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Digital Terrain Model retrieval within a Coastal Dune Systems by integrating Unmanned Aerial Vehicles' optical and LiDAR sensors by using a FOSS workflow

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Biodiversity supervising through remote sensing assumes crucial importance in monitoring ecosystem integrity and resilience. This study features the integration of optical and LiDAR data coming from Unmanned Aerial Vehicles (UAV) for Digital Elevation Models (DEM) retrieval of the Lesina (Puglia, Italy) Coastal Dune Systems (CDS), aiming to support ecosystem monitoring for the habitat type 2250* "Coastal dunes with Juniperus spp". This work aims to provide a Free and Open-Source Software (FOSS) workflow able to extract and calculate Digital Surface Model (DSM), Digital Terrain Model (DTM), and Digital Difference Model (DDM) through LiDAR and optical data in a very dense vegetation environment. By using the contribution of RStudio, Cloud Compare, and Quantum GIS software, it was possible to develop a useful methodology for DDM extraction, to compute Juniperus spp. architecture (areas and volumes), which can reflect habitat reduction and fragmentation when compared at different timescales. According to this, a point cloud integration from the two datasets (optical and LiDAR) was provided. Consequently, the generation of an orthophoto and a DSM occurred, needed for the extraction of a vegetation mask using spectral indices (e.g., Excess Green) and for the choice of a pixel threshold, both able to isolate as much as possible the contribution of the vegetation along the DSM. Using scripts in RStudio it was possible to simplify and speed up the processing procedure, inserting additional useful codes for a further isolation of the vegetation matrix from the terrain. Consequently, areas belonging to the presence of vegetation took "*NoData*" values. So, to fill these areas with significant elevation values of their surroundings, a linear interpolation technique was used by using Inverse Distance Weight (IDW) interpolator, obtaining a "raw" DTM populated by fewer signal noise due to wind disturbance and shading. Following this, the subsequent processing involves the elimination of persistent noise from the point cloud extracted from the "raw" DTM. By using the *segmentation tool* in Cloud

Compare software, not-inherent cloud's points were removed, allowing to eliminate altimetric errors in the elevation model. Following this operation, a final DTM was extracted from the point cloud representing more accurately the altimetry of the terrain in the study area. Finally, to obtain the height of the canopies, through the expression "DSM-DTM=DDM" used in the QGIS Raster Calculator, the DDM was obtained. The canopies have been considered as 2.5D geometries, resulting in heights representing only the contribution of the above ground biomass. Finally, vegetation areas and volumes were designed from the DDM computation, where canopies' total volume calculation occurred by adding all the results obtained for each pixel of interest. Hence, this methodology allowed us to monitor biomass parameters (areas and volumes), by a FOSS methodology, in a CDS context with very dense Juniperus spp. vegetation.