Annual project report

# Surge-Pro

**The past development, present status and likely futures of Norway spruce in Eastern and Central Europe - A scenario-based projection of forest resources and wood supply to support transition to green economies**

Reporting for year 2022 (01.01.2022 – 31.12.2022).

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### Preface:

The year 2022 was marked by extremely difficult circumstances due to Russia's war against Ukraine, which began on 24th February. Our project was also affected. The Russian partner was first suspended from the cooperation and in view of the ongoing conflict, the cooperation was terminated. In addition to formalities, insecurity and the ongoing difficult circumstances for the Ukrainian colleagues, the project had to be reorganised in terms of content and new staff had to be found for the necessary work. All these factors meant that the progress of the project was less than originally planned.

## 1. Scientific results

[short summary of the scientific results]

### WP 1: Forest inventory data base (WP leader: SPSFTU)

Data collection and analysis of forest inventory data was finished at the beginning of 2022. Results were presented internally. A draft manuscript for publication was in preparation but could not be completed due to the exclusion of the Russian partner who acted as leader of this WP.

### WP 2: Growth data base (WP leader: VL, UNFU)

The distribution of spruce stands in western Ukraine in the forest fund of Zakarpatska (29,134 taxed stands), Ivano-Frankivsk (73,661 taxed stands), Lviv (22,707 taxed stands), and Chernivtsi regions (18,547 taxed stands) was analyzed according to a database of the national forest assessment.

The distribution of spruce stands by forest types was made. For the six predominant forest types, the area of spruce plantations was grouped according to the following characteristics: 1) height above sea level; 2) slope exposure; 3) steepness of the slope; 4) protection category of forests; 5) age group; 6) site class; 7) stand density; 8) tree stand composition; 9) age of the tree stand; 10) the origin of the tree stands. Based on the performed typological analysis, 52 sample plots were established in the two most common forest types on the territory of eight forestry enterprises and one National Park.

On the basis of the sample plots, tables of the growth forecast of spruce stands for two dominant forest types - pure spruce forests on relatively rich wet soils (C3–Nspr) and beech-silver fir-spruce forests on relatively rich wet soils (C3–Be-SF-Nspr) were built, and a comparison of the dynamics of stand indicators with the data of the growth tables of Y.I.

Tsuryk and Khodot H.A. was made. It was found that the tree stands of the sample plots are characterized by a 20% higher density for young and middle-aged stands, and in terms of average stand height and average stand diameter, they are closer to the tables of the growth table of Y.I. Tsuryk, and with a growing stock to the one by H.A. Khodot.

A comparison of growth with spruce forests in the Black Forest, Germany, was also completed, which made it possible to found the following correspondence:

- in terms of average stand height, spruce stands of the I site class in Ukrainian Carpathians have dynamics that are consistent with the corresponding stands of the Black Forest, the average annual volume increment of which at the age of 100 years ($dGz_{100}$) is 10 m³/ha, and of the Ia site class - 12 m³/ha;
- in terms of the average stand diameter, spruce stands of the I site class have dynamics that are consistent with the corresponding stands of the Black Forest, the average increment of which is 10 m³/ha at the age of 100 years, and the Ia site class - 13 m³/ha;
- according to the growing stock by the relative stand density of 0.8, spruce stands of the I site class in Ukrainian Carpathians have dynamics that are consistent with the corresponding stands of the Black Forest, the average increment of which by the age of 100 years is 10 m³/ha, and of the Ia site class - 12 m³/ha.

In addition, an analysis of the radial growth of 246 dominant spruce trees from all 52 sample plots in Ukrainian Carpathians was carried out. The increment cores were measured using "TSAP-Win" software for annual increment in the Laboratory of Dendrochronology at UNFU. All data was gathered into a database of tree increments for the Ukrainian part. The analysis of this data was started using analysis software packages in R, namely dplR. Script for analysis were developed and synchronized with analyses prepared for the German part. The German increment core collection consists of 83 cores from 27 sample plots. Individual raw ring-width-measurement series were detrended using cubic smoothing splines, and stand chronologies were aggregated based on the resulting index data. Analyses of climate-tree-growth relationships are ongoing (see WP 4).

## WP 3: Satellite data base (WP leader: SH, UNFU)

The first approach to assess NDVI (Normalized Difference Vegetation Index) and EVI (Enhanced Vegetation Index) was to download the images for all areas of interest (Black Forest in Germany, and Ukrainian Carpathians in Ukraine)[1] annually from 1985 to 2022 during vegetation period (from May to October). For all sample plots (where increment cores were taken), NDVI and EVI was calculated from the acquired satellite images. Several difficulties were encountered using these data. One of the main hurdles was cloud cover and with that the different time periods for which satellite images between different sample plots could be used. Also, the acquired satellite images originate from different satellites, namely Landsat-4, Landsat-5, Landsat-7, and Landsat-8 systems for the period 1985 to 2022 and Sentinel-2 for the period 2015 to 2022. Yet another challenge is the comparability of NDVI/EVI taken from different satellites.

From the calculated NDVI/EVI values, summary statistics were derived. These showed very high variation of the NDVI/EVI indexes because they very much depend on the time of the image acquisition and the weather conditions at this time. From this first data acquisition and

[1] Satellite images for the Russian sample plots were also collected, but after 24th February 2022, this work was stopped.

analysis, it got clear that the data pre-processing and homogenization is crucial to receive reliable results.

To overcome the stated difficulties, we decided to implement an approach, which is not so dependent on the time of the image acquisition. The open instrument of Google Earth Engine (https://earthengine.google.com/) offers online selection, pre-processing (e. g. cloud masking, synchronization), calculation and storage of desired satellite products. But it is required to use JAVA or Python scripts for each satellite separately. The workflow of generating valid indexes is presented in Fig. 1.

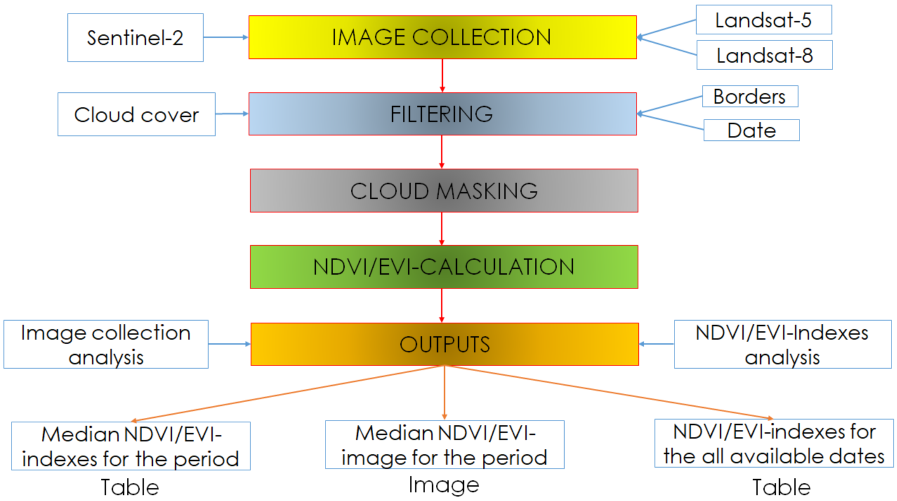


Fig. 1. The workflow of the estimation of NDVI/EVI indexes in Google Earth Engine.

As a result of the calculation of NDVI/EVI indexes using Google Earth Engine, there are (i) images for each year from 1985 to 2022 from all available satellite systems in different periods (Landsat-5, Landsat-8, and Sentinel-2), (ii) a database of the NDVI/EVI indexes for all available dates of the years for each satellite system for the available period (for example, for Landsat-5 from 1985 to 2012; Landsat-8 from 2013 to 2022; for Sentinel-2 from 2017 to 2022) and, (iii) additionally the median values for the year's periods from different satellite systems. For the synchronization of the indexes from different satellite systems we used the coefficients described in Nguyen et al. (2020). All NDVI/EVI values and corresponding satellite, space and time information are stored in a database. The database was cleaned from noise (due to the weakness of cloud masking) and will be used for the further statistical analyses, results of which will potentially be used as input to the EFISCEN model.

### WP 4: GIS data base (WP leader: UNFU)

The project builds on data of different origins (forest inventories, remote sensing, tree-ring measurements, historical climate data, climate projections and forest development projections) that are in different formats and require different processing. QGIS was selected as a basis for the project database because of the following advantages (QGIS documentation):

- processes georeferenced vector and raster data in several formats,
- has multiple instruments for processing the data,
- open-source software,
- well-developed graphic user interface.

Test plots used in the project for studying the tree growth and NDVI/EVI are in mountainous terrains where climatic parameters show considerable spatial variation. Therefore, fine-scale weather data and climate projections are preferable for the analysis of the weather and climate change impact on forest growth parameters. A few datasets of gridded historical and projected weather parameters were compared at the locations of the test plots. As a result, the dataset of historical weather data and climate projections by Marchi et al. (2020) was selected. The dataset has 1 x 1 km resolution, it contains weather data for 1900-2018 and climate change projections for the RCP4.5 and RCP8.5 scenarios and are based on an ensemble of climate models. We extracted weather data for 1900-2018 for the test plots in Germany and Ukraine and set-up data for further analysis of the tree-ring and NDVI data against the climate data.

A preliminary analysis of the tree-ring data from the test plots in Germany against the weather parameters was done. The temperature has had an increasing trend since 1960-s while precipitations have high interannual variability masking a trend. Between tree variability in climate-growth responses is quite large: Tree-ring widths of some individual trees in low altitudes decline with the increasing temperature while some trees behave differently. The preliminary analysis confirms that the tree-ring data of individual trees is noisy, therefore, they require special pre-processing before combining for further analysis. The pre-processing is described under WP-2.

For integrating the information on the tree-ring growth response to climate change into EFISCEN model it should be interpreted in terms of growing stock increment. Therefore, a script for calculating the stem volume and stem volume increment tree-ring widths was developed. The script is based on the usage of an allometric equation, which relates stem wood mass and stem diameter at breast height (DBH), developed for Germany (Zianis et al. 2005).

## WP 5: Growth simulation (WP leader: FVA)

The EFISCEN modelling about pure Norway spruce forests was continued. Baden-Württemberg data for Norway spruce (area, volume stock and volume increment per age class) was taken from the third German national forest inventory (NFI 2012). Also, area loss and mean wood production was extracted from data of the two previous NFIs (2002 and 2012). Volume stock and forest area data for 20-year age classes was provided for western Ukraine by the project partner. Corresponding volume increment data were not available for Ukraine and, hence, were calculated from Ukrainian yield tables. To do so, it was necessary to expand these yield tables to cover all site productivity classes actually present in Ukraine. This was done by rebuilding the underlying relations by means of a Chapman-Richard growth function. Hence, data to be processed in EFISCEN is completed now for both Ukraine and Germany.

Meanwhile, the development of the rEFISCEN package continued especially with regard of uncertainty and sensitivity analysis using a Monte-Carlo approach. In a first step, the basic EFISCEN simulation was implemented as MC-approach; further scenario files (e. g. wood demand, area loss and species change) still need to be implemented. Preliminary results indicate an uncertainty of 3,5 % to 4 % (Coefficient of variation) with respect to volume stock development of Norway spruce in Baden-Württemberg (base scenario).

Still, the model parameterization for our data (as of December 2022) needs to be revised as estimated increments are still too high. Contact with EFISCEN developers (M.J. Schelhaas, University Wageningen) was established and the provided suggestions promise improvements in parameterization.

**WP 6 and WP 7:** not yet started.

## 2. Contribution towards the funding initiative's specific goals

[In this program, the Foundation wants to strengthen cross-border cooperation between scholars, scientists, and academic institutions from the countries [involved in this conflict]. Thereby, it intends to contribute to building rapprochement, confidence, and understanding in the region and to maintain a dialogue with colleagues in Germany, too.]

Cross-border cooperation was fruitful and cooperative from the beginning of the project. Unfortunately, the Russian war on Ukraine totally changed the project. With the suspension of the Russian partner, the project turned into a bilateral project. Cooperation with the Ukrainian partner continued and continues to be fruitful and cooperative. Personal meetings were not possible during 2022, except hosting Serhii Havryliuk at University of Freiburg as a guest researcher. In order to receive necessary administrative information, we had sporadic contact to the former Russian partner.

## 3. Comparison with original goals and planned objectives

[unexpected findings, other intrinsic/methodological divergence]

The planned "Freiburg"-meeting (16$^{th}$ to 20$^{th}$ of May 2022) must be cancelled due to the Russian war on Ukraine. It is now planned to make up for the meeting in 2023. Also, the projects goals and timeline had to be revised. This was done in agreement with Volkswagen foundation in Summer 2022.

## 4. Gain in knowledge

[as result of interdisciplinary and international cooperation]

With the working package 1 almost ending, we gained overview on the development of Norway spruce during the last 30 to 40 years in the three partner regions (see section 1). The other working packages are quite involved in field works and preparatory works. New gains in knowledge and cross-working package insights are expected for the next year of the project.

## 5. Inclusion of junior researchers

**UNFU:** In 2022 a master-student of Forestry at UNFU Iryna Khita was employed for 6 months to assist in preparatory work with the investigation of increment cores from spruce.

**ALU:** From September 2021 until May 2022 a junior researcher, Philipp Eisnecker, was employed to assist in preparatory and methodological work, for writing code for the rEFISCEN-package as well as for literature study. In June and July 2022, the SURGE-Pro project was assisted by MSc-student Dastan Torokulov from Kyrgyzstan, European Forestry Master Program, doing his "applied period" at the Chair of Forest Growth and Dendroecology, University Freiburg. He collected, digitized and analysed yield tables from Russia and Ukraine and compared them to the yield tables used in Baden-Württemberg, Germany.

## 6. Further perspectives and sustainable effect of the project

The difficult situation in 2021 with COVID-19 eased considerably in 2022. Sadly, the political situation escalated further and resulted in an ongoing Russian war of aggression against Ukraine. The project continued to offer partnership and collaboration between the Ukrainian National Forestry University and University of Freiburg. Due to the necessity to involve new project staff as substitute for the Russian part, new colleagues from Ukrainian National Forestry University were involved into the project (namely Prof. Dr. Sc. Mykola Gusti and Dr. Mykola Korol).

## 7. Other aspects

[e.g. any particular advantageous or constraining circumstances, appraisal of cooperation, integration in the scientific or institutional environment]

The planned meeting in Freiburg (May 2022; substitute for 2021 meeting in St. Petersburg) was cancelled due the Russian war on Ukraine. Nevertheless, it was possible to invite Serhii Havryliuk as a guest researcher at University of Freiburg.

# Literature:

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