INSTITUTO POLITÉCNICO DE BRAGANÇA Escola Superior Agrária

Environmental and landscape rehabilitation plans
The case of Foz de Tua dam

Presented and defended publicly by

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«. . . Indeed, Three years are three days . . . »

. . . . Rest in peace dear Dad

Dedicated to your dear soul . . .

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Abstract

The construction of Foz de Tua dam caused a severe environmental change at local level, producing a considerable visual impact that must be remedied and the disturbed area must be rehabilitated and recovered, approaching to the previous landscape before the dam construction. The affected area is close to the Alto Douro Vinhateiro World Heritage, what means special care is needed, considering at same time the humanized landscape and also the natural characteristics present in the area, namely for the vegetation.

With this work, several interventions were proposed, aiming to reduce the visual impact caused namely by slope excavation, but also by vegetation removing, needed for the Foz Tua dam construction. For vegetation recovery, natural vegetation was identified and a recovery plan were developed, aiming to reproduce the previous landscape configuration by planting and seedling, considering both natural vegetation and cultivated areas structures. For exposed rocks we started some assays with the purpose of find a treatment for fresh cutted granite that could be used as a general rock treatment for visual impact of fresh excavated rocks. Some organic mixtures were tried, using also autochthonous lichens and moss, as well as chemical treatments, like acid or paint. Granite blocks were selected and five different treatments were applied to cover the fresh granitic blocks and trigger their colonization and aging. The experiment has been established on two groups of blocks, one submitted to irrigation three times a week and the other group does not. Each treatment had two repetitions per group. Two blocks for control were also established in each group to interpret the gaps of variation in comparison to the treated blocks. All the stone blocks were maintained in a greenhouse, with controlled temperature and humidity. The monitoring of the treatment was by taking pictures every 20 days, that were analyzed using RGB color characteristics and parameters that shows the evolution of pigmentation of the blocks. The results of this study show that three or at least two from the five experimented treatments are recommended to use in the disturbed area. The irrigation can be recommended also for the two to three first weeks after treatments establishment.

Keywords: visual impact, quarrying, granite treatment, rock colonization, change in color

Resumo

A construção da barragem de Foz de Tua causou uma grave mudança ambiental a nível local, produzindo um impacto visual considerável que deve ser corrigida e a área perturbada deve ser reabilitada no sentido de repor, tanto quanto possível, da paisagem anterior à obra. A área afetada está próxima do Alto Douro Vinhateiro Património Mundial, o que exige um cuidado especial, considerando ao mesmo tempo a paisagem humanizada e também as características naturais presentes na área, nomeadamente para a vegetação.

Com este trabalho, foram propostas várias intervenções, com o objetivo de reduzir o impacto visual causado, nomeadamente pela escavação das encostas, mas também pela remoção da vegetação, necessária à construção da barragem de Foz Tua. Para a recuperação da vegetação, foi preparado um plano de plantação, com o objetivo de reproduzir a configuração da paisagem anterior à construção, considerando também a estrutura da vegetação das áreas cultivadas. Para rochas expostas, iniciamos alguns ensaios com o propósito de encontrar um tratamento para granito cortado fresco com o intuito de reduzir o impacto visual da rocha recentemente cortada. Algumas misturas orgânicas foram testadas, usando líquenes e musgo autóctones, bem como tratamentos químicos, como ácido ou tinta. O ensaio foi estabelecido em blocos graníticos cortados frescos, mantendo-se dois grupos de blocos, um recebendo irrigação três vezes por semana e o outro grupo não. Cada tratamento teve uma repetição por grupo. Dois blocos de controle também foram estabelecidos em cada grupo para interpretar as lacunas de variação em comparação com os blocos tratados. Todos os blocos foram mantidos em estufa com temperatura e humidade controlados. Foi efetuada a recolha de fotos a cada 20 dias e analisada a evolução das intensidades e parâmetros de luz RGB dos blocks de rocha tratados e respetiva pigmentação. Os resultados mostraram que três dos tratamentos resultaram em alteração da cor da rocha, podendo ser recomendados para uso na área perturbada.

Palavras chave: impacto visual, escavação, tratamento de granito, colonização de rocha, alteração de cor**.**

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RECAPE: Relatório de Conformidade Ambiental do Projeto de Execução/ Environmental Compliance Report of the Execution Project

RELAPE: espécies com interesse para a conservação/ species with interest for conservation

EIA : Estudo de Impacto Ambiental / Invironmental impact study

PRAIP: Projeto de Recuperação Ambiental e Integração Paisagística/ Project of Environmental Recuperation and Landscape Iintegration

ADV: Alto Douro Vinhateiro/Alto Douro Vineyard

LVIA: Landscape and visual impact assessment

Treatments

T1: Made using moss, lichen, gelatin, flour, soil and fertilized water.

T2: Coloration

T3: Made of moss, lichen and soil mixed with the flour and fertilized water

T4: Made of gelatin and the mixture of soil, fertilized water, moss and lichen.

T5: Nitric acid

T6: Control

I. Introduction

Growing population and rising levels of economic activities increase human demand for water and related services. Development, technological change and income distribution affect the level of water demand. Moreover, lifestyle is changing all over the world causing a very significant impact on water use.

For these reasons, demand for water is steadily increasing throughout the world. However, freshwater resources are limited and unevenly distributed in both time and place. In addition to this, seasonal variations and climatic irregularities in flow lead to the inefficient use of river runoff, with floods and droughts causing problems of catastrophic proportions (Altinbilek and Dogan, 2002).

From the beginning of human history, for almost 5000 years, dams have served to ensure an adequate supply of water, by storing water in times of surplus and releasing it in times of scarcity. Thus preventing or mitigating floods and making a significant contribution to the efficient management of finite water resources, that are unevenly distributed and subject to large seasonal fluctuations. In other words, the construction of dams in the concept of water resource management has been always considered as a basic requirement to harmonize the natural hydrological regime with human needs for water and water-related services. In addition to that, dams have an important role in generating electricity, they are considered as the largest renewable energy source in the world. More than 90% of the world's renewable electricity comes from dams. (Altinbilek and Dogan, 2002).

The case of Foz de Tua Dam, situated in the downstream of the Tua River located in the Douro basin, northeast of Portugal. This dam is constructed mainly to produce energy; the reservoir reaches 170m altitude at full capacity, it has a length of 27 km and a flooded area of 420 hectares. It has 108m height, its total volume is 106 hm^3 and its construction has many benefits at the national level (Profico, 2008). Also according to the same source, the Foz de Tua Dam allows the growth of national water production capacity by 6%, which can provide half of the municipality of Porto. The annual gross output is more than 660 gwh, which is twice the annual electricity consumption of the five municipalities covered by the project (Alijó, Carrazeda de

Ansiães, Murça, Vila Flor and Mirandela) (EDP, 2017). According to the same source, the construction of this dam will provides several advantages as the annual reduction of 20 million euros in imports of fossil fuels of which three million euros avoided CO_2 equal to 200 kt / year.[1] However, dams generates several kinds of negative impacts, like those that include effects of the dams on territorial biological systems encompassing indeed, water quality, fauna , vegetation water-soil-nutrient relations which were settled after floods in the downstream of the dam, change in a long period of time. Furthermore, compulsory changes occur in flora, fauna and the agricultural traditions of people in the region. This effect can extend for kilometers (Tahmiscioğlu, 2006).

Dams construction can block the continuity of hydrology, disrupt sediment transport and fish migration by modifying the seasonality of flows, it also alter surface and subsurface water levels, changing the magnitude, duration, frequency, timing, predictability, and variability of flow events (Nilsson and Berggren., 2011)

Furthermore, during the construction of dams, the landscape doesn't escape to the negative impacts generated by this fact, the disturbance, produced en general by the excavation of the area, engenders globally the unbalances of the ecosystem. In addition to that there is also the visual impact that occurs from the beginning of the project works till after its establishment. This impact reflects the modification of the configuration and the arrangement of the different patterns and processes of the landscape.

Visual impact can be generated from activities using quarrying as mining (Mouflis et al. 2008) and dam construction. In both cases, the excavation gives rise to a serious impact that extends over larger areas as noticeable scars of high color contrast, reducing the aesthetic appeal of the landscape and deteriorating the scenic quality of areas (Prieto et al., 2006).

The ability of a landscape to absorb development and the associated visual impact is related to the scale or size of the development. The association or affinity of the development with the surrounding landscape (such that the same feature will be less or more noticeable in an industrial or semi-natural rural landscape) and finally the upset of harmony of the landscape by contrasts of color or shape, which distract the focus of an observer (Prendergast and Rybaczuk, 2004). For Foz de Tua Dam the case was not different, the construction has generated a damaged and disturbed area of about 10 hectares. The quarrying of the two flanks of the river and also the spaces dedicated for the staff and construction support buildings has generated a big visual impact of fresh cutted granite rocks as shows the illustration below (figure 1).

Figure 1: Study area before the dam construction. (Google Earth image, on 2006)

Figure 2: **Excavated area due to the dam construction in Foz de Tua. (Adapted from Google Earth, 2017)**

The visual impact of quarrying receives considerable attention particularly in view of the long duration of quarrying activities and often permanent re-profiling of the landform. Quarries are often located in areas with high scenic value and sometimes lying within areas with important statues of conservation (Ramos and Panagopoulos, 2006).

The case of Foz de Tua Dam doesn't escape to this issue; it is located in an important area, classified as World Heritage Site Status for its outstanding example of a traditional European wine producing region, which make its rehabilitation an important step to maintain the status of that area. Despites of the status that can has the circle where the concerned area is located, rehabilitation of degraded areas is an urgent matter from the perspectives of both compensation or enrichment of ecosystems and sustainable use of degraded areas on regional and global scales (Forestry Agency and ITTO, 1991).

The landscape rehabilitation enables the generation of morphology in harmony with that of the surroundings, capable of reestablishing the potential geomorphological processes. It establishes an hydrological balance and promotes soil formation and evolution (edaphogenesis-biostasia) to create a substratum of biotic activity. Landscape rehabilitation allows the establishment of initial vegetation covers and creates the conditions for this cover to develop alone, either naturally or within a forestry and pastureland system, into a formation with similar features to those of the original vegetation(Duque et al. 1998).

In the Foz de Tua case, the rehabilitation of the area responds simultaneously to both reducing the visual impact resulting from the quarrying during the dam construction and reintegrating the damaged area into its own ecosystems.

To respond to this kind of rehabilitation this work is proposing the idea of hiding out and reducing the visual impact by: (1) the colonization of the fresh cutted rocky granitic area. This colonization is made based on treatments of Moss and Lichen to set off the natural dynamism of fresh cutted rocks natural colonization. (2) The coloration of the rocks using the paint techniques in order to mitigate immediately the visual impact of the excavated area and by the end allowing the slow natural colonization of the rocks as a natural process. (3) The use of nitric acid, trying to accelerate the degradation of the rock so that the natural colonization of these ones can be easily and early established and maintained and finally the recovery of the area by the plantation and the seeding of the endemic species using spread soil in flat spaces.

II. Literature and review

- **Visual impact of quarrying**

Visual impact ,represented usually by a strong contrast between the patterns of the landscape, results from the quarrying activity regardless of the reasons that are behind this quarrying (mining activities, dams or highway construction, etc). In order to assess the impact produced by surface excavation, (Dentoni and Massacci, 2013) see that some aspects of landscape modification can be objectively measured, such as the extent of the visible alteration, its shape and the chromatic contrast with the surroundings.

Landscape and Visual Impact Assessment (LVIA), in fact, relies more on judgment and less on measurements, involving individual perceptions, aesthetic tastes and visual comprehension (Nicholson, 1995). The alteration of the landscape arising from mining activities or other activities as dam construction might be perceived very negatively by those individuals who do not live in the area (tourists or occasional visitors) and who therefore are not prepared to accept in congruities in the landscape; this is a major issue in areas of high scenic value or where the tourist industry has potential for growth (Dentoni and Massacci, 2006).

For (Pinto et al., 2002), one of the most important environmental impacts resulting from opencast mining, and especially quarries, is the visual impact. It might be argued that scenic quality, despite its no direct utilitarian value, is an important component of the quality of life. Landscape visualization techniques (3D virtual reality) can help as decision support systems to reduce subjectivity in visual impact assessments and effectively communicate landscape changes to planning authorities and the public before planning permission is given (Nakamae et al., 2001; Orland et al., 2001; Paliokas et al., 2007; Ramos and Panagopoulos, 2004; Schmid, 2001).

Evaluation of the visual impact can considers two aspects as the author Pinto says : first, the area occupied by the quarry as seen by an observer from a specific place, and, second, the chromatic contrast existing between landscape and exploitation(Pinto et al. 2002).

- **Mitigation of the visual impact of quarrying**

Several works has treated the visual impact as an important impact generated from quarrying in general (Panagopoulos et al., 2007), (Mouflis et al., 2008), (Dentoni and Massacci 2013). Some of them didn't stop only in the stage of the assessment, Prieto and Silva studied the induction of biofilms on the open rock faces of quartz quarries, this induction is reported as a feasible method of correcting the visual impact generated by the industry. Experiments were carried out to colonize quartz samples with microorganisms isolated directly from aged quarry faces. The results demonstrated the viability of inducing colonization on quartz, which is not the most favorable material for such treatment. Furthermore, biofilm development caused a significant change in the color of the surface of the quartz samples to greenish- or reddish yellow, which may be quantified by a colorimeter for solids. The notable change in the color is sufficient to attenuate the bright white aspect of the quartz faces and therefore to correct the visual impact generated. (Prieto et al., 2006).

For other authors, they studied colonization by lichens of five granite dolmens in Galicia (NW Spain); they have evaluated microscopic-level effects of colonization granitic dolmens by five species of lichen in samples taken from nearby outcrops of the same granite as the dolmens. Hyphae were observed to penetrate almost exclusively through intermineral voids (Prieto et al., 1994).

Others, like (Kaliampakos,1998) had suggested rehabilitation scheme includes the following steps: (1) biogas management because the area was an abandoned quarry used as uncontrolled landfill (2) material relocation-reshaping of disposal slopes (3) new land use establishment (4) reforestation at selected points.

All these cases represent the several rehabilitation processes which use different interventions on the landscape in the aim to reduce the visual impact due to quarrying or other slope excavation actions, like in big dams or highways construction.

- **Granite colonization ability**

Life on the rocks – at the interface between the atmosphere and a solid substrate (lithosphere) – is an ancient terrestrial niche. Today, rock surfaces freshly exposed to the atmosphere (e.g. after volcanic eruptions, following construction of buildings, etc.) are rapidly colonized by microbial communities (Gorbushina, 2007), all major groups of microorganisms – chemolithotrophic, chemo-organotrophic and phototrophic – can be found in SAB communities: Algae, bacteria, fungi, protozoa as well as microscopic animals like mites and other insects (Gorbushina and Petersen 2000) may be present. In damper locations, moss may form part of the community.

In Galicia-(NW Spain)-, the colonization was studied on five granite dolmens, the factors most strongly influencing colony initiation and position were degree of exposure to rain, insolation, substrate verticality /horizontality, humidity and location (Prieto et al. 1994). These authors have studied microscopic-level effects of colonization by five species of lichen (*Xanthoria parietina, Aspicilia cinera, Diploschistes scruposus, Pertusaria coccodes* and *Ochrolechia parella*) in samples taken from nearby outcrops of the same granite as the dolmens. Hyphae were observed to penetrate almost exclusively through intermineral voids, except in the case of micas which were penetrated between layers. The only minerological effect observed was degradation of micas to mica-aluminium hydroxy vermicultie intergrades.

In another study in Belgium, the vegetation was formed only of lichens mainly from the genus Parmelia, especially in convex granite slabs, foliaceous, encrusting, closely applied to the rock. Their coating is very important and often reaches 80%. Under this layer of lichens, there is a slight accumulation of organic matter from their in situ decomposition. Thanks also to the maintenance of certain humidity; the granite is very distinctly coarse gravel. In the concave granite slabs and with low slopes, these perfectly smooth parts are irrigated abundantly by rainwater during periods of precipitation. On these surfaces absolutely hues, there are no lichens and the first colonization is carried out by moss, this latter forms small balls strongly adherent to the substratum (Taton, 1949).

The colonization has an effect on the chemical weathering of granite (Zambell et al. 2012). both lichens and other microbial land cover may have been relatively more important to biogeochemical cycles and global temperature, through their biotic enhancement of weathering (Schwartzman and Volk 1989) In addition, lichen hyphae have been widely demonstrated to penetrate surfaces on a variety of rock types, and have been found to be associated with greater spacing between mineral grains (Cooks and Otto 1990). These authors reasoned that the expansion and contraction of such penetrating hyphae should generate sufficient tensile stresses to break loose fragments of material that might otherwise have remained intact.

De Los Rios et al., (2005), in their study of "Ecology of endolithic lichens colonizing granite in continental Antarctica", they found that the symbiont cells of several endolithic lichens colonize granite in continental Antarctica and the relationships they have with the abiotic environment were analyzed *in situ*, in order to characterize the micro ecosystems integrating these lichens, from a micro ecological perspective. Mycobiont and photobiont cells, the majority classified as living by fluorescent vitality testing, were observed distributed through the fissures of the granite. The fact that extracellular polymeric substances were commonly observed close to these cells and the features of these compounds, suggest a certain protective role for these substances against the harsh environmental conditions. Different chemical, physical and biological relationships take place within the endolithic biofilms where the lichens are found, possibly affecting the survival and distribution of these organisms. The alteration of bedrock minerals and synthesis of biominerals in the proximity of these lichens give rise to different chemical microenvironments and suggest their participation in mineral nutrient cycling.

- **Moss and lichens ecology**

In the ecological studies of the moss and lichen communities, the Japanese searcher Nakanishi, see that the distribution of the moss associations was analyzed in relation to the pattern of water supply. From this investigation, it was ascertained that the distribution of some associations was closely correlated with this pattern. A remarkable relationship between lichen communities and bird nests was observed in the central region. It seems that the species composition and the distribution of the lichen communities are influenced decidedly by the organic nutrients supplied from the excrement of sea birds. The direction of the habitat of each terrestrial community was examined in all ice-free areas. Most of the communities grew in habitats on the leeward side of wind-barriers facing from west-northwest to southwest, although the direction was somewhat determined by the pattern of water supply in their habitat (Nakanishi, 1977).

Bryophytes occupy very varied habitats (biotopes) and are therefore almost everywhere, except in marine environments, in coastal environments too salty, in a too dry environment like some deserts or in polar ice environments or high mountains. Because of their biology and physiology, these plants react very finely to the microconditions of the environment and therefore constitute mostly good bioindicators. The habitats involved range from terrestrial to aquatic environments, with all intermediaries, from very sunny to very shady environments, with a great variety of supports (rocks, sand, soil, humus, peat, bark, dead wood, living leaves in tropical environments ...). Some species may colonize several habitats (bark and rocks, soil and rocks, dead wood or peat or crude humus). Finally, it is necessary to underline the importance of the pH (acidity more or less strong) and the chemical nature, linked to the rate of limestone or that of organic matter. (Manneville ,2011).

III. Materials and methods

- **Study area**

The study area is the Foz de Tua dam located in the downstream of the Tua river located in the east of Douro basin, Northeast of Portugal (Figure 3) .Its extent approximately is around 10 ha. The climate is temperate with continental influence, with cold winters and hot and dried summers; the average of precipitation varies between 700 and 800 mm. The annual average temperature varies from 15°C to 16°C (IVDP, 2017). The elevation is between 80 m as a minimum (the bottom of the river) and 250 m as a maximum (the upper part of the river flanks). Granites and schists are the geological outcrops after decapitation of the river flanks for the dam construction.

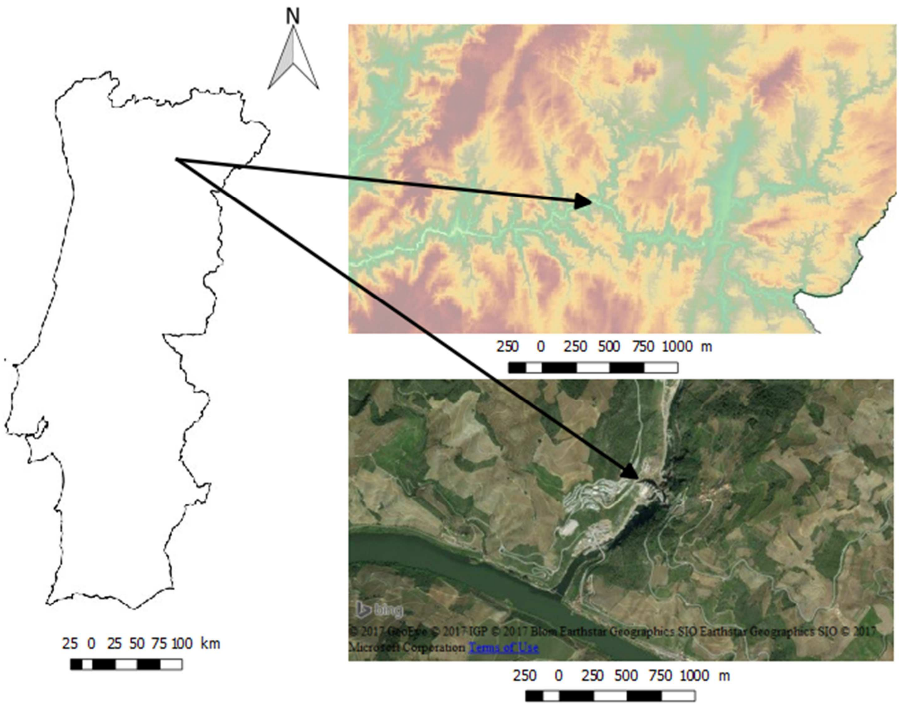

Figure 3: **Location of the study area, the Tua River's downstream, in Northeastern Portugal.**

The bioclimatic indices were applied to the Portuguese mainland by Monteiro Henriques et al. (2016) as can be seen in Figure (4) and Figure (5). Without going into unnecessary details, from the observation of the figures produced by those authors, it is concluded that the final section of the Tua River valley lies in the lower mesomediterranean bioclimatic floor, Dry top. Bioclimatically, the mouth of the Tua is similar to the mouths of the great tributaries of the Douro, in Trás-os-Montes and in the Beira-Duriense region. As is typical of the Mediterranean climate, rain is concentrated in the cold season. The combination "soil water" x "plant growth temperature" boils down to a small spring period and an even smaller one in the fall. Winter is too cold and summer too dry to allow plants to grow on zoned soils. The Mediterranean climate has a second characteristic: a high year-on-year variation of climatic elements. These factors explain the natural susceptibility of Mediterranean vegetation to anthropogenic disturbances.

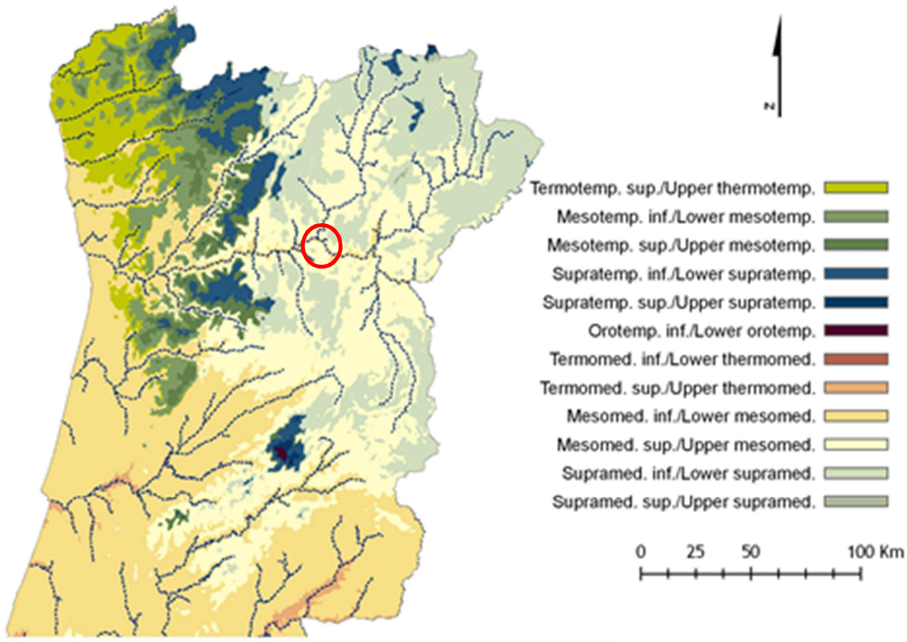

Figure 4: **Termoclimate of the center and Northern Portugal (Monteiro-Henriques et al 2016).**

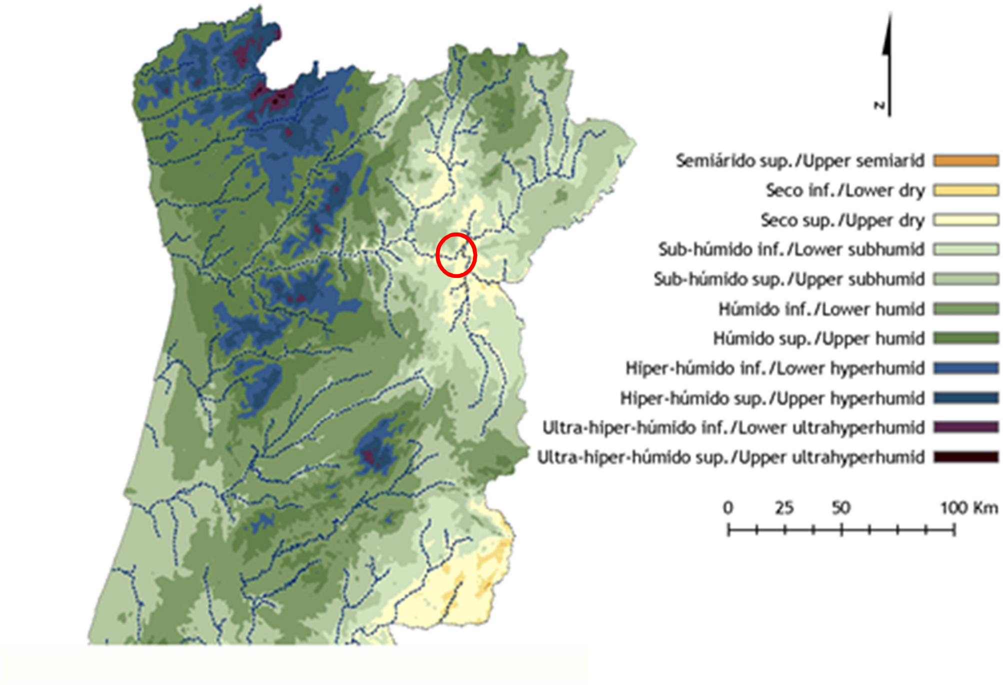

Figure 5: **Ombroclimate of central and northern Portugal (Monteiro-Henriques et al 2016**

- **Cultural value of Foz de Tua river**

The Douro river is one of the important ecosystems in Portugal, this last has been granted as World Heritage Site Status for its outstanding example of a traditional European wine producing region and since Tua river is a tributary river for the Douro river and the concerned dam is exactly constructed where Tua river meet Douro river, the dam construction space has to be well managed and maintained to not impact the value of the site and its status as a world heritage.

- **Foz de Tua Dam**

The Dam of Foz Tua is located on the river Tua, a tributary of the right bank of the river Douro, about 1.1 km from the confluence of these two rivers. The dam is located in the municipality of Alijó - district of Vila Real (meeting of the right bank) and in the municipality of Carrazeda de Ansiães - District of Bragança (meeting of the left bank). Its reservoir also affects the municipalities of Murça, Vila Flor and Mirandela.

Its construction began in 2011, the aim of its establishment is firstly the production of electricity and also the storage of water for the agriculture, its useful capacity is $28x10^6$ cubic meters, the annual average production is estimated as 275 GWh, and also the avoided gas emissions directly and indirectly are estimated to be 200 Kt which shows its positive impact on the environment from this viewpoint.

Figure 6: Perspectives of the Foz de Tua dam during construction phase. Photo by Paulo Cortez

- Foz de Tua land use

The figure below represents the map showing the land use of the area where the dam is constructed.

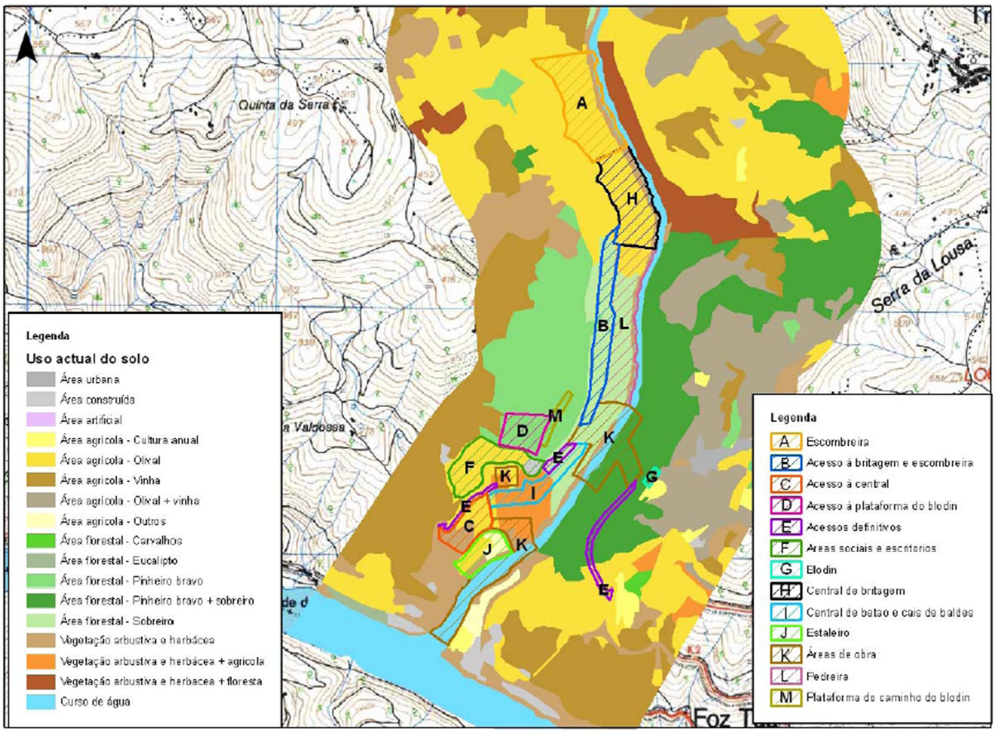

Figure 7: Land use and infrastructure of the dam are

The land use in the area of dam is very diversified, but we find mainly agricultural areas destined to the annual culture, olive trees and vineyard, forest areas of oaks, junipers, eucalyptus, pine trees and cork oak trees. Adding to that shrubs and herbaceous vegetation.

1. Vegetation recovery

The first part of this work is interested in landscape rehabilitation through vegetating the area trying to imitate the previous landscape before the interventions of the dam construction

Before planning about the recovery of the area a good knowledge of the ecological successions is essential to establish an adapted planification of the rehabilitation that imitate the original landscape and get rapidly integrated to it.

- **Ecologic succession**

For the Tua river valley, the ecological succession can be illustrated in a very simplified way through the regressive sequence characteristic of the sub-humid Meso-Mediterranean climatophilic Lusitanian-Douro vegetation series, presided over by the overlays of the Physospermo cornubiensis-Quercetum suberis. This series of vegetation prevails in the plateaus overlooking the Tua River, at altitudes immediately inferior to the series of deciduous forests of *Quercus pyrenaica*. The climatic vegetation is of the forest type - forest - and dominated by the cork oak. The climatic soils (zonal soils), usually classifiable in the class of the luvisoils, are deep, well-structured and with an organic matter of the mull type forest. On the fringes of the cork oaks, high grasses are developed, still based on soils with forest characteristics (mainly organic matter), dominated by arbutus trees (Arbutus unedo) or legumes of the tribe of the genisteas - giestas (*genus Cytisus* and *Genista*) . These communities constitute the first stage of the replacement of climatic forests in the regressive sense.

In mosaic with the high marshes, in soils still with some depth, communities of herbaceous perennial plants arise - the perennial GRASS LANDS dominated by deeply rooted clonal grasses (e.g. *Agrostis castellana, Dactylis glomerata s.l., Arrhenatherum elatius* subsp. *Baeticum)*. In a more advanced regressive stage, the heliophilous low - mottled oligotrophic grasses - dominated by the stele (*Cistus ladanifer*) and by the arule (*Lavandula sampaioana*) appear. These weeds settle in tendonly eroded and thin soils (leptosols) with poorly decomposed and acidic "mor" type organic matter, a very low exchange content (oligotrophy), usually presenting coarse materials enriched in coarse materials due to fine fractions by laminar erosion. The coarse texture of these soils and "mor" organic matter imply a reduced capacity for cation exchange and water retention, and consequently low physical and chemical fertility. The water deficit during the dry season is aggravated by its small thickness. In these low forests, nitrogen and (possibly) phosphorus are important limiting factors of primary productivity. In the glades of the stellar, there are pioneer communities of annual plants (*Helianthemetea guttati*) - the annual meadows - that enter senescence badly the rains cease in the spring.

In a progressive sense of ecological succession, new plant clusters may emerge, such as the pioneer communities of crassifolia terophytes (*Sedion pedicellato-andegavensis*), the low-lying bushes (communities of pulviniform pods of *Hieracio castellanae-Plantaginion radicatae* or *Armerion eriophyllae*) and secondary forests (Eg secondary forests of *Quercus faginea* subsp. *Faginea* and *Q. x duriensis*). The starting point of a succession in the progressive sense may be either a secadal marsh (*Stipo giganteae-Agrostietea castellanae*) or a recently abandoned agricultural land or bare rock. The following steps depend to a large extent on the soil depth and the rainfall of diaspores. In the Lusitanian-Douro mesomediterranean territories, recently abandoned agricultural land is normally colonized by a mosaic made up of the pioneering community of *Cytisus multiflorus* and *Lavandula sampaioana* and by another community dominated by Spanish Agrostis and other perennial grasses. Depending on the depth of the soil, the system can evolve towards a mosaic of pre-forest and teased perennial clones of *Agrostis castellana* or toward a subserial stellar. If in its proximity there are no diaspores of species from other stages of the ecological succession, this mosaic may prove to be temporarily quite stable.

- **Vegetation of the final section of the Tua river canyon**

In the valley of the Tua river two series of vegetation are identified:

- Series of Holm oak-juniper vegetation*: Rusco aculeati-Juniperetum lagunae*;
- Series of climatophilic and climaxophilic vegetation of the over-Junipers: *Junipero lagunae-Quercetum suberis*.

Regosoils derived from thick pediment deposits and abandoned (eg deadly) antrosoils are the Junipero lagunae-Quercetum suberis overhang-juniper habitat. The forest in question has an original combination of trees: three angiosperms of the genus Quercus (*Q. faginea s.l., Q. suber* *and Q. rotundifolia*), with a gymnospermic (*Juniperus oxycedrus*). *Pistacia terebinthus*, *Olea europaea* var. *Sylvestris*, *Crataegus monogyna* and *Pyrus cordata*, for example. The Junipero-Quercetum suberis contacts the forests of *Q. rotundifolia* and *J. oxycedrus* (*Rusco aculeati-Juniperetum lagunae*) on the drier, thinner soils. The interaction of low precipitation with climatic continentality delays or prevents the closure of the canopy of the arboreal stratum, favoring the penetration of these subspecies (*eg Retama sphaerocarpa, Cytisus scoparius, Cistus ladanifer, or Cistus ladanifer*) in these forests - zircon and junipers. (*Lavandula pedunculata*).

Cytisus multiflorus, the white-flowered broom, is a pioneering plant of soils abandoned by agriculture or disturbed by forest operations. The properties of the soil condition their evolution towards high grasses (thicker soils) or low grass (soils truncated by erosion). Of yellow blossom, *C. striatus* has a marked preference for soils abandoned by agriculture or modified by afforestation; *C. scoparius* prefers forest matrix territories. Under the dry shoulder, as in the Tua valley, the high brush also contains *Retama sphaerocarpa* (Cytisus multiflorus-*Retametum sphaerocarpae*). The low grasses fit into the *Cisto-Lavanduletea* vegetation class because they are dominated by aromatic species such as *C. ladanifer*, *L. pedunculata* subsp. *Sampaiana*, *Thymus mastichina* or *Th. Zygis* subsp. *Zygis*.

For subsurface pastures, there are omnipresent perennial grass communities with *Dactylis glomerata* s.l. And *Arrhenatherum elatius* subsp. *Baeticum*, where several hemicriptophytic dicotyledons such as *Ornithogalum concinnum*, *Centaurea langeana*, *Daucus carota* subsp. *Carota*, *Hypericum perforatum* and *Sanguisorba verrucosa*. Pastures of annual plants (*Tuberarietea guttatae*) are very diverse in the study area because the annual life cycle is an advantageous adaptation to summer dryness. They are enriched in *bulbous Poa* and *Trifolium subterraneum*, and other species, when subjected to grazing, of domestic or wild species.

The high grasses, low grasses and perennial and annual pastures listed are serial steps common to the two vegetation series mentioned above, which fill abundantly the slopes of the canyon of the river Tua. To complete the description of the vegetation of this territory it is necessary to approach the plant communities that make up the edafo-hygrophilous and tempori-hygrophilous series, the rupicultural vegetation, the nitrophilous communities and the vegetation of temporarily soaked soils.

Here and there, along the valley, temporary timber hybrids of *Celtis australis* are placed in soils moistened by natural water exsurgencies. Generally, they accompany the lodge-bastard, shrubs and lianas of the rosaceae family (e.g. *Rosa sp*.pl., *Rubus ulmifolius* and *Crataegus monogyna*) or araliaceae (e.g. *Hedera hibernica*). In the communities of *C. australis* also enter willow trees (*Salix atrocinerea* and *S. salviifolia*) and *Acer monspessulanum*. The construction of the Tua Line has increased the potential habitat of this community, as witnessed by the abundance of thorny rosacea along the railroad track.

The riparian and rupiculum vegetation of the floodplain of the Tua cannon was seriously altered in the zone of construction of the dam. During the EIA and RECAPE process, a mosaic of vegetation involving *Salix atrocinerea* willows, *Alnus glutinosa* trees, *Buxus sempervirens* communities and flood bed communities (with *Festuca duriotagana*, *Petrorhagia Saxifraga* and *Bufonia macropetala* subsp. *Willkommiana*). The rupicolous communities rich in endemic species have already been mentioned. It is worth mentioning that the populations of *Silene marizii* and *Digitalis Amandiana*, which are concentrated in the proximity of the mouth of the river Tua, rarify upstream and disappear when the valley widens, not far from the Brunheda bridge. The rupicultural vegetation includes other types of vegetal communities that it is not necessary to deepen here. Numerous types of nitrophilous vegetation were also identified. This flora has a strong pioneering character. So much is developed in soils mobilized by the agriculture and in margins of ways, as in soils disturbed by mass movements or by turbulent waters.

- **Proposals for the environmental recovery and landscape integration**

The objectives behind this proposal as those behind the rocks colonization are of the Environmental Recovery and Landscape Integration of the disturbed area due to dam construction:

The environmental recovery and landscape integration of the areas temporarily affected by the dam construction (yards, fronts and temporary accesses of work), where there have been changes to the morphology of the land - which today is dissonant with the surrounding - and / Or that they will be devoid of vegetation (the bare soil) with the conclusion of the same one.

Through the implementation of PRAIP (Plano de Recuperação Ambiental e Integração Paisagística or Environmental Rehabilitation and Landscape Integration Plan), it will be possible to minimize and compensate for the negative landscape and ecological impacts resulting from the construction of the work, namely:

- the immediate degradation of the visual and ecological quality of the landscape;
- the destruction of the vegetation cover;
- modification of the original relief;
- the potentiation of erosive effects by surface runoff

- **Intervention strategies**

The general strategy based on three main types of solutions for PRAIP:

• "**Humanized Scenario**", to be implemented in the downstream areas affected by the work and that, prior to this, corresponded to the humanized landscape (mostly the olive grove on the terrain), ie in the surroundings of the mouth of the river Tua, in the vicinity and already inside Of the ADV(Alto Douro Vinhateiro) area;

• "**Naturalized Scenario**", to be implemented in upstream areas, already in contact with the canyon areas of the Tua river where natural vegetation occurs;

• "**Adaptive Management**", to be adopted in the right bank of the Tua river, downstream of the dam, including the corresponding bed range and, in the area above the left dam encounter, in the steep rocky slope.

In the "Humanized Scenario" we envisaged the use of terrain modeling solutions, based on terraced frames with dry stone support walls and levels, restoring a network of rural roads, using olive groves and mixed orchards and to a hedge meadow hydrossiment, thus establishing a visual link to the surrounding ADV cultural landscape.

In the "Naturalized Scenario" the environmental restoration was foreseen, modeling the terrain in order to bring it closer to its natural morphology and resorting to the installation of natural plant communities (either by planting native trees and shrubs or incorporating Native shrub species in the mixture of the meadow of cover to hydroseeding in these areas), thus promoting the ecological and visual continuity with the surrounding natural areas.

Figure 17 is intended to illustrate, in extremis, the reference landscapes of these two strategic solutions of the PRAIP Base Project.

Figure 8: The reference landscapes of the PRAIP Base Project in back to the left, a hypothetical illustration of the "Humanized Scenario" (ADV region); in the front to the right, a hypothetical illustration of the "Naturalized Scenario" (Tua river canyon)

Finally, "Adaptive Management" provided for a monitoring of the natural regeneration of riparian and rupicolous communities in affected areas (which would support such communities), with minimal intervention, i.e. only when necessary.

In this Implementation Project, the general zoning proposed in the framework of the Base Project is respected, as well as the defined guidelines, clearly distinguishing the interventions for the PRAIP area - where the restoration of native plant communities will be promoted - , Which is proposed for the surrounding area at the mouth of the River Tua (more downstream) and which already integrates the ADV region - where it will promote the construction of the land, regular planting measures and the establishment of a network of rural roads .

- **Guidelines for project implementation**

  - Stone walls with self-supporting design

It is planned to use walls that will be executed in stone, always with the appearance of a dry joint, and whose design and layout of the blocks should always reflect the design of the traditional self-supporting walls. The wall density will be higher upstream, i.e. towards the surrounding area at the mouth of the Tua River, which integrates the Alto Douro Wine region.

  - Removal of designed concrete restraints

Whenever safety conditions permit, it is foreseen to remove any reinforcement of built slopes (projected concrete restraints) in the areas where they are visible (ie if they are not permanently flooded by the reservoir or buried by the modeling work Foreseen). Specific solutions are also envisaged within the scope of the PRAIP Implementation Project, to be applied, whenever possible, to designed concrete restraints, the removal of which is not feasible (in the case of restraints to be maintained, with a view to safeguarding people and property).

  - Transfer of soil with local origin

Soil is the product of a secular accumulation of nutrients and organic matter, and carries an enormous amount of diaspores of indigenous species (seed bank). Its application, even if later hydro-seeded, accelerates the installation of a wide range of local / regional autochthonous species, increasing the thickness of the soil, recreating environments suitable for species with higher biomass and with greater visual impact, bringing unequivocal advantages from the point of view of landscape integration and environmental recovery. With a thicker soil, rich in diaspores and biologically active, the ecological succession processes faster. Such acceleration of ecological succession through the manipulation of basic environmental conditions is probably more effective than through the dissemination of diaspores.

In addition to the use in PRAIP of the vegetal land from the previous pickling of the areas affected by the work and stored, during the construction phase, for this purpose (already included in the General Construction Contract Charges), this project also provided for , The collection of forest soil (hereinafter referred to as vegetable land) and of substrata in floodplains and rocky cliffs (hereinafter referred to as terraces), potentially rich in RELAPE species, in the area that was later flooded by the AHFT reservoir.

- Criteria for selecting the flora to be used in the surrounding area at the mouth of the Tua River, which integrates the ADV's cultural landscape.

It is planned to plant tree species traditionally used in ADV's agricultural systems (such as orchards and olive groves). Preference to wild varieties, whenever available, aiming not only to increase the success of the plant, but also to reduce the maintenance and phytosanitary needs typical of cultivars with higher agricultural value.

- Use of autochthonous founding species in areas subject to natural regeneration

Diaspores are not generally a limiting factor in restoring disturbed areas of AHFT. Therefore, the gains - measured by the anticipation of ecological succession processes - resulting from deliberate sowing, spores or propagules of indigenous plants are probably not significant. The gains are expected to be higher in barochoric species with large and heavy seeds (eg Quercus) than the ones with small seeds (possibly transported by surface runoff, eg *Digitalis*), anemochoric (eg Ceomposts and *Acer monspessulanum*) or ornitochoric (eg *Myrtus*, *Olea*, *Pistacia* and *rosacea*).

The present proposal is based on the planting of founding species (mostly arboreal and shrub species, multiplied in nurseries), i.e. structuring species for the communities, being their fundamental presence for the establishment of these same communities (Whitham et al, 2006). The use of these species will accelerate the creation of nemoral environments favorable to the germination and persistence of species typical of these environments and, consequently, accelerate ecological succession, reduce maintenance needs and contribute to the preservation of the local genetic heritage. It is proposed to define regions of provenance for native flora to be used.

- Propagation and reservation of local plant material

In relation to the species that were locally eradicated with the construction of the dam and whose occurrence is expected in the section of river downstream of the dam, regardless of its dispersion vector, it is expected to be reintroduced, as is the case of boxwood (*Buxus sempervirens*) and some species specialized in the colonization of rocky outcrops of the river floodplain, always using material previously collected in the Tua river valley. Once such a need to use plant material of relevant native species (eg *Buxus sempervirens*) which would be unavailable after the filling phase of the AHFT reservoir was identified, it was proposed to collect it in a timely manner and propagate in an oven. The implementation of this guiding premise implied the accomplishment of previous work.

In addition, EDP also collected germplasm (seeds) of RELAPE species or with interest for conservation that is preserved in its own bank, to be used in the disturbed area.

Finally, there are stored in the yard (in large bags or transplanted) some large olive trees, to be used in the disturbed area.

- Barochoric dispersion (i.e. by gravity) of relevant elements of the local flora

The substrate of the valley downstream of the dam wall between the dissipation basin and the central one is not yet stabilized. Significant changes of its morphology are expected in flood years, with the displacement of blocks of variable dimensions and elements of other granulometries. Within the scope of this project, some actions (plantations and utilization of the collected lands) are proposed with a view to the restoration of vegetable communities in this area, in accordance with the philosophy of "Adaptive Management" defended in the PRAIP Project. However, it is important to take into account that the risk of failure, especially as long as such stabilization does not occur, is high. In view of the fact that some of the proposed interventions may or may not be successful, it is also proposed to plant relevant elements of the local flora (eg *Buxus sempervirens*, *Acer monspessulanum* and *Celtis australis*) in locations above the natural occurrence areas of these species, promoting Thus the future colonization of these zones, by barocoria (ie by the action of gravity). These plantations thus fall, by definition, into the

"Adaptive Management" solution provided in the PRAIP Project. For the same reason, it is proposed to use rocky cliff lands (partly already scattered on rocky slopes.

- Plantations and sowing

The proposal for planting and sowing is shown in Drawings in Annexes

The plantations and sowings of areas aim to allow a better recovery and landscape integration of these spaces, favoring and accelerating (in time) colonization by plant material and restoration of Its biophysical balance (progressive soil formation, better conditions of retention and infiltration of rainwater, greater activity of microorganisms, emergence of diverse fauna, etc.), in articulation and continuity with the surrounding landscape, whether more or less humanized. The plantations and sowing should follow the work of modeling and preparation of the land, with the shortest possible interval.

Improved soil fertility with nutrient application is predicted, since soil stripping and excavation have exposed layers of soil or rock, naturally poor in available nutrients. Many indigenous plants can not settle and thrive without restoring the fertility of regolith (fragmented rock). Inert deposits are proof of this. In natural systems, the increase in regolith fertility is due to the slow accumulation of organic matter and the progressive replacement of the flora (progressive ecological succession). The incorporation of nutrients - in particular of phosphorus - accelerates with enormous advantages, this process. The application of nutrients can be done simultaneously with the sowing, knowing no valid technical-scientific argument against this technique.

Also within the scope of the plantations and sowings foreseen in the PRAIP, which will be the subject of an own contract, with an associated guarantee period, it is proposed a tight control of invasive alien species in all areas of PRAIP subject with frequent manual removal, since such plants (such as *Ailanthus altissima, Opuntia sp*., *Phytolacca americana*, *Arundo donax*, etc.) will appear predictably after (Either because they may be present in the local seed bank or because of the rainfall of seeds from infested contiguous areas) for at least five years, in order to guarantee the establishment of native flora and minimize the risk of failure.

- **Sowing**

(*Lolium multiflorum, Astragalus pelecinus, Trifolium subterraneum and Ornithopus compressus* - hardly any improved allochthonous genotypes will be able to maintain viable populations in an ecologically demanding environment such as the Tua River, without continued disruption by herbivory). It is assumed that the persistence of the mixture of seeds to be applied will be brief; which is attested by the widespread use of these species in mixtures for agricultural purposes in rural areas, where it is observed. The risks of introgression will also be small because any hybrids will be eliminated by selection (unadapted hybrids), as it is also known for agricultural uses in rural areas. However, in soils with a corrected fertility, these species have, even before alien species and at an early stage, the ability to cover the soil rapidly, producing a remarkable biomass. The biomass protects the soil and increases surface roughness, facilitating the retention of diaspores of indigenous species.

Mixture 1: Sowing density of 5.0 g of seed / m2, estimating a total area to be sown of 59 602 m2.

The weight percent composition of the hydrosseed mixture is as follows:

Gramines:

Lolium multiflorum..18%

Legumes:

Astragalus pelecinus..16%

Trifolium subterraneum...49%

Ornithopus compressus 15%

Total...100%

Mixture 2: Seeding density of 5.1 g of seed / m2, estimating a total area to be sown of 46 156 m2.

The weight percent composition of the hydroseeding mixture is as follows:

Gramines:

Lolium multiflorum..18%

Herbaceous legumes:

Astragalus pelecinus...16%

Trifolium subterraneum...49%

Ornithopus compressus 15%

Pre-forest shrub legumes

Cytisus grandiflorus 0.4%

Cytisus multiflorus..0.2%

Cytisus scoparius...0.2%

Cytisus striatus...0.2%

Retama sphaerocarpa...1%

Total...100%

Mixture 3: Seeding density of 1.3 g of seed / m2, estimating a total area to be sown of 807 m2.

The weight percent composition of the hydrosseed mixture is as follows:

Gramines:

Lolium multiflorum..11%

Herbaceous legumes:

Astragalus pelecinus...30%

Trifolium subterraneum...30%

Ornithopus compressus 23%

Species characteristic of the phytosociological alliance Rumici indurati-Dianthion lusitani:

Anarrhinum duriminium..0.05%

Digitalis amandiana...0.15%

Rumex induratus..3%

Silene marizii..2.8%

Total..100%

The seeds of *Silene marizii* and *Anarrhinum duriminium* to be used in Mixture 3 shall come from the Germplasm Bank, since they have been previously collected and stored for this purpose under RECAPE. They may also be collected in the Tua valley, subject to prior approval by the competent authorities. The remaining species (*Cytisus striatus, C. scoparius, C. grandiflorus, Retama sphaerocarpa, Digitalis amandiana,* and *Rumex induratus*) should be collected in the Tua valley, subject to prior approval by the competent authorities.

❖ **<u>Plantations</u>**

The selection of tree and shrub species to be planted (mid-autumn to mid-winter) reflects not only the design options assumed in the baseline project phase (see "Naturalized Scenario" vs. "Humanized Scenario" in the PRAIP Baseline Project), But also the thickness of the friable soil resulting from the modeling work and the physiography of the terrain. The selected species, as well as their spatial distribution in the field, are as follows:

I) In the PRAIP amount region, it is proposed to plant alone or in small clumps and / or edges, creating a diverse mosaic that aims to facilitate the creation of the mentioned nemorais environments and seed dispersal. The selected taxa are: *Acer monspessulanum, Arbutus unedo, Buxus sempervirens, Celtis australis, Crataegus monogyna, Fraxinus angustifolia, Hedera hibernica, Juniperus oxycedrus, Olea europeae var. Sylvestris, Pistacia terebinthus, Prunus avium, Quercus rotundifolia, Q. suber, Rubus ulmifolius, Salix salviifolia* and *Sambucus nigra.*

II) In the downstream region, ie in the surroundings of the mouth of the Tua River that integrates the ADV, it is proposed to plant using compasses and provisions of customary use in contiguous areas of orchard and olive grove, with the use of the following taxa: *Citrus X aurantium*, *Ficus carica* (only on time), *Olea europaea var. Sylvestris*, *Cydonia oblonga*, *Prunus avium* and *P. dulcis.*

The indigenous plant material to be used should respect the regions of provenance defined in Table 2, in order to favor landscape integration, minimize maintenance costs and maintenance, and genetic introgression (see Whitham et al., 2006). In fact, these authors give an example in which, the planting of specimens with non-local provenance extinguished an autochthonous local genotype of the same species, so that the use of plants with provenance (ie the area from which The original natural or plant material that has been used for propagation in a nursery) must be from local or, at the most, regional level.

Table 1 : Origin of the native flora to be installed in the surrounding area of the AHFT.

Scientific name	Territorial scope of provenance
Acer monspessulanum, Celtis australis, Fraxinus angustifolia, Pistacia terebinthus, Juniperus oxycedrus	Portuguese part of the Douro river basin.
Arbutus unedo, Crataegus monogyna, Olea europeae var. sylvestris, Prunus avium, Quercus rotundifolia, Quercus suber, Sambucus nigra	North and Central-North Region.
Buxus sempervirens	Terminal section of the Tua Valley, material replicated in the IPB.
Hedera hibernica, Salix salviifolia, Rubus ulmifolius	Valley of the Tua

It is planned to plant large trees and shrubs (both those stored in the yard and those that have to be transplanted in the framework of the modeling work) to places considered strategic, to be defined in the framework of the monitoring of the work.

In the case of Buxus sempervirens, each area to be planted shall contain specimens of all collected.

Thus, we propose the planting of 1186 trees and shrubs, according to Table.

Table 2 : Total number of trees and shrubs to be planted under the AHAP PRAIP

Scientific name	Total number of trees / shrubs to be planted
Acer monspessulanum	29
Arbutus unedo	46
Buxus sempervirens (material já recolhido e propagado no IPB)	92
Celtis australis	41
Citrus x *aurantium*	19
Crataegus monogyna	14
Cydonia oblonga	15
Ficus carica	7
Fraxinus angustifolia	14
Hedera hibernica	38
Juniperus oxycedrus	83
Olea europeae subsp. *europaea* var. *sylvestris*	238
Pistacia terebinthus	159
Prunus avium	12
Prunus dulcis	39
Quercus rotundifolia	132
Quercus suber	130
Rubus ulmifolius	9
Salix salviifolia	59
Sambucus nigra	10

The list of native tree and shrub species proposed for use under the AHAP PRAIP and a brief characterization based on a specialized literature review (eg Bingre et al. 2007) is presented in the annex to this document.

- **Use of local soil**

It is planned to use the soil of flood beds collected during the previous works, potentially rich in RELAPE species and other species typical of those biocenoses, in the support to the planting of the boxwood, which should be used to fill the joints and other cracks Of the exposed parent rock and assist in accommodating and fixing the plants to the rocky substratum.

Likewise, the soil that was collected in rocky cliffs, potentially rich in RELAPE species and other species typical of those biocenoses, that is left over from the scattering already done on the left bank slope, should be used during the *Hedera hibernica* plantations on the slope with Contained in projected concrete, over and above definitive access to the crown.

- **Barochory**

As a way of guaranteeing the maintenance of a seed bank and the dissemination of seeds of species more specific to floodplains, taking into account, as already mentioned, the strong probability of failure of direct measures of installation of plants in the floodplain , It is intended to plant specimens of *Buxus sempervirens*, further away from the bed of the river, but they overlook it. In this way, we intend to create foci of seed dispersal in order to increase the probability of natural occurrence of these species when the bed and the banks in the vicinity of the river acquire stability, as recommended in the scenario of "Adaptive Management".

It is also planned to plant specimens of *Celtis australis* and *Acer monspessulanum* in the area of the rolling path of the blondins, since this area is overlooking the work front access to the left encounter of the dam where these two species have great colonizing potential.

Finally, *Hedera hibernica* and *Rubus ulmifolius* are expected to be planted on top of some slopes, hoping that these species may not only contribute to a decrease in their expression in the landscape, but also to be dispersed by gravity through the underlying areas.

- **The current works**

In order to improve and accelerate the ecological and landscape recovery of the disturbed areas subject to recovery, and in accordance with the general strategies defined, a number of previous actions / works were carried out. Specifically:

1. Removal of projected concrete, at the time of lifting some support areas that were no longer necessary to the work.

Solutions were also planned to minimize the visual impact of projected concrete in situations where, for safety reasons, it is impossible to remove it.

2. Collection of local soil (vegetal or living soil) by pickling areas that would be flooded when filling the AHFT reservoir.

Some 25 000 m3 of the surface horizons of shrub land and forest communities (deforested areas) were collected and stored in the reservoir area. The collection was carried out with the supervision of a technician of flora and vegetation, in order to avoid the use / storage of soils from areas covered by alien weeds and / or invasive plants.

This collection guarantees the plant land requirements foreseen under the PRAIP, which, taking into account the expected local seed bank, is an undoubted asset for the environmental and landscape recovery of the AHFT construction zone.

3. Collection of floodplain and rocky escarpment lands, originated in the Tua valley, in areas that would be flooded by the reservoir (and partial spreading) as seen in Figure 9.

Figure 9: Collection of land from floodplains and rocky cliffs in places that would be flooded by the AHFT reservoir

During 2016, floodplains and rocky cliffs, potentially rich in RELAPE species and other species typical of these biocenoses, were collected from sites that would be flooded by the AHFT reservoir. The latter were partially scattered on the construction site of the access to the left dam encounter

4. Seed collection (carried out by EDP under the RECAPE of the AHFT).

Seeds of species of conservation interest (RELAPE) and / or with relevance to environmental recovery and landscape integration, which are available in a germplasm bank, were collected in the framework of the AHFT RECAPE to complement the Hydrosseed..

5. Collection of branches of *Buxus sempervirens* for vegetative propagation (by staking).

Branches of Buxus sempervirens were collected to obtain new plants rooted by vegetative propagation (staking). The propagation was carried out in the IPB greenhouses in Bragança, at present, 165 rooted feet from 22 different individuals (Figure 10).

Figure 10: Rooted stems of *Buxus sempervirens*

6. Storage of large trees (olive trees).

They were collected in the area of the reservoir or the site of the work, stored or transplanted by EDP in the vicinity of the platforms of the large olive yards (Figure 11), to be used within the PRAIP.

Figure 11: Large olive trees taken from the reservoir and construction site.

2. Rocks recovery

For the second part of this work that is interested to the rocks recovery , we are proposing a recovery of the fresh cutted granitic rocks made of five different treatments, these latter will be experimented first and when it's interesting results, the treatments will be implemented in the areas where there is the fresh cutted granitic rocks.

- **Treatments composing:**

The elements used to produce the treatments are organic matter based; this choice was not taken randomly. The use of organic matter provides the facilitation of the integration of the disturbed area into the landscape. Organic matters can be easily absorbed in the landscape without generating any negative impact on the habitat and organisms living in the area and without creating the independency and the isolation of the area from the ecosystem.

For the first trial and for the present work, the organic materials that were used were collected from IPB's granite surface (for instance moss and lichen). It's very important to use the organic material collected for the rocks where the natural colonization occurred naturally, and since it's the case for the granite of the IPB, we have collected the moss and the lichen from that granite Figures 12 and 13). This was established in the aim of having a good compatibility between the moss and the support that is used (fresh cutted granitic rocks).

Figure 12: **White mica granite naturally colonized by moss**

Figure 13: **White mica granite naturally colonized by lichen**

The treatments used here were subdivided into five types depending on the composition and the proportion of the organic ingredients, two of these five treatments are based on other matters than the organic ones, one of them is essentially the application of the nitric acid directly on the rocks, especially that it seems that some rock-forming minerals in the granitic rock are significantly unstable due to the environmental condition of acidic rainfall and steep slopes, where they are susceptible to be dissolved incongruently leading some elements to be highly depleted (Lee et al., 2008). This type of treatment is applied to rough out and accelerate the chemical degradation of the rock so that the natural colonization of these last can be easily and early established and maintained. The other one is based on the coloration of the rocks by the use of paint techniques in order to mitigate immediately the visual impact of the excavated area and by the end allowing the slow natural colonization of the rocks as a natural process. The use of this treatment is only in the aim of reducing the visual impact till the establishment of the colonization in the time which will cover itself the rocks instead of the coloration.

The treatments based on organic matters are mainly composed of: moss, likens, gelatin, flour, soil and fertilized water.

The first type based only on gelatin and the mixture of soil ,fertilized water and moss ,here the use of gelatin is a sort of providing adhesion , the jellification, the keeping of the moisture the and nutrition for the growth of the moss and the lichen. The determination of the proportions of these ingredients is based on the reasoning of the consistency and the color of the mixture.

The second treatment is based on the use of moss, lichen and soil mixed with the flour and fertilized water, the flour here will serve us for the adhesion of the treatment into the granitic rock supposing that the fertilized water and the soil contain the necessary nutrients for the moss and the lichen.

The third treatment is a kind of a combination between the two previous treatments; we use moss, lichen, gelatin, flour, soil and fertilized water with reasoning the proportions through the consistency and the color as usual.

Figure 14: Preparation of the mixtures in the laboratory

- **Treatments proportions**

The different proportions were subject of numerous essays before opting for the final ones; the treatments were made essentially by reasoning the viscosity, the compactness and the homogeneity of the mixtures, without forgetting the verification of the variation of the mixture color also.

This work is based on the convergence between the characteristics mentioned before and the mixture color towards the ability to the application of mixtures on the granitic fresh cutted rocks.

For the first organic treatment, made of the combination between the two following treatments, were used moss, lichen, gelatin, flour, soil and fertilized water. One application of these proportions can cover an area of 2, 02 m²

The second treatment, was prepared with moss, lichen and soil mixed with the flour and fertilized water. One application of these proportions can cover an area of 1, 37 m²

For the third treatment, we used gelatin and the mixture of soil, fertilized water, moss and lichen. One application of these proportions can cover an area of 0, 92 m²

Figure 15: Different treatments prepared and applied on the fresh cutted rocks

❖ **Experimental protocol**

→ **Cleaning of the fresh cutted rocks**:

Twenty four blocks were chosen with at least one flat face (around 10cm by 10cm), the fresh cutted blocks were chosen from the common granite type in IPB. It's the white mica granite as represented in the figure 16.

Figure 16: White mica granite of IPB colonized by moss

After choosing the fresh cutted rocks with the possible regular shape of the face concerned by the application of the treatment, we cleaned them to remove all the dusts and specks, so that we can judge significantly the effect of the treatments after their application.

→ **Experience organization into two groups of essays**

– **Randomization**

The fresh cutted rocks were randomly separated into two groups; those two groups were created to evaluate the effect of the irrigation. For the same treatment we find the rocks that belongs to the first group (group with irrigation) and to the second group (group without irrigation).

– **Repetitions**

In each group of treatments (Irrigation/ Without Irrigation), we have repeated the treatments two times to control the error that might be caused by the experimenter and to estimate the experimental error. The role of the repetitions is to evaluate the part of experimental error in the construction of the observation. Indeed, without repetitions of each treatment on several units, it is not possible to distinguish the effect due to the treatment from the experimental error.

– **Error control**

To reduce the uncontrolled part of the experience we should reduce the experimental error.

→ **Treatments application**

After preparing the mixtures in the laboratory, the random identification of the rocks that will receive the different mixtures in each of the two groups takes place. After that step we apply the mixtures on the appropriate fresh cutted rocks. Afterwards we list and enumerate on each rock the attributed number of the treatment, the group that belongs to and the attribute of the repetition.

Figure 17: treated rocks listed and enumerated on their upper side

After applying the mixtures and listing the rocks, these last are transported to the green house, a controlled space to ensure the adequate temperature and humidity for the treated blocks as these two factors are determinant for the moss colonization. The temperature of the greenhouse turn around 26 °C to 27 °C and the humidity is about 80 %.

The group of rocks concerned by the irrigation receives it 3 times per week, with a volume of 60 to 70 ml per irrigation distributed equally between all the treated blocks.

❖ Treatments monitoring

The treatments were installed in the month of April and the pictures were taken every twenty days to monitor the change of the treatments over time. Taking picture is one of several ways to monitor the evolution of the treated rocks. We choose the taking pictures monitoring to evaluate minutely the change of the treated rocks faces appearance each 20 days.

The distance between the camera and the treated blocks is experimented at length of 60 cm with automatic focusing. The images always captured with the lowest size of the camera. The position between samples was also checked.

By the fact of taking pictures periodically, we are registering in each time the composition and the amount of RGB (Red, Green and Blue light intensities) of each treated face of the rock in that time. So mainly we are monitoring the evolution of the amount of RGB for each treatment and the parameters expressing the hue (L) expressed as a percentage, represents lightness and a and b are the chromaticity coordinates that indicate the red (+a), green (−a) directions, the yellow (+b) and blue (−b) directions. (Prieto et al., 2006)

The RGB value indicates the picture red, green, and blue light intensities. Each intensity value is on a scale of 0 to 255, or in hexadecimal from 00 to FF (Frery and Perciano 2013a).

RGB color system, constructs all the colors from the combination of the Red, Green and Blue colors. The red, green and blue use 8 bits each, which have integer values from 0 to 255. This makes 256*256*256=16777216 possible colors.(Frery and Perciano 2013b).

RGB ≡ Red, Green, Blue. Each pixel in the LED monitor displays colors this way, by combination of red, green and blue LEDs (light emitting diodes).

→ Color checker passport use

While taking the pictures the use of the color checker passport is essential. (Frey and Warda, 2008).

The color checker passport is a color calibration target consisting of a cardboard-framed arrangement of 24 squares of painted samples.

The chart's color patches have spectral reflectances intended to mimic those of natural objects such as human skin, foliage, and flowers, to have consistent color appearance under a variety of lighting conditions, especially as detected by typical color photographic film, and to be stable over time.

The X-Rite Color checker passport itself is made of grey plastic, and opens up to display the color patches shown below (Figures 18 and 19).

Figure 18: X-Rite Color Checker passport

The use of color checker passport consist in taking a photo of this passport itself in daylight using the Raw format , then by using a software; on the left of the figure below; I convert the pictures to the DNG format and then I drag the DNG file to the color checker passport software.

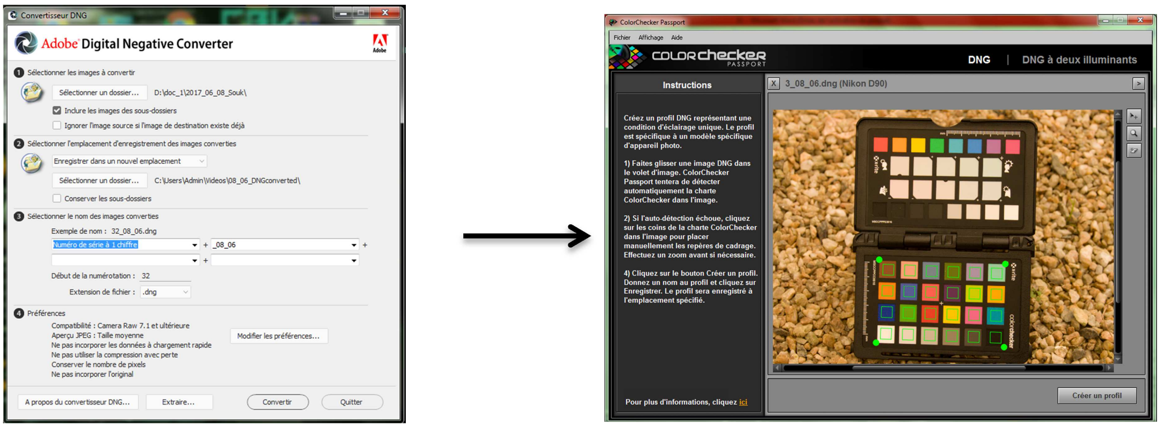

Figure 19: Process of converting the pictures file from raw format to DNG format and their dragging to the color checker software

The color checker passport software created by McCamy, Marcus and Davidson creates a profile, calibrated for our camera, for each pictures taking date I create a special pictures file of DNG format that has its specific profile created on the software of the color checker passport showed on the right of the figure above, so for each file we had the specific profile created for it.

These ones are stored along with the other profiles of the other files that will serve after for the correction of the pictures taking with in the same date and the same light conditions.

On the software Adobe Photoshop created by *Thomas* and John *Knoll*, I corrected the pictures using the Camera calibration Button and changing the camera profile Into the corresponding picture profile of the same date of picture taking.

The correction concerns also the automatic calibration of white balance, this latter is selected from the picture profile of the concerned file.

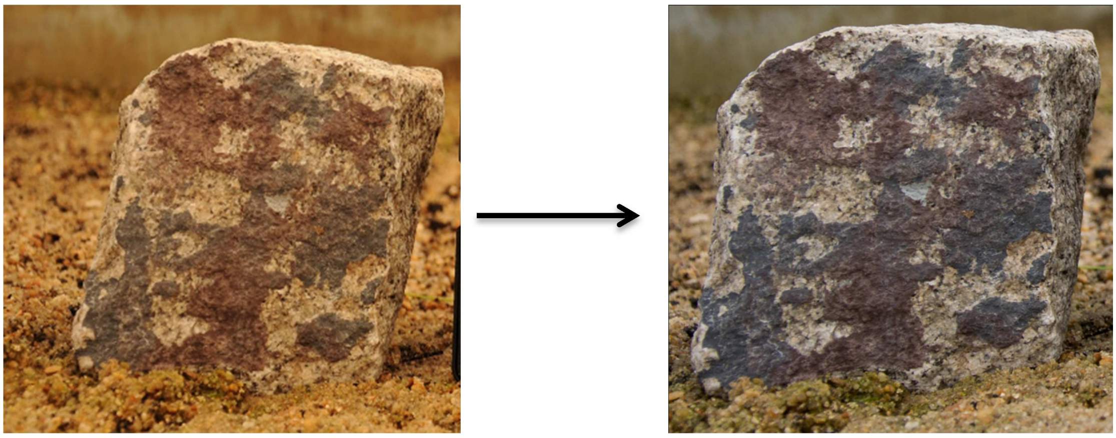

Figure 20: Difference between original picture and corrected picture based on the profile created on the color checker passport software

- **Data collection**

After the correction process using the profiles pictures, created on the software of the color checker passport, through the software Adobe Photoshop .The collection of the data in this study is based on covering almost all the treated faces of the blocks letting only the margins in order to have regular shape of the selected area. For each taking picture date, the corresponding pictures file has been corrected and opened on the Adobe Photoshop software. After that each picture has been treated.

Since we have two groups of treatments (those with irrigation and those without irrigation), each group of treated rocks was treated separately on the Adobe Photoshop.

The data collection were implemented by selecting a regular rectangle with dimensions of 900 Pixels by 900 Pixels as showed on the figure below (figure16), with this method we are carrying out the selections in the way of having the maximum of representativeness of the photographed space letting almost only the marginal parts.

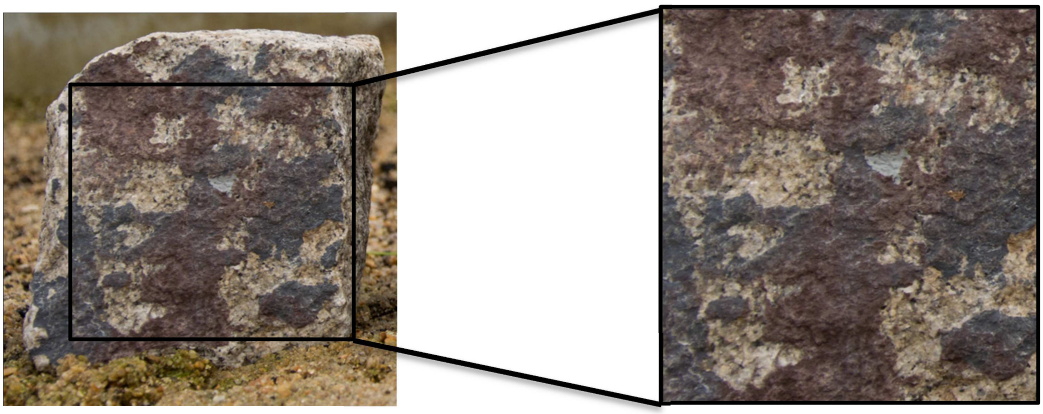

Figure 21: Selection of the treated area

After the selection of the treated faces, another software "R" created by *Ross Lhaka* and *Robert Gentleman* Outputs from these selected areas averages with their standard deviation of the amount of RGB intensities. Zero intensity for each component gives the darkest color (no light, considered the black), and full intensity of each gives a white; the quality of this white depends on the nature of the primary light sources, but if they are properly balanced, the result is a neutral white matching the system's white point. When the intensities for all the components are the same, the result is a shade of gray, darker or lighter depending on the intensity. When the intensities are different, the result is a colorized hue, more or less saturated depending on the difference of the strongest and weakest of the intensities of the primary colors employed (Poynton, 2003).

The averages of RGB are carried out in the aim of having a good representativeness of the amount of RGB of the treated faces of the blocks since we are selecting all the treated faces of each block.

Since the intensities of RGB are not necessary equal for each pictures treated, the hue, the saturation, and the brightness becomes also important to take into account and to collect too.

Accordingly to that our data in this study are the averages of R (red) G (green) B (blue) light intensities and their standard deviation , the parameters expressing the hue (L) expressed as a percentage, represents lightness and is characteristically represented vertical axis where the origin coincides with the 50% value (grey or neutral) and the extremes of the axis correspond respectively to 0% (black or total absorption) and 100% (white) (note that in this case black, grey and white are not different colors but are simply the absence or presence of lightness); and a and b are the chromaticity coordinates that indicate the red (+a) , green (−a) directions, the yellow (+b) and blue(−b) directions. The parameters (L), (a) and (b) will be used for the calculation of the differences in total color ΔE which is equal to $((\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2)^{1/2}$ and in the chromaticity ΔC which is equal to $((a)^2 + (b)^2)^{1/2}$. These parameters reflect the evolution of the growth, they are increasing when the population is growing and they are decreasing when this last is aging or senescing (Prieto et al., 2002).

IV. Results

The experimentation carried out in this study aims to be applied in the recovery of the disturbed area after dam construction in Foz de Tua River, located in the east of Douro basin, Northeast of Portugal. We had the first results of the different treatments applied on the fresh cutted granitic blocks; we have measured the evolution of the rock pigmentation for the different treatments, the parameters ΔE and ΔC and examined the effect of irrigation between the two groups.

The figures below show the results obtained reflecting the evolution of RGB light intensities for all the five treatments adding to that 2 repetitions of control blocks for each group of blocks (irrigation/without irrigation).

Table 3: Mean intensities of RGB for the different treatments during 3 successive times

Treatments	26 April	27 April	20 June
T5	0,580	0,468	0,523
T6	0,592	0,484	0,585
T3	0,667	0,399	0,452
T4	0,604	0,225	0,252
T2	0,638	0,394	0,430
T1	0,677	0,393	0,339

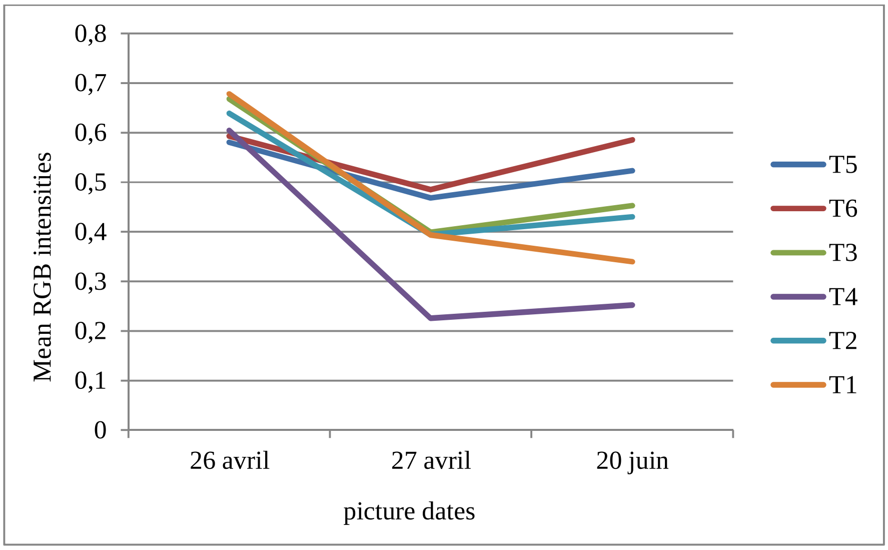

Figure 22: Evolution of RGB intensities of all the irrigated treatments during the three successive times

The pictures below represent the evolution of the 5 treatments and the control block.

Figure 23: Evolution of the control block (T6)

Figure 24: Evolution of the treatment number one (T1)

Figure 25: Evolution of the treatment number two (T2)

Figure 26: Evolution of the treatment number three (T3)

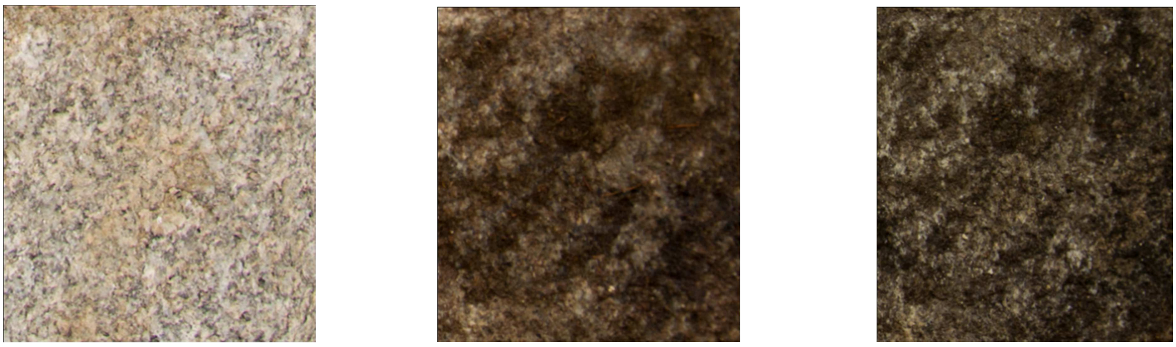

Figure 27: Evolution of the treatment number four (T4)

Figure 28: Evolution of the treatment number five (T5)

We have recorded the RGB light intensities of the blocks over three dates in this experience, before the application of the treatment, one day after the application of the treatment and after 54 days from the application of the treatment.

The figure (18) shows the evolution of the mean RGB light intensities of the irrigated group of blocks. The control block (T6) is also represented in the same figure (22).

According to the latter we can notice that the amount of RGB light intensities means of the blocks has decreased considerably after applying the treatments especially (T1, T2, T3, and T4). This shows that the visual impact of quarrying generated by the dam construction can be mitigated immediately after their application in the disturbed area; on the fresh cutted granitic rocks; From the first period of observations (between the 26th and the 27 of April) we can say that the most appropriate treatment to mitigate considerably the contrast in the disturbed area is the fourth treatment made of gelatin and the mixture of soil, fertilized water, moss and lichen. After the date of the twenty seven of April to the twenty of June, the treatments have evolved differently, the RGB intensities of the first treatment (T1) has continued decreasing after the second time of taking pictures. On the other hand the RGB intensities of the second treatment (T2) which is the coloration treatment and the third treatment (T3) has increased just slightly, this latter is explained by the irrigation action. Apart from the fact that the irrigation increased the moisture of the blocks this last has also lightened them a little bit. The same case for the treatment four (T4), but even so, this las one produces the best and the fastest decrease of the amount of RGB intensities.

A color in the RGB model can be described indicating the amount of red, green, and blue. Each color can vary between the minimum value (totally dark) and the maximum value (totally intense). When all the colors have the minimum value, the resulting color is black. On the contrary, when all the colors have the maximum value, the resulting color is white.(Frery and Perciano 2013a).The decrease of the RGB light intensities amount reflects the decrease of the rocks whiteness appearance. From a landscape point of view this reflects also that the contrast of the disturbed area after the dam construction with the surrounding landscape will be mitigated after its application in the study area.

For the fifth treatment which is the application of the nitric acid, the RGB intensities have increased. The application of this latter aimed to accelerate the alteration of the rock. From the figure (18) we can see that the amount of RGB intensities has slightly increased. This rock behavior can be explained by the beginning of the alteration of the biotite or dark mica, this mineral is responsible of the darkest patches of the granitic rock and since this mineral may be easily dissolved by acidic percolated water (Lee et al., 2008), in our case the application of the nitric acid directly on the rock accompanied with the irrigation has favored the dissolution of the biotite which contributed to the increase of the clearness of the granitic blocks. From the same figure (18) we can see the big gap between the RGB intensity of the control block and the fourth treatment which has evolved considerably, this reflect the effect of the application of the treatments that mitigate immediately the whiteness of the blocks.

The Figure 29 below as well as the Table 4 represent the evolution of RGB intensities of the group of treatments which didn't receive the irrigation.

Table 4: Mean intensities of RGB for the different treatments during 3 successive times

Treatments	26 April	27 April	20 June
T5	0,545	0,438	0,504
T6	0,450	0,450	0,532
T3	0,683	0,401	0,460
T4	0,653	0,279	0,251
T2	0,580	0,346	0,356
T1	0,678	0,401	0,330

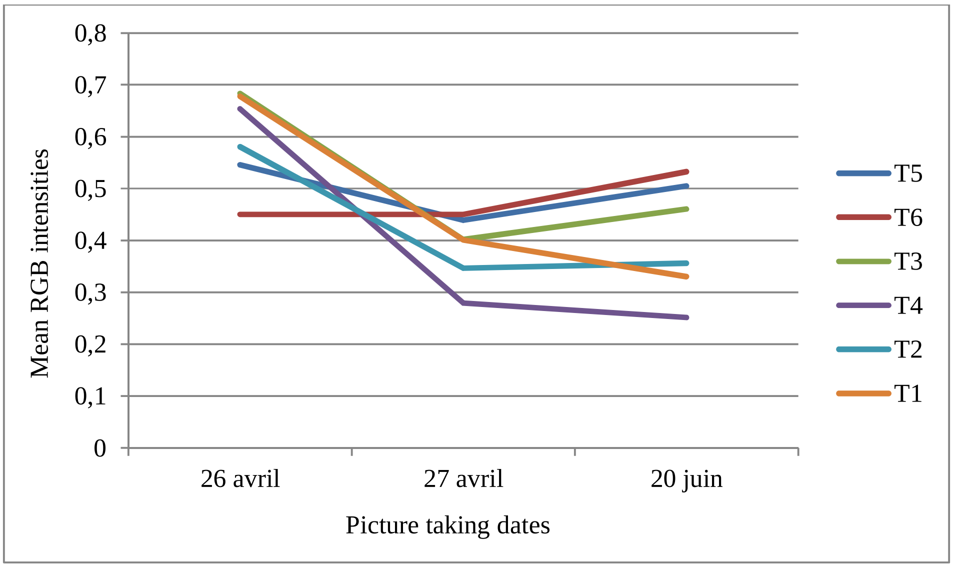

Figure 29: Evolution of RGB intensities of all the non- irrigated treatments during the three successive times

The pictures below represent the evolution of the 5 treatments in comparison the control one

Figure 30: Evolution of the control block

Figure 31: Evolution of the treatment number one (T1)

Figure 32: Evolution of the treatment number two (T2)

Figure 33: Evolution of the treatment number three (T3)

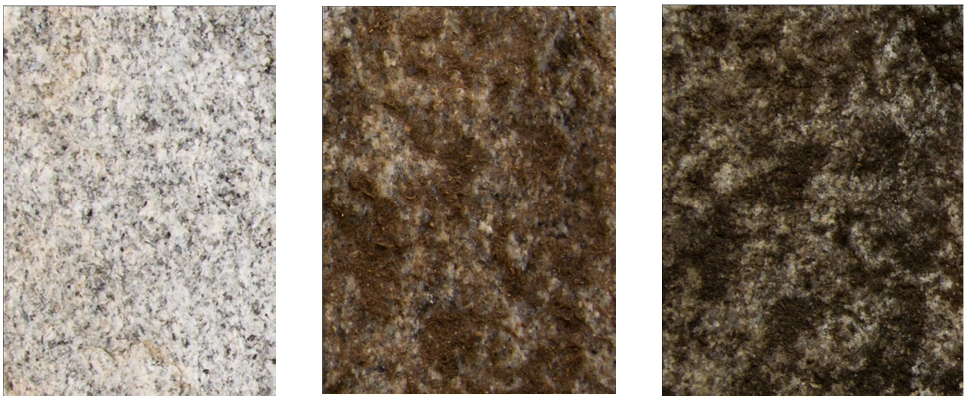

Figure 34: Evolution of the treatment number four (T4)

Figure 35: Evolution of the treatment number five (T5)

For the case of the RGB intensities of the treatments which didn't receive the irrigation, we can see from the figure (25) that the evolution is more beneficial for the blocks that have received the treatment number four (T4) and the treatment number one (T1), we can notice the decrease also in the period after the application which is very interesting for both the mitigation of the visual impact and the start off of the rock colonization . The differences between before and after the application of the treatments on the fresh cutted blocks are all beneficial from the point of view of mitigating the whiteness of the rocks.Since the second treatment is about the coloration of the block and knowing that this group of treatments doesn't receive the irrigation we can notice from the figure (25) that the amount of RGB intensities stayed stable after the application of the treatment. For the third treatment ,the amount of RGB intensities has increased due to the fact of loosing some of the applied material because of that the whiteness of the rock has increased.Also the use of only flour in this treatment seems to not be very well contributing to the mitigation of the block whiteness(see figure (22) and (29)).

For the fifth treatment, the application of the nitric acid has slightly increased the RGB intensities, this behavior can be explained as in the first case by the beginning of the alteration of the biotite or dark mica, this mineral is responsible of the darkest patches of the granitic rock and may be easily dissolved by acidic percolated water(Lee et al., 2008).

The figures below shows the differences between the same treatments from the different groups (with irrigation/without irrigation).

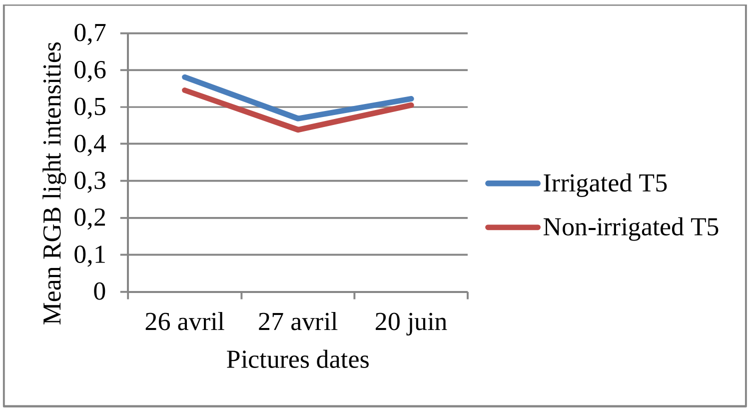

Figure 36: Difference of RGB intensities between the irrigated and non-irrigated acid treatments

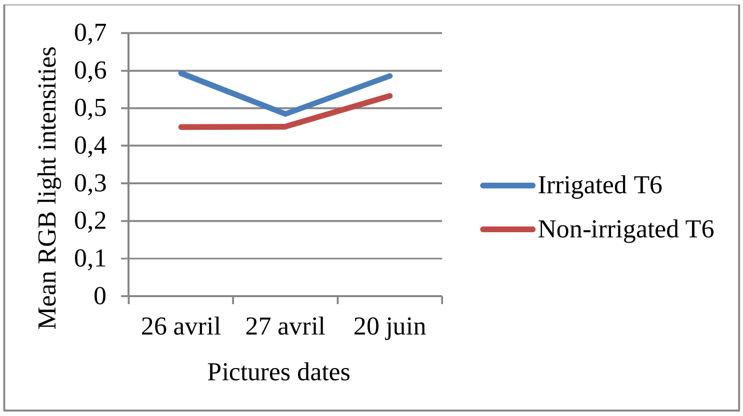

Figure 37: Difference of RGB intensities between the irrigated and non-irrigated control blocks

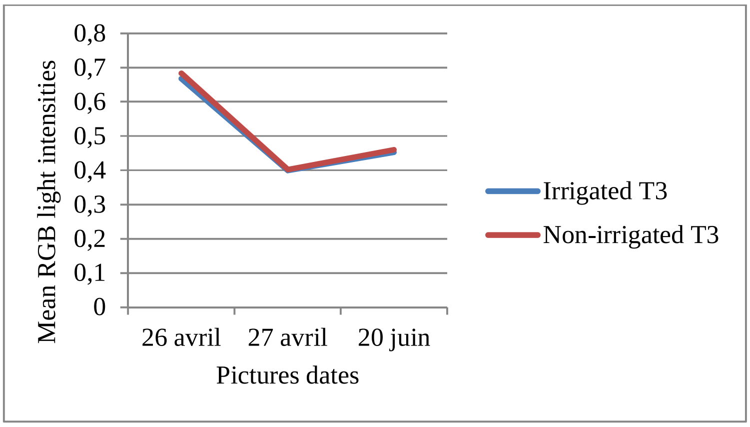

Figure 38: Difference of RGB intensities between the irrigated and non-irrigated third treatments

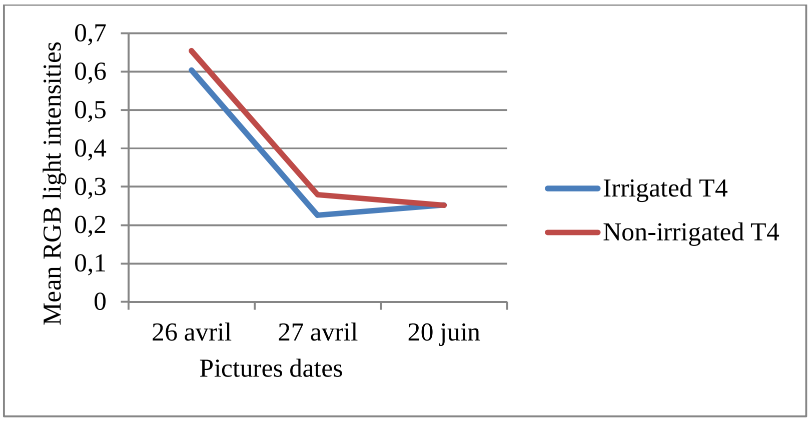

Figure 39: Difference of RGB intensities between the irrigated and non-irrigated fourth treatment

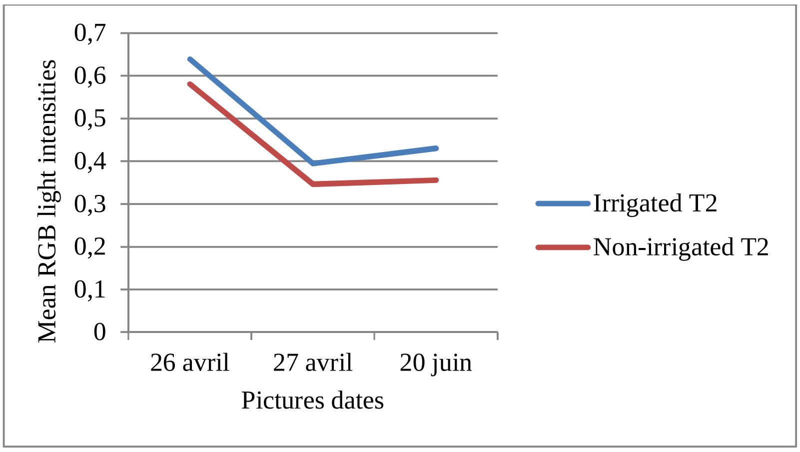

Figure 40: Difference of RGB intensities between the irrigated and non-irrigated second treatments

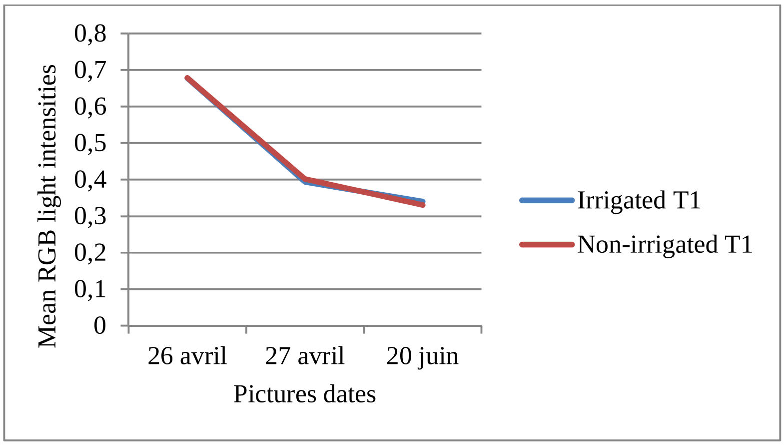

Figure 41: Difference of RGB intensities between the irrigated and non-irrigated first treatments

The figures (34) and (37) show that for the treatments number one (T1) and number three (T3) the irrigation has not generated any effect , we can notice from the figures that the evolution of RGB intensities is practically the same in the two groups, . It means that irrigation didn't produce any change on the treatment, showing that there is probably enough humidity in the air and in that case there is no need of irrigation.

For the treatments number two (T2) and number five (T5); figures (32) and (36);we can see the effect of the irrigation, it has generated an increase of RGB intensities for the irrigated second treatment because it lightened the coloration of the block. For the acid treatment its effect is almost the same; with some alteration of the biotite or dark mica; in the two groups of blocks.

For the treatment number four (T4), it has generated a good response when is irrigated but only in the first day of the treatment application, after that ; the irrigation has lightened a little bit the block face which caused the increase of RGB intensities, while the non-irrigated one prove a good evolution after its application, this latter can be explained by the fact of the water capture of the gelatin, this one doesn't let the water evaporate so easily and maintain some humidity benefits moss and lichen treatment..

After seeing the evolution of the RGB light intensities and seeing the effect of the irrigation, now we will represent the parameters ΔE and ΔC, as we mentioned before these parameters reflect the total color and the evolution of the growth, they are increasing when the population is growing and they are decreasing when this last is aging or senescing. Our data are organized in the aim of interpreting these parameters in two periods of time, the first is before the application of the treatments and one day after their applications and the second is between before treatments application and the last day of taking pictures. Since we are interested to the variation of total color and the growth, only the treatments made of organic materials are concerned.

The figures below show the ΔE and the ΔC evolution of the treatments made from on organic materials during time for both the group of irrigated and not irrigated blocks.

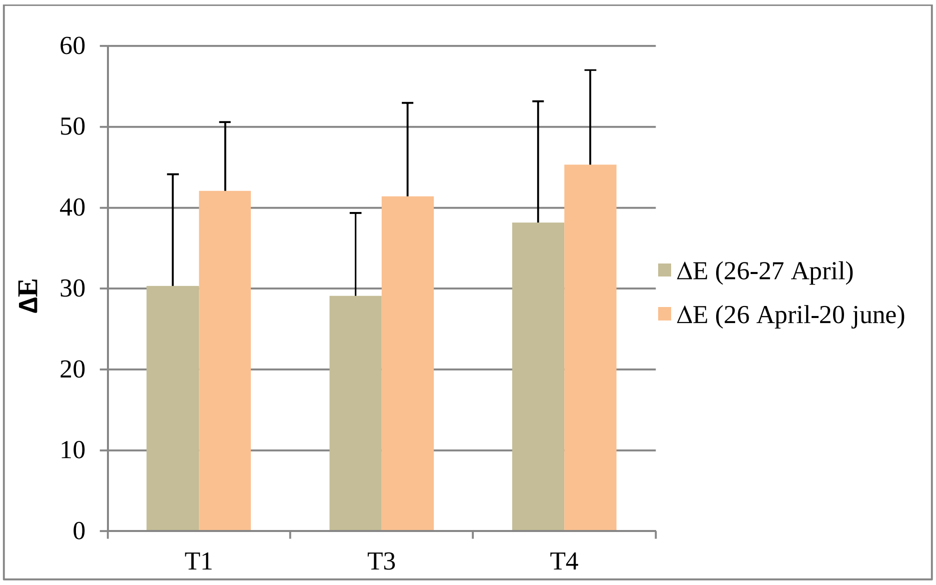

Figure 42: Variation in total color ΔE of the three blocks treated with organic materials (the irrigated group)

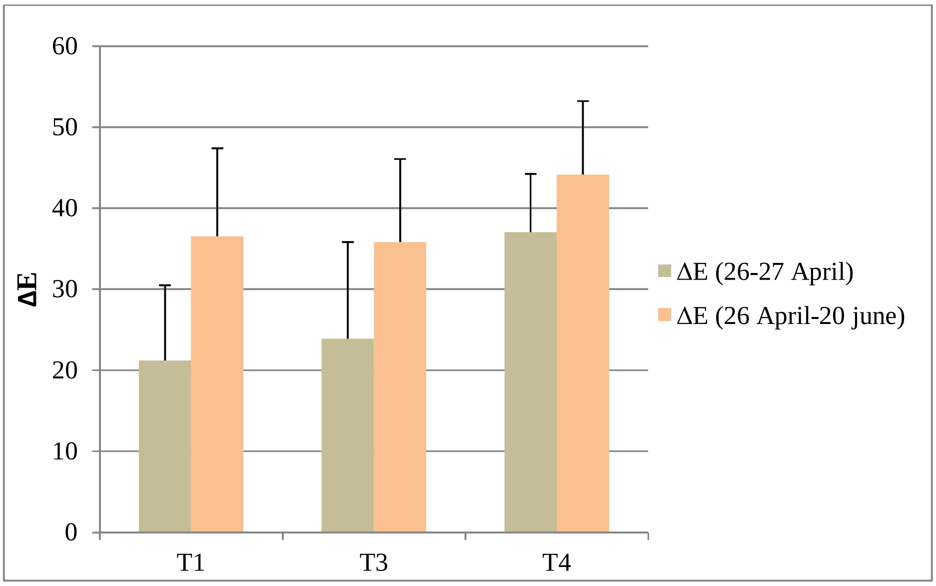

Figure 43: Variation in total color ΔE of the three blocks treated with organic materials (the non-irrigated group)

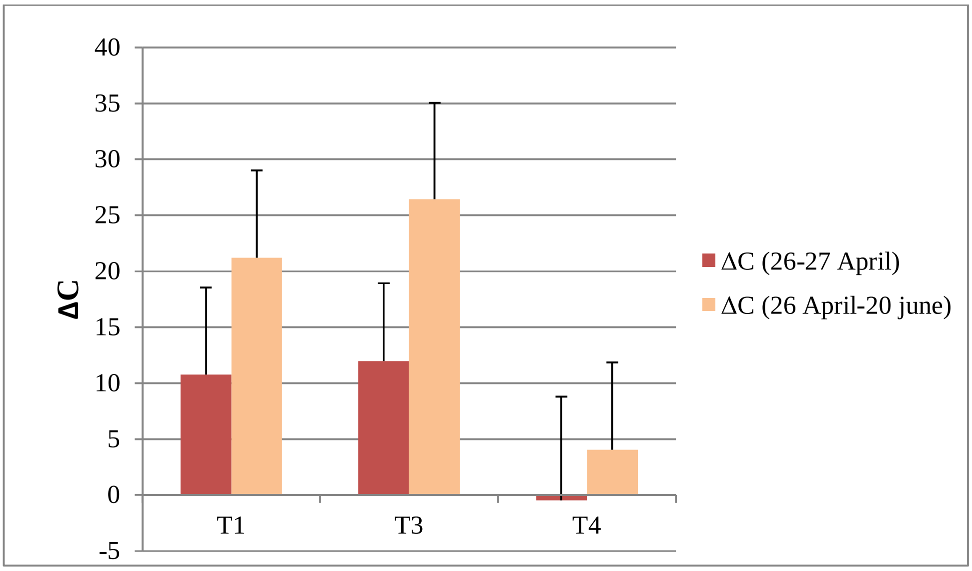

Figure 44: Variation in chromaticity (ΔC) of the three blocks treated with organic materials (the irrigated group)

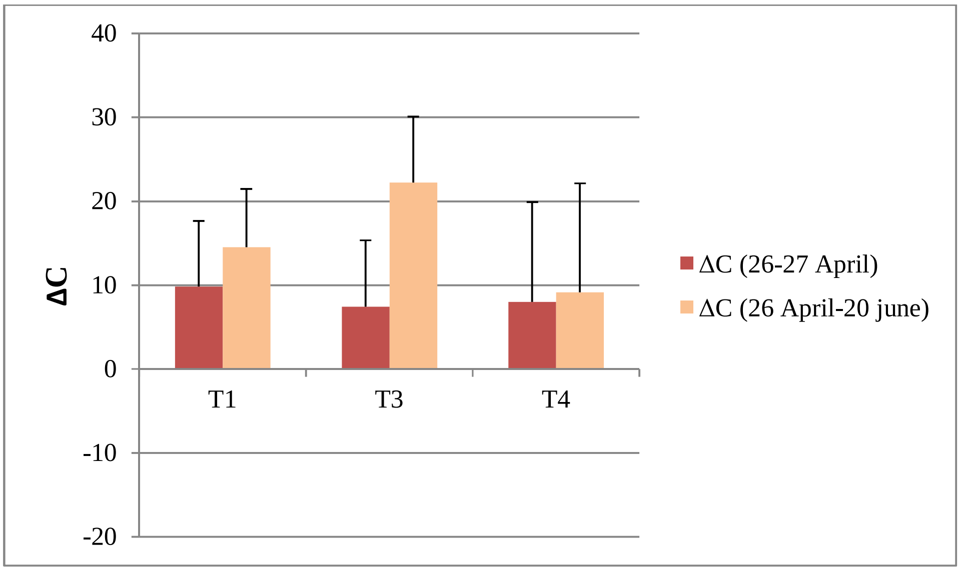

Figure 45: Variation in chromaticity color ΔC of the three blocks treated with organic materials (the non- irrigated group)

The figures above are showing the evolution of the parameters ΔE and ΔC representing respectively the variation of the total color and the chromaticity, these two parameters are the best indicators of the change in population because they increase in value when the population is increasing and they decrease when the population is aging or senescing (Prieto et al., 2006).

From the figures (38) and (40) , we can notice that the variation of both the total color and the chromaticity for all the treatment is important and specially after one day of the treatment application except for the treatment number four which its variation of the chromaticity is negative in the beginning. For the figures (39) and (41) representing the variation in total color and the chromaticity for the non-irrigated group the variation is also important but not as much as the variation of the treatments from the irrigated group.

After 54 days of the treatments application the amount of variation in comparison to the previous period is encouraging and reflecting that there is a positive evolution in moss colonization for all the treatments and specially for the first and the third treatments in both of the groups(irrigation/without irrigation). The fourth treatment stills the best one even if the evolution from one day after its application to 54 days after the application is less in comparison to the treatment T3 and T1 because the amount of variation in each period of time is important.

Treatments costs

Apart the fact of the effectiveness of a treatment and its respond after its application we should also have an idea about its cost. For that a study is made to estimate and evaluate the costs of each treatment based on the costs of the components from which is made, For the soil, moss and lichen since they will be collected from the same area, their costs will be represented by the costs of the workforce that will be used to collect the soil, the moss and the lichen from the disturbed area and in the surrounding.

The costs are calculated by square meter and also by one liter of the treatment,

Table 5: Costs of the treatments per one square meter and per one liter of the treatment

Treatments	Cost per square meter (Euros)	Cost per liter (Euros)
T1	0,72	2
T2	1,78	5,2
T3	0,26	0,9
T4	0,34	1,47

the third treatment made from moss, lichen and soil mixed with the flour and water seems to be the cheapest one with a cost of 0, 26 euros per square meter and 0, 9 euros per one liter of the mixture, followed by the fourth treatment composed from gelatin and the mixture of soil, water, moss and lichen which its costs are respectively 0, 34 euros per square meter and 1,47 euros per one liter of the mixture , in the third position comes the treatment number one which is made from moss, lichen, gelatin, flour, soil and water its costs are respectively 0, 72 euros per square meter and 2 euros per one liter of the mixture. And finally comes the most expensive which is the second treatment which the coloration of the rocks with a cost of 1, 78 euros per square meter and 5,2 euros per one liter of the treatment.

The costs of the treatments should be taken into consideration while choosing the appropriate treatments. If we are reasoning from only cost point of view we can say that the more appropriate treatments to apply in Foz de Tua disturbed area are the third and the fourth treatments.

All these costs can be increased if we add the costs of the treatments application especially when it comes to a big rock that needs a specialist to be treated.

VI. Discussion

The main objective in this study is the rehabilitation of the disturbed area after the Foz de Tua dam construction by mitigating the visual impact generated from quarrying during the work phase. Mitigating the visual impact of quarrying by the integration of the disturbed area into the surrounding landscape. This integration is based on two separated procedures, first the recovery of the area by the plantations and the sowing of the endemic species of the region trying to mimic the original landscape and second, the establishment of treatments made from organic materials with moss and lichen to facilitate the colonization of the rocks and in the same time mitigate the visual impact created by quarrying , other treatments are also proposed to mitigate only the visual impact like the coloration of the rocks which creates a mosaic of patterns that imitate the appearance of aged rocks, and the application of the nitric acid to accelerate the alteration of rock and facilitate its colonization by the bryophytes and lichens.

In this study we are interested to experiment all these treatments on the fresh cutted blocks of granite and see their effect on mitigating the visual impact (whiteness of the fresh cutted blocks) and triggering the colonization of the rocks by moss and lichen.

The results obtained from this experiment shows first the effect of the treatments in mitigating the visual impact (whiteness of the blocks).from the figures 18 and 25 we can say that the treatments T4 and T1 especially when they are not irrigated they represent a good proposal for the use in the disturbed area, we can interpret this by the fact of the use of gelatin which capture the water and doesn't let it evaporate. A little early irrigation during the two or three first weeks can be effective to trigger the growth. For the third treatment (T3) (see figure (22) and (29)). We can notice that the use of moss and lichens only with flour generates whitish patterns that can not reduce the contrast in the study area as much as the previous treatments (T4 and T1).While for the second treatment (T2) which is simply the coloration of the blocks, creating randomly a mosaic of patterns that imitate the appearance of aged rocks is recommended only as an immediate suggestion to reduce the whiteness and the contrast with the surrounding landscape till the natural colonization occurs. For the application of the acid, since this latter increase the whiteness of the blocks by the induction of the alteration of the biotite (Lee et al., 2008) which represents the darkest patterns of the granite this proposal can be abandoned in my point of view.

And adding to that the cost effect cited in the previous paragraph, we can say that the more adapted treatments from the two points of view; cost and evolution; are the treatment number 1, the treatment number 4 and the treatment number 2 but only if needed.

We found a luck of literature about this kind of studies about the use of the same treatments or even the same procedure to get the data (RGB intensities).For the second part of the results we can compare (Prieto et al.,2006) concerning the remediation of the visual impact generated by quartz mining by induction of biofilms, in Spain, For their case the treatment were biofilms, some blocks were inoculated with 15 ml of a culture containing organisms isolated directly from the mine, mainly cyanobacteria together with bacteria and bryophytes other blocks 10 to 18 were inoculated with the same culture but with 10 g/l of adhesive added, in their case the amount of the treatments applied were added during time while in our case the application were once only in the beginning of the experiment. The duration of their experiment was 100 days while ours is only 54 days and still continuing, all these different situation make the comparison more hard to make, but still, the general trend is towards the same thing, the evolution of ΔE (variation in total color) and ΔC (variation in chromaticity) were very satisfying for them in the cases of the culture with the adhesive and adding some nutrition, while for our case the adhesion and the nutrition were represented in the use of gelatin, flour, some soil and fertilized water, these ingredients were unproportionally composing the different organic matter treatments made which make the differences between there responds, we were also experimenting the use of irrigation and we observe that the gaps of ΔE and ΔC variation between the two periods are more important comparing with non-irrigated treatments. But still, the effect of the irrigation can be more or less arbitral during le long term of the experiment.

VI. Conclusion and final considerations

The main objective in this study is the rehabilitation of the disturbed area after the Foz de Tua dam construction by mitigating the visual impact generated from quarrying during the work phase. Mitigating the visual impact of quarrying by the integration of the disturbed area into the surrounding landscape, for vegetation could take some time, because some autochthonous vegetation grows slowly, but even so, using the right species is possible to take some advantage, including in the genetic point of view for local plant populations. This integration is based on two separated procedures, first the recovery of the area by the plantations and the sowing of the endemic species of the region trying to mimic the original landscape and second, the establishment of treatments made from organic materials with moss and lichen to facilitate the colonization of the rocks and in the same time mitigate the visual impact created by quarrying. The results shows three treatments from five that could be recommended to apply in the disturbed area, if it is possible to maintain some humidity and fertilization at the first phase can highlight good and faster results for the treatments, the plantations and the seedlings. Maybe to apply the treatments during autumn could be more fruitfull, but it was not possible for the present work.

Finally, all the results and the proposal that we had may effectively contribute to mitigate the visual impact and integrate the disturbed area into its ecosystem. This experiment can be reproduced for other types of rocks; since these latters were able to be colonized.

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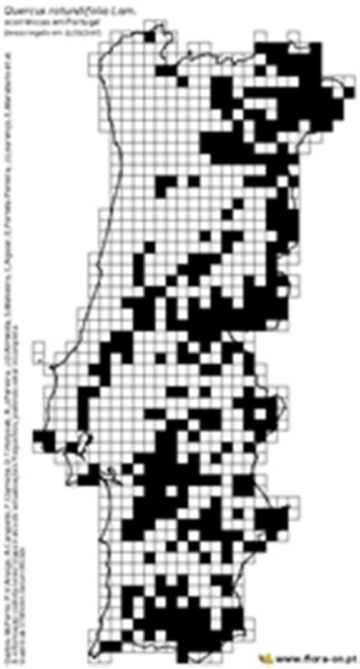
IX. Annexes

– Trees

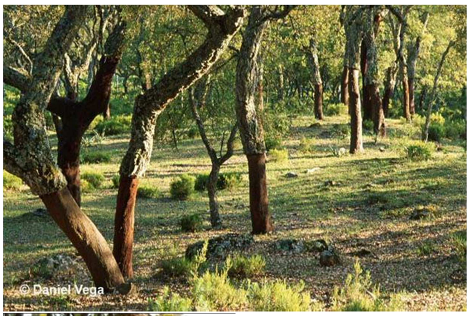
Holm oak (*Quercus rotundifolia*)

It is a species of perennial leaf, perfectly adapted to the Mediterranean climate. It appears frequently accompanied by other species, such as Retama sphaerocarpa, Cytisus sp., G. polyanthos or Lavandula pedunculata, depending on local edaphoclimatic characteristics.



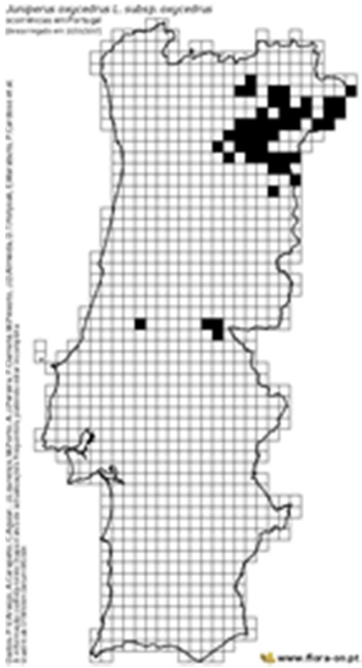
Cork oak (*Quercus suber*)

A medium-sized tree that can reach 20 m in height, with a broad and slightly dense crown. The cork oak appears in pure or mixed forests, accompanied by species of the same genus, and others may occur, such as Juniperus oxycedrus, Olea europaea var. Sylvestris, Pyrus cordata, or Celtis australis.



Juniper(*Juniperus oxycedrus*)

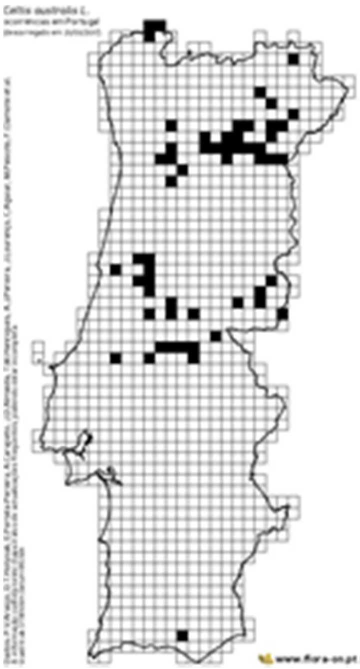
Shrub, can reach 10 m in height, is often associated with holm oak forests and is indigenous in the area, as can be seen in the distribution represented on the map next to it.



***Mediterranean hackberry* (*Celtis australis*)**

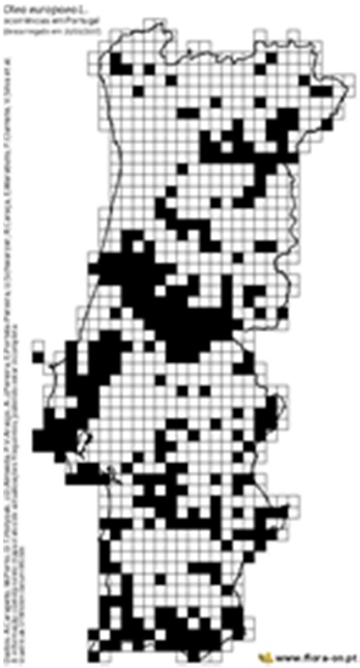
A deciduous, robust, medium-sized tree that can reach 30 m in height.

Southern species of full light that appreciates heat, supports climates with dry summer periods, low rainfall, finding optimal conditions on rich and moist soils, such as river banks and wet meadows.



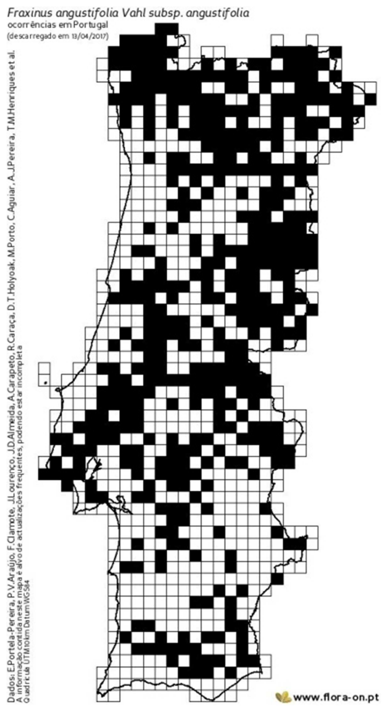
European olive tree(*Olea europeae var. sylvestris*)

Small tree, often bushy, with possible presence of thorns in the branches, with preference for well-lit places, well withstand heat and dry climates. Slightly demanding on the soil, the zambujeiro well supports rocky slopes with pockets of cooler soil.



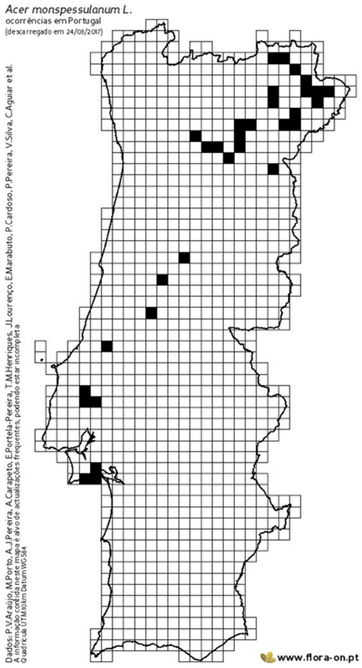
narrow-leafed ash (*Fraxinus angustifolia*)

Medium-sized tree. It is more frequent in riparian forests along the riverbanks and waterways in the hottest areas of the territory, but it is also a companion in deciduous forests in mountain slopes, mainly in the north of the country.



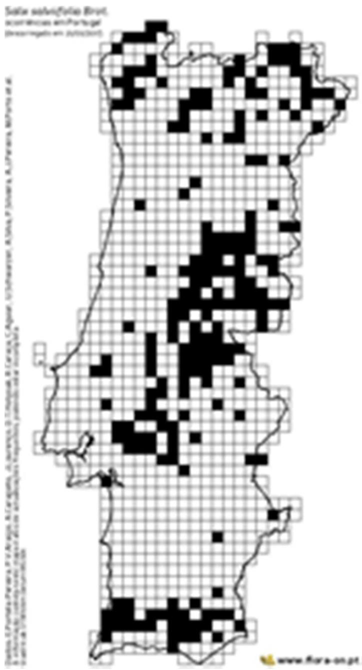
French maple (*Acer monspessulanum*)

Small deciduous tree, usually up to 10 in height. It appears in shrubs and Mediterranean deciduous or mixed forests, on rocky slopes, with preference for dry places and soils of calcareous origin, although it occurs in other types of soils.



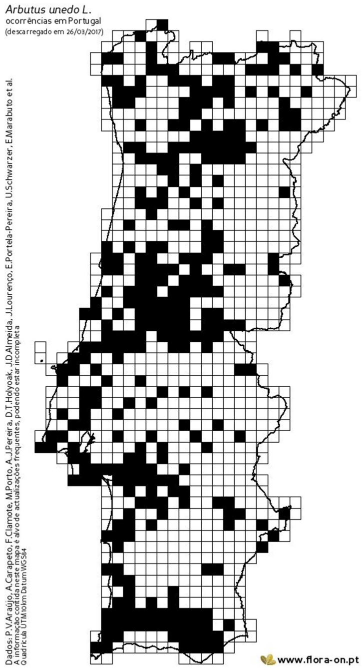
White bladed (*Salix salviifolia*)

Plant shrub or small tree, which occurs on banks of torrential watercourses.



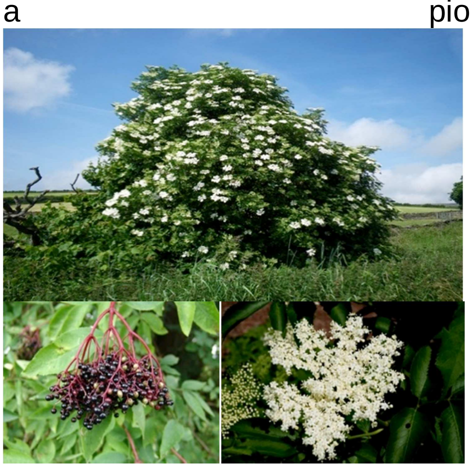
Strawberry (Arbutus unedo)

Small tree or shrub, very branched, with rounded crown. Mediterranean bushes, also in perennial forests (azinhais, sobreirais). Indifferent edaphic, in diverse types of soils, including rocky



Elderberry (*Sambucus nigra*)

Small tree or shrub, dense, very branched, with rounded crown. It is common in riparian galleries and grows in warm, bright places. Used as a pioneer.



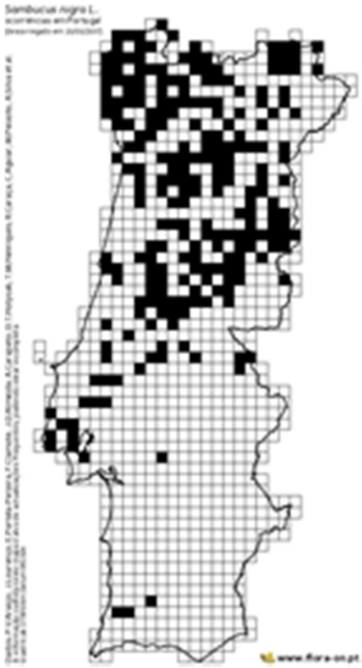
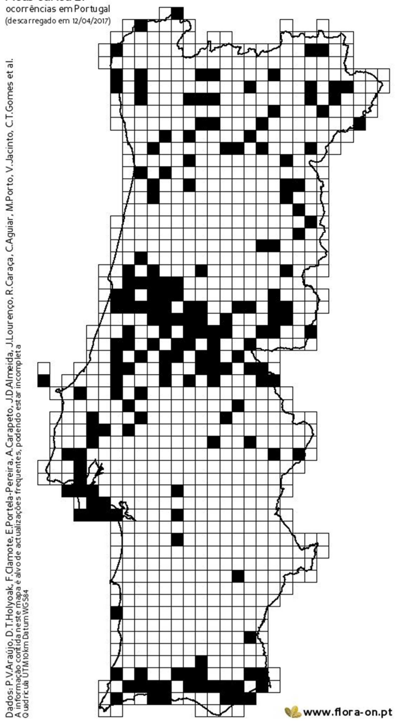


Fig tree (*Ficus carica*)

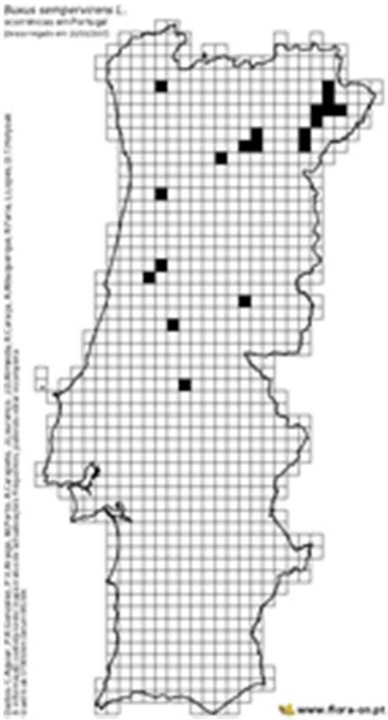
Small tree or shrub, rainforest orchards, vegetable gardens, ruins. Naturalized in the margin of watercourses, deep ravines and shores, in cool, rocky and somewhat humid places.



– Shrubs

Boxwood (*Buxus sempervirens*)

Perennial leaf shrub up to 5 meters high, typical of floodplains and riparian gallery in some rivers in NE of Portugal.

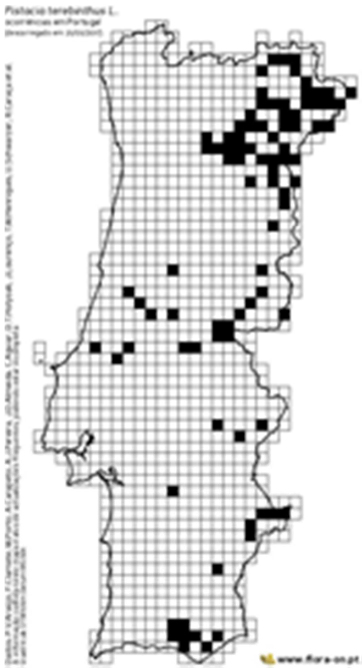


Pilrite (*Crataegus monogyna*)

Shrub or small tree with rounded crown, with a smooth and gray trunk that becomes split with age. White flowers in early spring. The fruits are reddish drupes, 6-10mm and with very hard seeds.

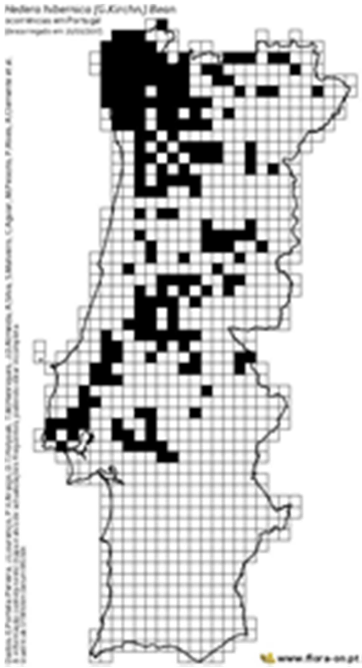
terebinth (*Pistacia terebinthus*)

Mediterranean shrub, deciduous and can reach 10 meters in height. The flowers are reddish-purple in color, appearing with new leaves in early spring. All parts of the plant have a strong resinous odor.



Atlantic ivy (*Hedera hibernica*)

A fast-growing evergreen, shrub and climbing specie. It adapts well to rocky and humid habitats



emleaf blackberry (*Rubus ulmifolius*)

It is the most frequent species of silva in mainland Portugal. It shows a very broad ecology, with a clear preference for habitats with humid and humanized soils.