



Implementation of a Virtual Research Environment (VRE) to the study of forest environments

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The monitoring and study of forests is essential to understand their condition, dynamics and to adopt optimal management to ensure their sustainability. Long-term studies require the installation of permanent field sites with sensors and equipment and collection of data, also from other sources, which are often difficult to obtain both in terms of discovery and standardization.

In this framework, Virtual Research Environments (VRE) are online research platforms that allow easy access to the available FAIR data, to find smart solutions and to support decision making. The Virtual Research Environment for Essential Variables (VRE-EVs), created within the ITINERIS NextGeneration EU project (<https://itineris.cnr.it>) and hosted on the D4Science infrastructure (<https://itineris.d4science.org>), offers several services to registered users to develop open and reproducible science. The VRE-EV aims to enable virtual environmental research in the perspective of the two global frameworks of Essential Biodiversity Variables (EBVs; e.g., phenology, species distribution) and Essential Climate Variables (ECVs; e.g., surface air temperature, precipitation, relative humidity), which are known to be critical for plant and soil biogeochemical processes (e.g., tree growth, soil mineralization, water fluxes, litter decomposition). This is very interesting in experimental sites with long-term monitoring, such as that installed in the 3000-ha forest environment of Collelongo - Selva Piana (<https://deims.org/9b1d144a-dc37-4b0e-8cda-1dda1d7667da>), one of the founding sites of the Italian ICP Forests network and also part of the eLTER and AnaEE international research infrastructures. The main study site is a pure mature beech forest (*Fagus sylvatica* L.) with trees over 125 years old. This study describes the VRE-EVs and demonstrates, through a use case, how data from heterogeneous sources, made easily accessible within the VRE-EVs, are useful to analyse Forest environments Essential Variables.

We propose the use of an interactive application (Shiny App) specifically developed within the VRE-EVs, an RStudio platform, to integrate the functions provided by the ReLTER package (10.1016/j.ecoinf.2024.102915) and by all other ITINERIS project facilities, with the aim of merging different datasets available in European repositories (e.g., Copernicus Land and Climate Services,

European Environment Agency), international data publishers (e.g., Pangaea, Zenodo), other essential variables online repositories, and in-situ data. The joint analysis of the different datasets available through the VRE-EV allows the improvement of ecological, ecophysiological processes and carbon fluxes of the Collelongo beech forest in response to global changes.