

Deliverable on establishment success of plantations: Survival and Growth

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TECMINE After-LIFE. Action 1. MONITORING OF PLANT SURVIVAL AND GROWTH

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Introduction

This report presents the work carried out during the After-LIFE period and the results obtained in relation to ACTION 1: MONITORING OF PLANT SURVIVAL AND GROWTH. This action aimed to continue the monitoring of plant establishment (survival and growth), biodiversity and plant colonization in the main restoration unit (Geofluv West).

Methodology of this sampling followed the methods developed during Life project and can be found in the Deliverable Action C2: “Establishment success of plantations: Survival and growth”.

The After-Life actions conducted were:

- 1.- Monitoring of survival and growth of planted species.
- 2.- Assess new natural colonization, biodiversity, and soil protection.

This monitoring survey was carried out in the *Geofluv West* Unit composed of three differentiated Restoration Units (RU, Fig 1)

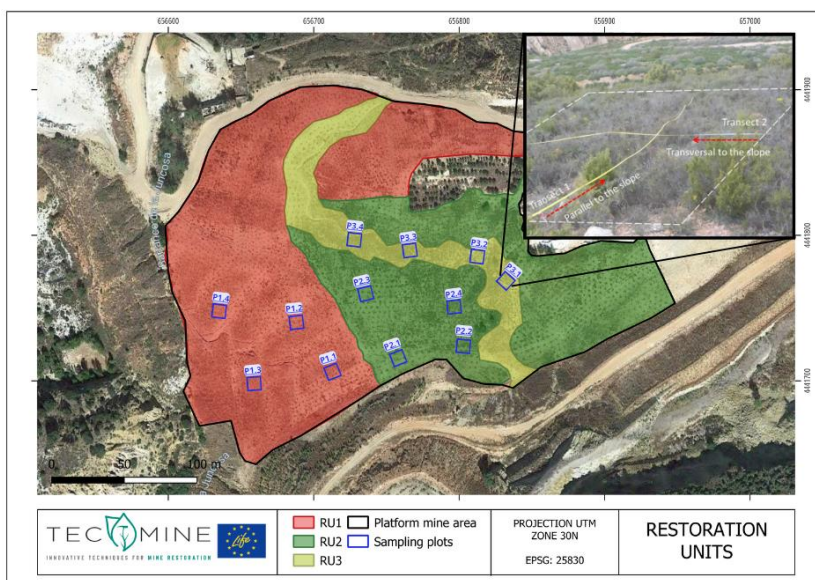


Fig 1. Sampling plots distribution (100 m² each) through the study area for each RU (RU1: red; RU2: dark green; RU3: light green).



Results:

1.- Evolution of seedling survival

During the After-LIFE monitoring conducted in July-23 (4.5 years after outplanting), average survival rates of the introduced seedlings in the *Geofluv West* restored unit, was 66% (± 0.02 SE). Regarding each restoration unit: RU1, RU2 and RU3 was 70% (± 0.02 SE), 68% (± 0.03 SE) and 51% (± 0.04 SE) respectively. The results showed the lowest survival rates in RU3 (Fig 2). Nevertheless, survival kept still over 50% of the introduced seedlings.

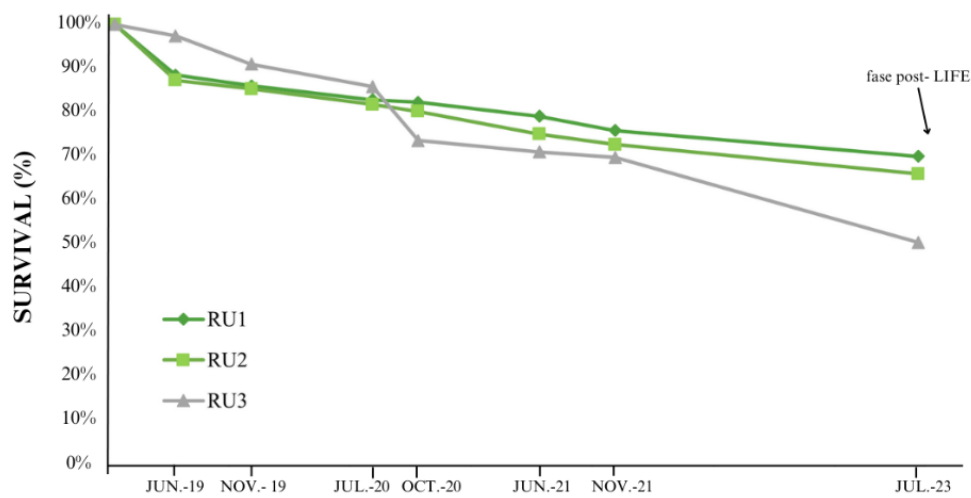


Fig. 2. Survival dynamics across time in the restored area (Geofluv West area) of the TECMINE project for each Restoration Unit: dark green - diamonds = RU1; light green - square = RU2; grey - triangle = RU3.

Among species, a 36% of species showed survival rates over 80%, and about 57% of species ranged between 50 and 80% of survival. The best performing species in survival were *Brachypodium phoenicoides*, *Dorycnium pentaphyllum*, *Juniperus phoenicea* and *Salvia rosmarinus* (before known as *Rosmarinus officinalis*) with survival rates higher than 85% (Fig. 3)

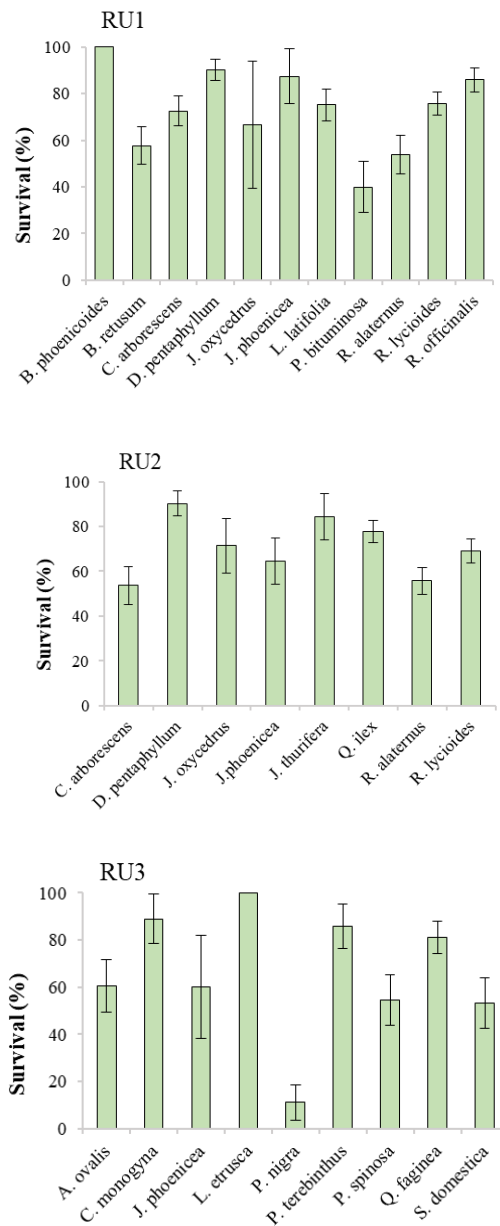


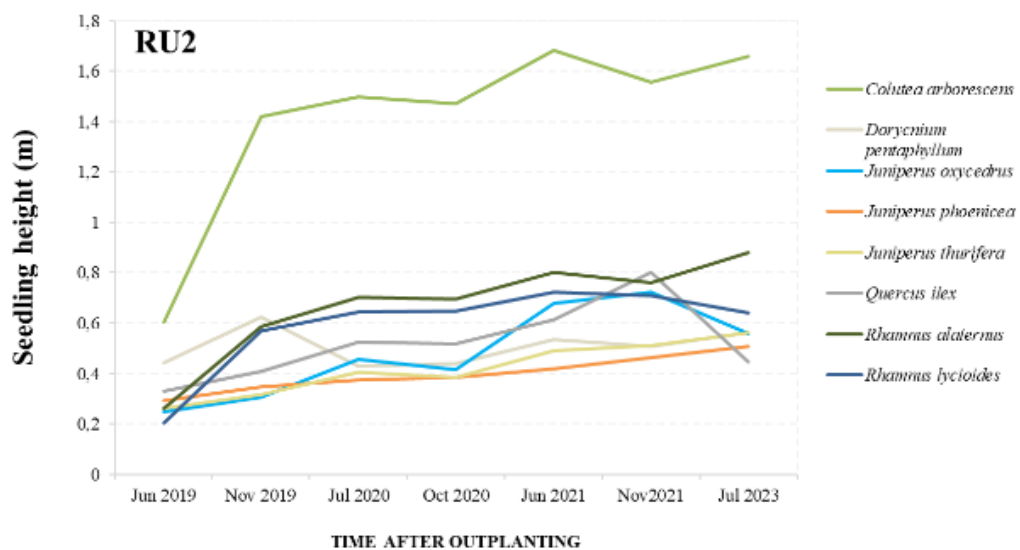
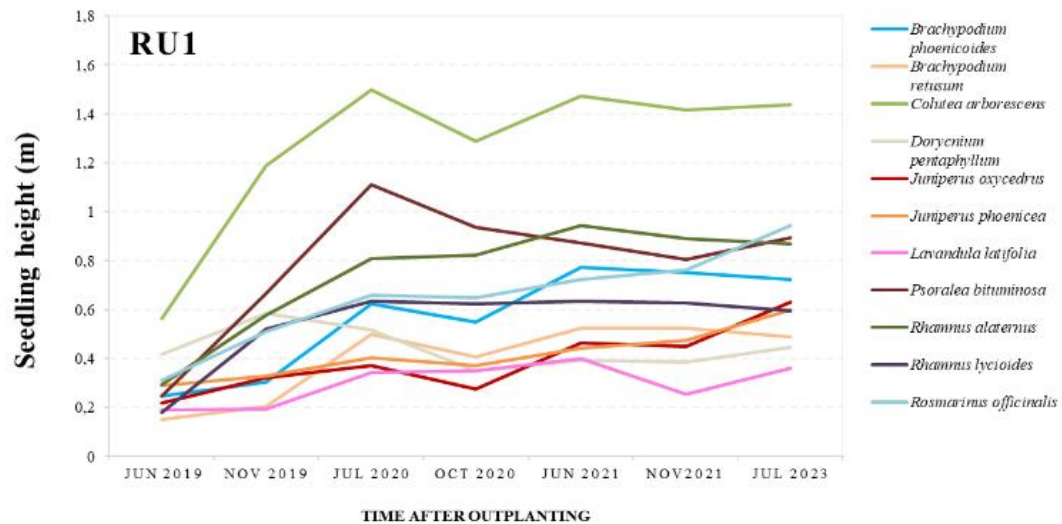
Fig 3. Survival rates (%) by species in the After-LIFE phase of the TECMINE project (June 2023) in each Restoration Unit: RU1 (left), RU2 (right) and RU3 (bottom). Values are means \pm SE.

2.- Analysis of plant growth

Seedlings growth was variable depending on the species and the RU restoration unit (Fig. 4). Some species such as *Colutea arborescens* or *Sorbus domestica* showed higher growth than the



rest of the species. In general, all species showed positive growth rates, however, some of them were specially affected by predation (by roe deer or wild pigs) showing slightly lower values than previous samplings.



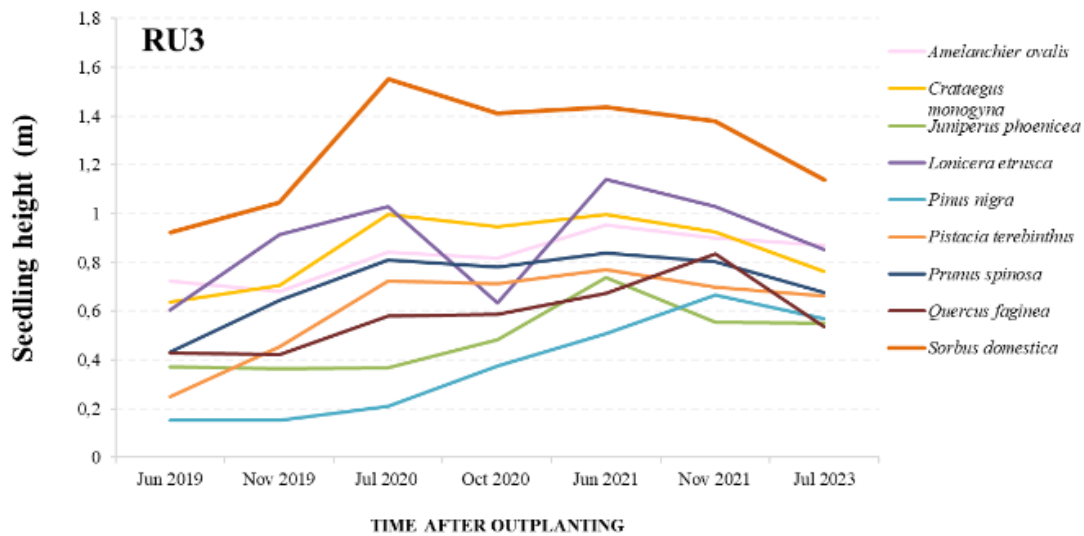


Fig. 4. Average seedling height over time for each planted species. The period covers from the nursery to the After-LIFE survey (July 2023) for each Restoration Unit: RU1 (upper plot), RU2 (middle plot) and RU3 (lower plot).

3.- Natural colonization, biodiversity, and soil protection

Vegetation cover in the three restoration units was around 66% on average. This meant a 4% increase in two years (from 2021 to 2023). This increment mainly corresponds to the plant cover found in the RU2, while the other two restoration units RU1 and RU3 decreased by 11% and 7% respectively (Fig. 5). Nevertheless, these small reductions in plan cover were very low and statistical test were not significant. In both cases, the restoration units RU1 and RU3 had similar decreasing trends possibly due to the high solar exposure for RU1 and the enlargement of a gully observed in situ in RU3 which belongs to the valley bottom area.

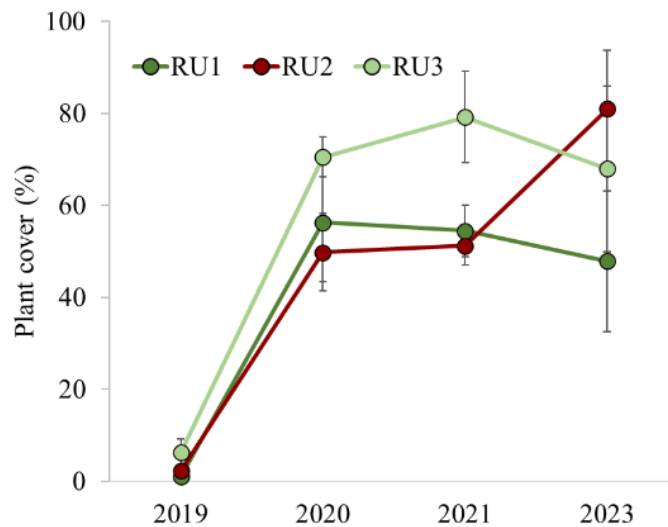


Fig 5. Plant cover (herbaceous + woody species) in each Restoration Unit: RU1 (upper plot), RU2 (middle plot) and RU3 (lower plot). Values represents means \pm SE.

In relation to sown species for soil protection (*Lotus corniculatus*, *Melilotus officinalis* and *Dactylis glomerata*), the absolute plant cover significantly changed over time, depending on the species. In the last monitoring (July-23), their cover decreased considerably in all restoration units (Fig 6), which may have favoured the natural colonisation of native species.

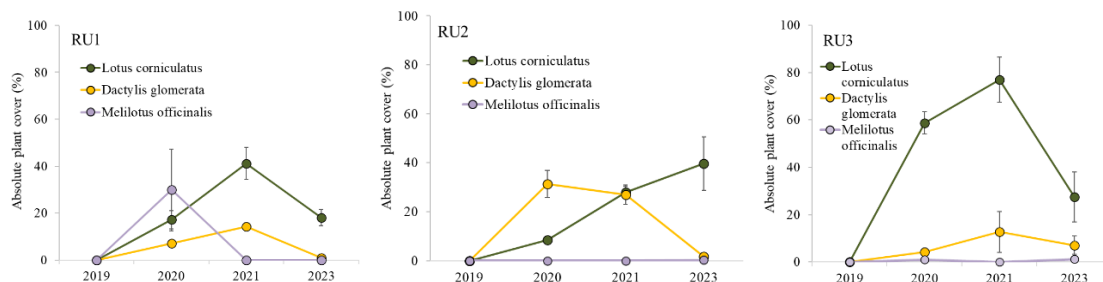


Fig 6. Absolute plant cover of the sown herbaceous species (*Lotus corniculatus*, dark green; *Dactylis glomerata*, yellow; *Melilotus officinalis*, grey) during the different monitoring periods (2019, 2020, 2021 and 2023). Values are means \pm SE.

Regarding plant diversity, 20, 33 and 27 non introduced species were found within restoration units RU1, RU2 and RU3, respectively. Although diversity and species richness indices were higher in RU2 (Fig 7a, Fig 7b, Fig 7c) we did not find significant differences between restoration units (95% CIs overlap) which is positive as it was not intended to have differences between them.

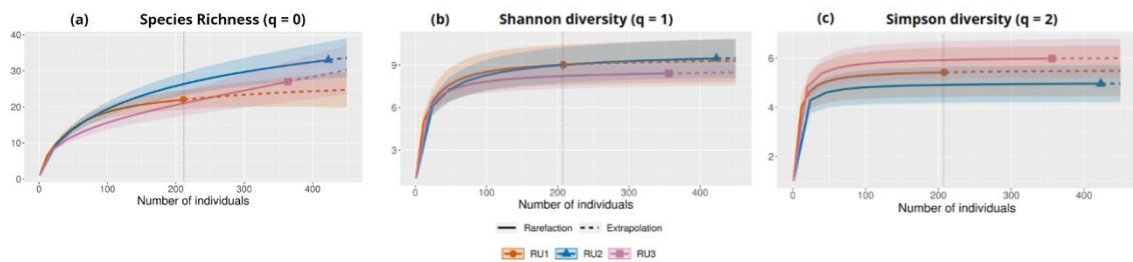


Fig 7. Diversity indices. In the curves: rarefaction (solid lines) and extrapolation (dashed lines) and in the mark (triangle, circle or square) the number of individuals observed. (a) shows species richness in each area ($q=0$). (b) Shannon index ($q=1$) and (c) the Simpson index ($q=2$). (Orange circle = Restoration Unit RU1), (Blue triangle = Restoration Unit RU2), (Pink square = Restoration Unit RU3). The grey dashed vertical line indicates the number of individuals considered when assessing the indices.

CONCLUSIONS:

1. During the After-LIFE monitoring period (4.5 years after restoration), we still may affirm that a proper species selection promotes high survival rates regardless of abiotic conditions, even in the most unfavourable scenarios, like RU1. In comparison to previous restoration actions performed in the mining area and prior CEAM's own experiences, the overall survival rates achieved in TECMINE can be considered high. Especially considering that one factor contributing to the reported mortality is browsing by wild animals, which is difficult to prevent.
2. Height growth of species follows the expected development patterns, with some species growing faster than others. Numerous species have been reported to undergo fructification and flowering, and in certain instances, the recruitment of new individuals from these fructified species has been noted.
3. Achieving a high amount of plant cover is essential for halting soil degradation processes and accelerating the restoration of key ecological processes. After 4.5 years, plant cover showed average values over 60%. Furthermore, significant presence of dead biomass—such as plant debris and necromass—that have incorporated into the soil and subsequently increased fertility are visible.
4. Species diversity has increase over time. This entails improving ecological conditions to facilitate the recruitment of new native plants. In addition to plant cover, additional elements covering the soil, such as stones, litter, or organic matter waste (such as



organic fences), were also crucial in raising the roughness of the soil surface, which promoted seed germination and the establishment of new native colonising species.

5. According to our expectations, plant cover of sown species is declining 4.5 years after seeding. It is a sign of a good species selection, with herbaceous with a fast growth during early stages after restoration to ensure soil protection from erosion and after that time, gradually disappear to allow the entry of natural colonization.



SUPPLEMENTARY INFORMATION



Fig. 1. General view of restoration unit RU1 during the After-LIFE monitoring (July-23). Plant cover in this unit is lower than in RU2 and RU3. However, we found high survival rates of introduced seedlings.



Fig. 2. General view of restoration unit RU2, with high degree of plant cover.



Fig. 3. Transects display in RU2. We assess every 20 cm soil cover, species richness and abundance.



Fig. 4. Detailed image of *Rhamnus alaternus* fructification (left) and new recruitments of *Colutea arborescens* (right).

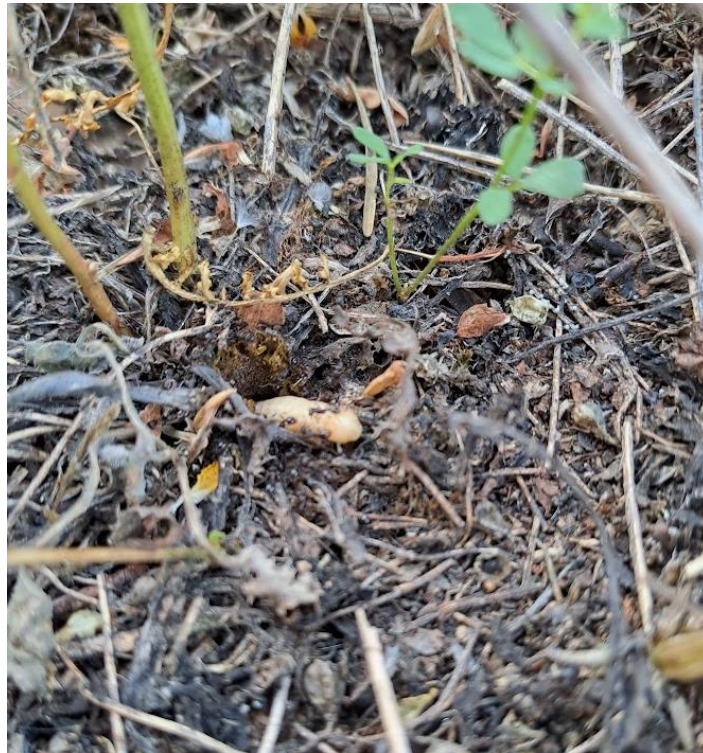


Fig. 5. Detailed image of soil cover under vegetation. 4.5 years after restoration, we found significant presence of organic matter and plant debris that are being incorporated into the soil, increasing fertility, and composing step by step a real soil that started from mining tails.