 70		1150
WS	Prof. Dr. Lavnyy	**P2**	Train: 80 Air: 400	7 days x 80 Euro = 560 Euro	7 days x 10 Euro/day = 70	Visa and Insurance: 80	1190
WS	NN (...)	**P2**	Train: 80 Air: 400	7 days x 80 Euro = 560 Euro	7 days x 10 Euro/day = 70	Visa and Insurance: 80	1190
WS	NN (...)	**P2**	Train: 80 Air: 400	7 days x 80 Euro = 560 Euro	7 days x 10 Euro/day = 70	Visa and Insurance: 80	1190
WS	NN (...)	**P2**	Train: 80 Air: 400	7 days x 80 Euro = 560 Euro	7 days x 10 Euro/day = 70	Visa and Insurance: 80	1190
WS	NN (...)	**P2**	Train: 80 Air: 400	7 days x 80 Euro = 560 Euro	7 days x 10 Euro/day = 70	Visa and Insurance: 80	1190
SY	Prof. Dr. Alekseev	**P3**	Train: 80 Air: 400	7 days x 80 Euro = 560 Euro	7 days x 10 Euro/day = 70	Visa: 30	1190
SY	NN (...)	**P3**	Train: 80 Air: 400	7 days x 80 Euro = 560 Euro	7 days x 10 Euro/day = 70	Visa: 30	1190
SY	NN (...)	**P3**	Train: 80 Air: 400	7 days x 80 Euro = 560 Euro	7 days x 10 Euro/day = 70	Visa: 30	1190
SY	NN (...)	**P3**	Train: 80 Air: 400	7 days x 80 Euro = 560 Euro	7 days x 10 Euro/day = 70	Visa: 30	1190
SY	NN (...)	**P3**	Train: 80 Air: 400	7 days x 80 Euro = 560 Euro	7 days x 10 Euro/day = 70	Visa: 30	1190

Table 6: Overview on costs for research stays (RS, host: P1).

Activity	Person	Partner	Transportation costs (Euro)	Accommodation costs	Allowance	Other costs (Euro)	Total travel costs (Euro)
RS1	Assoc. Prof. Dr. Serhii Havryliuk	**P2**	Train: 80 Air: 400	1 month = 600 Euro	30 days x 50 Euro/day =	Visa and Insurance: 80	2660
RS2	Assoc. Prof. Dr. Petro Khomiuk	**P2**	Train: 80 Air: 400	1 month = 600 Euro	30 days x 50 Euro/day =	Visa and Insurance: 80	2660
RS2	Dr. Natalia Pavliuk	**P2**	Train: 80 Air: 400	1 month = 600 Euro	30 days x 50 Euro/day =	Visa and Insurance: 80	2660
RS4	NN	**P2**	Train: 80 Air: 400	1 month = 600 Euro	30 days x 50 Euro/day =	Visa and Insurance: 80	2660
RS1	Assoc. Prof. Dr. Dmitri Tschernikowsky	**P3**	Train: 80 Air: 400	1 month = 600 Euro	30 days x 50 Euro/day =	Visa and Insurance: 80	2660
RS2	Assoc. Prof. Dr. Michael Gouriyanov	**P3**	Train: 80 Air: 400	1 month = 600 Euro	30 days x 50 Euro/day =	Visa and Insurance: 80	2660
RS3	Dr. Anna Michaylova	**P3**	Train: 80 Air: 400	1 month = 600 Euro	30 days x 50 Euro/day =	Visa and Insurance: 80	2660
RS4	NN	**P3**	Train: 80 Air: 400	1 month = 600 Euro	30 days x 50 Euro/day =	Visa and Insurance: 80	2660

Attachments:

- Cover letter, including explanation of the previous trilateral cooperation
- CVs, list of relevant publications incl. joint papers
- Statements of foreign partner institutions (containing information on structural support, possible financial contributions as well as conformity of salaries with local standards)
- Statement of German partner institution (concerning transfer of funds to the foreign partners / institutions)