	EXTENDED ABSTRACT OF THE FINAL DELIVERABLE
	Analysis of vegetation colonization and reforestation functionality through digital processing of high-resolution images obtained by Drone.
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Background & Objectives

Mining activities usually implies deep impacts on the vegetation, the fauna, and the soil. These impacts usually promote erosive and hydrologic processes associated to land degradation. Restoring an ecosystem after mining exploitation represents the opportunity to analyse and monitor how applied techniques progresses towards the recovery and the integration within the natural surrounding ecosystems. In this regard, there is a growing trend to combine field measurements and remote sensing technologies to monitor the success of reclamation practices. Unmanned Aerial Vehicles (UAVs), commonly known as drones, may provide the required data to estimate important indicators of ecological functioning such as changes in vegetation cover during colonization processes, water flow dynamics or the functionality of planting holes that contribute to the net gain or loss of resources. In this Deliverable we used drone technology to evaluate some key ecosystem variables that will determine the ecological restoration success over space and time after reforestation by using the data obtained from drone technology.

We established the following specific objectives: i) to generate high-resolution micro-scale characterization maps of the restored area at different time-scales after reforestation (Figure 1, Table 1); ii) to determine the efficacy of the applied treatments in each Restoration Unit. iii) to analyze the vegetation dynamics after restoration tasks and to compare the effectiveness among different Restoration Units; iv) to assess the relevance of drone technology for analysis of reforestation dynamics and success in the context of mining reclamation.

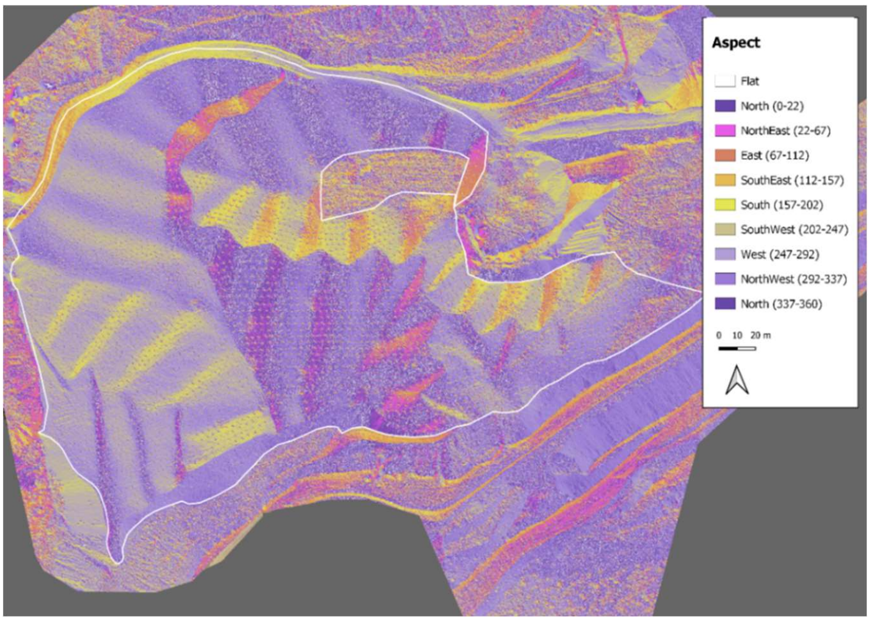

Figure 1. General Map of the Geofluv West restored area in the TECMINE Project showing the distribution of aspects. Different colors correspond to different aspects (Northernmost classes in purple and the Southernmost in yellow).

Table 1. Mean values of the general attributes estimated for each Restoration Unit (RU) through image analysis obtained by drone.

Geofluv Unit		Surface* (ha)	Holes Distribution (%)	Hole Density (plant/ha)	Slope* (%)	Aspect* (°)
West	RU1	2.77	61.2	975	34.7	251
	RU2	1.96	31.6	708	22.4	198
	RU3	0.46	7.3	697	22.6	207
East	-	1.83			34.9	225

*Note: Some values may slightly differ from other general values provided in other TECMINE reports. These differences could be due to image analysis estimations are based on highly detailed microtopography relief.

Main conclusions derived from results

- The analysis of ground characteristics highlighted that moderate slopes as in RU2 maintained better planting hole functionality.

- The implementation of microcatchments in the RU2 and RU3 favored to capture more resources. The lateral ridges provided roughness to the ground creating additional suitable microsites for the vegetation establishment (Figure 2) and acting as barriers decreasing the kinetic energy of water runoff. The application of this technique combined with moderate slopes provided the best results.

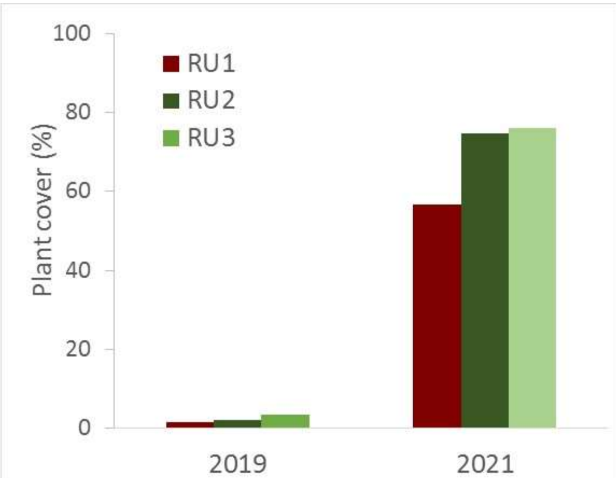

Figure 2. Plant cover (%) in the Geofluv West restored area depending on three restoration units (RU1 in dark red bars; RU2 in dark green bars; and RU3 in light green bars) at the starting point (July 2019) and two years after restoration (May 2021).

- Overall, the comparison of Restoration Units with very contrasting characteristics and different reforestation techniques showed important limitations, risks and advantages associated with slope angles and soil dynamics that must be considered in the design of future restoration treatments. The application of a colluvium with a high stoniness, and the implementation of field treatments (such as microcatchments, sowing, or the application of compost on the ground) have favored a faster stabilization of the restored area in terms of vegetation cover, with plant cover values above 75% two years after restoration in the most favorable areas (Figure 3).

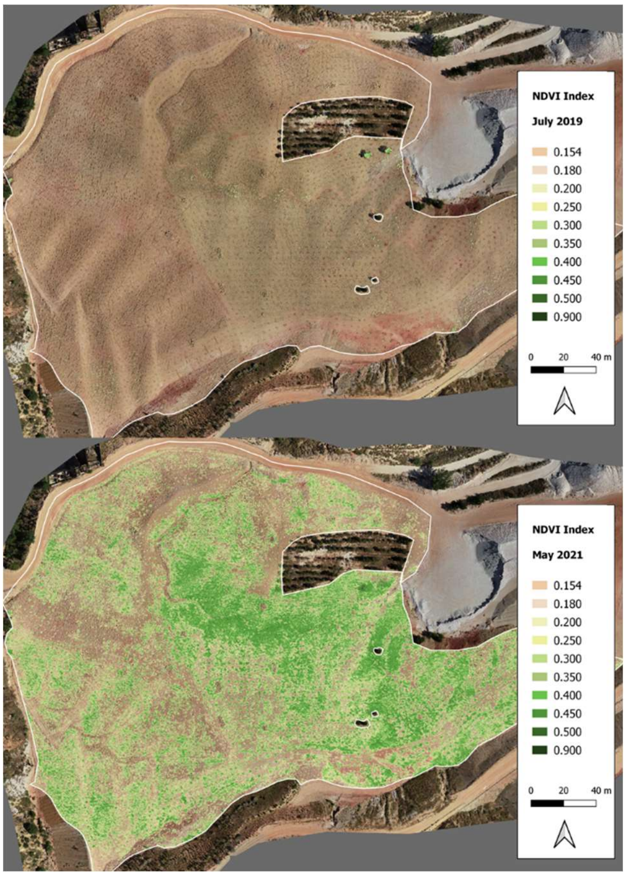

Figure 3. Plant cover in Geofluv West restored area estimated by the NDVI values obtained at the starting point (July 2019, upper panel) and two years after restoration (May 2021, bottom panel). Scale ranges from light to dark colors that indicate a progressive increasing in the NDVI values.

- The analysis of the hydrological parameters highlighted the importance of ground and soil properties. Thus, steep slopes combined with soil areas with an inappropriate texture did not allow that these hydrological processes took place and consequently in these areas, we found high hole degradation, and lower plant development and soil protection.
- We found certain limitations in the use of drone methodology that we must consider for future monitoring programs. We used photogrammetric flights using a multirotor drone (type DJI, Phantom 4 Pro) equipped with a high quality RGB sensor, with a mechanical shutter and a high-resolution camera (20 MP). Some limitations could be mitigated by using LIDAR technology (Light Detection and Ranging sensors), which uses light energy emitted from a laser. This technology scans the ground and measure variable distances, and also allows the direct classification to separate ground and vegetation points with high resolution and accuracy. However, this technology is currently expensive and not widely deployed. Other considerations are climatological features. Although the use of drones confers greater temporal plasticity than the use of satellite imagery, the use of multispectral cameras requires specific lighting conditions to reduce noise and increase accuracy in the image post-processing. During our monitoring, the flight had to be twice repeated due to the appearance of clouds. Clouds, despite the use of calibration cards, can distort the values obtained in the Red and Near Infrared bands used to calculate the NDVI index.