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ECOMED Protocol 3. Field Work Protocol

ECOMED - Ecoengineering in the Mediterranean Environment

ECOMED Protocol 3

FIELD WORK PROTOCOL TEMPLATE

Edited By: Guillermo Tardío

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INDEX

1. PREFACE

This field protocol describes the methods that will be employed by the field teams under the ECOMED project. The field protocol aims to encourage the standardisation that is necessary to enable data from the construction site analysis to be pooled for generating improvements at the following levels:

- Design of the eco-engineering works
- Constructive procedures of eco-engineering works
- Monitoring, maintenance, and long term performance (resilience) of eco-engineering works

The descriptions of the methods are intended to be a reference to the best practice for the Mediterranean region and to highlight any pitfalls that might impair the quality of the data. In many cases, detailed descriptions of recommended procedures are readily available in other manuals, handbooks or international standards. Those who have difficulty in finding or applying these methods should contact the WP3 co-leaders.

1.1 List of contributors

The Ecomed field manual has been compiled by Guillermo Tardio.

The EcoMed field manual contains contributions from:

1. Guillermo Tardio
2. Alejandro Gonzalez-Ollauri
3. Kristina Dimovska
4. George Zaimes
5. Joao Paulo Fernandes

Some parts of the described methodology have been taken from the ECOSLOPE field manual (2002).

2. CONSTRUCTION SITES SELECTION

A set of case studies (soil and water bioengineering work examples) has been selected according to the Protocol 1. This set comprises a representative sample of different scenarios incorporating soil- and water- bioengineering works within the Mediterranean environment (slope, fluvial and coastal conditions, and failed work).

3. REFERENCE SYSTEM

In order to describe and recover data from different places, a general reference system is needed. It is advised that grid references are made with respect to UTM co-ordinates, which fully comply with GPS measurements.

4. SLOPE PROFILE DESCRIPTION

The equipment for measuring the slope could be a spirit level, angle ruler, linen tape, ranging poles, protractor, etc.

The measurement should be presented in the form of slope profile along the steepest gradient. A number of characteristic profiles covering the whole slope length should be described for a good characterisation of the slope and to ensure an adequate number of measurements within the study. For this, marking several longitudinal transects of similar width (e.g. 10 m) should be ideal.

The slope aspect within each transect should be expressed with a reference to the North. The slope curvature should be described in terms of concave or convex, but it can be also described numerically. In addition to this attributes, it is also of interest to evaluate hill shade or radiation indices to evaluate the degree of sunlight hitting a given slope transect or zone. The topographical description of the slope could be carried out using GIS software (e.g. Q-GIS, ESRI ArcGIS) in which different points on the slope are recorded with a GPS and then processed using functions related to spatial analyst tool of GIS.

5. SOIL PROFILE DESCRIPTION

Soil classification:

The classification of the mineral soil profile should be based on the standard F.A.O. (1990) or the Unified Soil Classification System (USCS) (ASTM, 1985; Head, 1980). The latter permits to classify the soil on the basis of the particle size distribution (i.e. gravel, sand, silt and clay). The former, however, permits a more detailed soil profile description. Three field guides are recommended: (i) Field book for describing and sampling soils (Schoeneberger et al., 2012); (ii) Guidelines for soil description (FAO, 2006); and (iii) World reference base for soil resources manual on soil profile classification (Driessen et al., 2001). Aspects related to soil texture, colour, fauna occurrence, hydromorphic traits or stones content can be readily described onsite. The presence of carbonates can be evaluated by adding a drop of HCl to the soil. It is also recommended to provide the soil classification on the basis of local/national soil classification systems, if any.

Soil colours are described by using the Munsell scale handbook.

A third soil classification should also be made using the national soil classification system.

Organic soil profile classification (cf. Green et al., 1993):

The ectorganic horizons should be classified using an adapted method of Green et al. (1993) and its revised version (Klinka, 1997). This can be found at www.forestry.ubc.ca/klinka/sci_sil/sses/sses009.pdf .The description of the underlying horizons can be carried out according to Green et al. 1993). To identify the forms of humus within the organic soil horizons, the key from Klinka (1997) can be used.

Engineering soil classification:

It is proposed to use the **EN ISO 14688-1/2:2002 Geotechnical investigation and testing - Identification and classification of soil.**

Other codes can be proposed and arranged by the project partners.

The firmness or strength of the in-situ soil can be assessed by simple index tests (see Table below).

Soil type	Term	Test
Sand and gravels	Loose	Can be excavated with a spade; 50 mm wooden peg can easily be drive into the soil
	Dense	Requires pick for excavation; 50 mm peg is hard to drive into the soil
	Slightly cemented	Soil is excavated with pick in lumps. Lumps cannot easily be broken but particles can be

		abraded
Silt	Loose	Easily moulded or crushed with fingers
	Dense	Strong pressure required to mould material
Clays	Very soft	Extrudes between fingers when squeezed
	Soft	Moulded without pressure
	Firm	Can be moulded with pressure
	Stiff	Cannot be moulded but can be indented with thumb
	Very stiff	Cannot be indented except with the thumb nail
Organic	Firm	Fibres compressed together
	Spongy	Open and compressible structure
	Plastic	Mouldable and smears the hands

Information on the consistency limits of cohesive materials can be obtained by means of the Atterberg limits, while the grading of cohesion less soils can be obtained by means of particle size distribution (sieving) analysis. Both properties are determined in the laboratory and used to classify the soils according to the above standard or to the Unified Soil Classification System (ASTM, 1985).

6. GEOLOGY

The parent material (if proven) should be described as adequately as possible. For this, the use of national geologic maps (e.g. 1:50000) and their corresponding guides is recommended. These can normally be found in the geologic survey institutions (e.g. Spain: IGME; UK: BGS) websites and public libraries.

7. SITE HISTORY AND CLIMATE

The climate of the site should be described from existing data (total annual rainfall, mean maximum and minimum temperature ,insolation, prevalent wind direction, etc.) from the closest weather station, etc. This information should preferably reflect long-term averages (e.g. 30 years). Anyhow, the time period used to generate the information related to the climatic features of a given site should be specified, as the climate is changing. On the basis of rainfall and temperature values, the climate should be classified according to Köppen (1884).

Site history with regard to land use changes or extreme events (wind, precipitation, avalanching and rock fall, flooding, land sliding, storms, waves, etc.) should also be described, too, as this can provide important information about changes in vegetation and soil properties. Historic maps and aerial images can be used for this purpose.

8. ABIOTIC SITE DESCRIPTION

8.1 Gravimetric soil moisture content ($g.g^{-1}$) (destructive method)

The gravimetric soil moisture determination is based on the loss of the mass of water from a sample that is oven-dried at 105°C for 24 hours. Two methods are suggested, the core method for soils that are not too dry or stony (Blake and Hartke, 1986), and the excavation method for stony soils (Goudie, 1981; Huntington et al., 1989). The core method can be also used to determine the related properties of void ratio, bulk density, specific volume, degree of saturation, etc. (i.e. phase relationships). It is worth noting that the gravimetric soil moisture content is synonymous with the water content, w.

Core method: Field: standard stainless steel rings (50 mm diameter, 100 cm^3 volume), a ring driver, hydraulic pressure apparatus for driving cores into the soil (optional), trowel and/or spade, metal saw, plastic ring covers to prevent evaporation and disturbance, tape for sealing the samples.

Laboratory equipment: oven, digital scale (accurate to 0.01 g), desiccator.

Procedure: Drive the ring slowly into the ground, disturbing the soil as little as possible. A hammer should not be used. Inserting the ring with a hydraulic press should be preferred. Remove the soil around the ring with the trowel or knife, without disturbing the soil in the core. Remove the ring with the containing core carefully from the soil, by cutting at least at 2 cm from the core bottom. Soil protruding from the ring should be carefully cut away with a small metal saw, cutting perpendicular to the core edge. Cutting with a knife parallel to the ring edge will smear the sample.

Put the plastic lids on the top and bottom of the ring immediately after sampling.

In the laboratory, weigh the ring with the core (wW; g) as soon as possible, dry it in the oven at 105°C for 24 hours, cool it in a desiccator and reweigh (dW; g). The weight of the clean sampling ring is determined (rW; g) after drying in the oven.

Calculation: Gravimetric soil moisture content, w

$w = M_w/M_s$

where M_w – mass of water [g]

M_s – mass of dry solids [g]

Note: for soils with stones the excavation method should be used (Hanson and Blevins; 1979).

8.2 Volumetric soil moisture content (cm^{-3} cm^{-3}) continuous, non-destructive

Non-destructive tests for the volumetric soil moisture content usually use the relationship between the dielectrical constant of the sample volume and the proportion of air and water in the pore space. TDR (time domain reflectometry) and derived methods are preferred. TDR uses probes of various sizes that determine the moisture content for various soil volumes depending on the probe size.

Figure 8. TDR device

8.3 Organic matter content (O, $g.g^{-1}$)

The organic matter content is the gravimetric fraction of the soil comprising C-rich organic substances (e.g., living and decomposing organic matter, particulate OM). It is suggested that the roots of living vegetation are excluded from this characterisation as roots are covered in the vegetation description section.

A rapid assessment of the soil organic matter content can be done through the quantification of the soil total organic carbon with the loss on ignition (LOI) test. This test quantifies the loss in sample weight when ignited at 450°C to 500°C for ca. 1 hour in a muffle. The soil mass loss is attributed to the combustion of the organic carbon.

8.4 Void ratio and porosity

The void ratio (e) and the porosity (n) represent the proportion of soil pore space in relation to the total volume and to the volume of solids in the soil, respectively. The variables can be expressed in terms of each other,

e = n/(1-n) and n = e/(1+e)

The void ratio can be derived from the dry bulk density (i.e. mass of solids/total soil volume; dry bulk density = dry soil weight (g)/soil volume (cm^3)) or from the gravimetric moisture content (w) and degree of saturation (Sr) if the particle density (ρ_s) is known

$$e = \frac{w \cdot \rho_s}{Sr \cdot \rho_w}$$

Where ρ_s is the particle density (g/cm^3), ρ_w is the density of water (1 $g{\cdot}cm^{-3}$), w is the gravimetric moisture content and Sr is the relative degree of saturation ($m^3{\cdot}m^{-3}$), which is the volume of water over the total volume of voids. It is worth noting that ρ_s is normally assumed to be equal to 2.65 g cm^{-3}.

The preceding equation is readily applicable when it can be assumed that the sample is saturated (Sr= 1). In that case, the void ratio is the product of the particle density with the gravimetric moisture content.

8.5 Soil chemistry

The analysis of the soil chemistry should be carried out according to the standards specified by Page et al (1982).

A basic characterisation of the soil chemical properties should include pH, TKN and plant available P, soil ReDox potential (Eh) and CEC (cation exchange capacity). Soil pH and CEC may regulate soil water relationships. These two variables can be used within pedotransfer functions along with information related to particle size distribution and soil organic matter to obtain soil hydrological attributes –e.g. field capacity, wilting point, matric suction of wetting front, saturated hydraulic conductivity, etc. TKN and available P regulate plant growth and performance. Information related to these variables may contribute to evaluate the potential establishment of vegetation on a particular site or slope section. ReDox potential regulate the release and speciation of microelements to the soil solution, which, more oftent than not, regulate plant performance. Rapid tests can be carried out with the use of field kits http://www.lamotte.com/en/soil/agricultural/5029.html. For more accurate outcomes, it is advisable to carry out these analyses in the laboratory following the protocols described below.

pH: Soil pH can be measured in the soil and in the saturation extract. In both cases, a glass electrode conveniently calibrated with pH 7 and 4 buffer solution standards is employed. In the first procedure (soil pH; 1: 2.5)), a 20 g of soil per replicate is mixed with 50 ml of distilled water in a 100 ml plastic glass. The mixture is stirred with a glass rod and left to stand for half an hour followed by further stirring prior to reading the pH. In the second procedure the pH measurement is performed directly on the saturation extract with the same type of electrode.

Available P: Method retrieved from MAPA (1986). Weigh 2.5 g of soil sample, add one tablespoon of active carbon and 50 ml of $NaHCO_3$ 0.5M. Shake for half an hour in a mechanical arms shaker. Filter the suspension with Whatman # 40. Take a 5 ml aliquot from the filtered solution in a 100 ml beaker and add 5 ml of ammonium molybdate. Stir manually the mixture to provide a suitable evolution of CO_2. Thereafter, add 14 ml of distilled water and 1 ml of diluted Cl_2Sn. This will develop a bluish colour in case of containing phosphorus. After 10 minutes, proceed to the colorimetric analysis in a UVV spectrophotometer (e.g. Perkin-Elmer). It should be noted that the former mixture is only stable for 20 minutes, so the reading must be performed in this time interval.

To obtain the calibration curve, the following solutions are needed:

(Mix the different reagents in the order indicated in the table; volumes in ml)

P concentration	0.04 ppm	0.12 ppm	0.20 ppm	0.40 ppm	0.60 ppm	0.80 ppm	1 ppm
P (2 ppm)	0.5 ml	1.5	2.5	5	7.5	10	12.5
CO_3HNa	5 ml	5	5	5	5	5	5
Molybdate	5 ml	5	5	5	5	5	5
H_2O	13.5 ml	12.5	11.5	9	6.5	4	1.5
Diluted Cl_2Sn	1 ml	1	1	1	1	1	1

The blank was prepared by mixing 14 ml of distilled water, 5 ml of $NaHCO_3$ 0.5 M, 5 mL of ammonium molybdate and 1 ml of diluted Cl_2Sn.

The absorbance of the solution is measured at a wavelength of 660 nm. The reading values are used in the following formula to calculate the Phosphorus content:

$$P\left(\frac{mg}{kg\,Sample}\right) = \frac{reading\left(\frac{mg}{mL}\right)}{\ldots}$$

TKN: After Bremner, J.M. (1965)

<u>Materials</u>

- Analytical balance
- Watchglass
- Fume hood
- Digestion tubes (250 ml)
- Digestor or heating unit with temperature regulator adapted to digestion tubes
- Catalyser: Tecator Kjeltabs: 5g potassium sulphate + 0.005 g selenium
- Sulphuric acid (96%)
- Dispenser
- Automated distiller
- Borate buffer solution: Add 88 mL of 0.1 N Sodium hydroxide (4g NaOH/L) to 500 mL 0.025M Sodium tetraborate (Na2B4O7) solution (5.0 g Na2B4O7/L) and dilute to 1 L.
- Baker
- Automated colorimetric device or titrator

- Solution of sulphuric acid 0.5 N
- Acid resistant gloves
- Goggles

Protocol

Adjust the temperature of the heating unit (i.e. digester) to 420 C. Weigh 1g of sieved (<2mm) soil on a watch glass and add it to the digestion tube. Add a tablet of catalyser followed by 10 ml of sulphuric acid (96%) with the dispenser. Place the digestion tube into the heating unit located in a fume hood. It is desirable to leave two free spaces within the tubes set unit for a blank and a sample of known concentration, respectively. Digest the content of the set of tubes at 420 C for 90 minutes. Take the set of tubes out of the digester and allow them to cool down. Place each tube in the automated distiller where the ammonia generated during the digestion will be absorbed by 50 ml of boric acid. Empty the distillate into a beaker and measure the volume of sulphuric acid 0.5N spent until change of pH of the distillate in a titrator.

Calculations:

%N = 14.01* (Lm-Lb)*N*f /g*10

Where:

Lm: volume (ml) of sulphuric acid spent in the titration

Lb: volume (ml) of sulphuric acid spent in the titration of the blank

N: sulphuric acid normality

f: sulphuric acid factor

g: mass (g) of soil sample

Eh: Shake 25 g of the soil sample with 50 mL distilled water in an Erlenmeyer flask for 5min. After this time, immerse the Eh electrode in the suspension and measure the redox potential. It is important to stir the sample during the measurement to keep the suspension from settling. Depending on the composition of the soil, the final value will be reached after 30 ... 50 min. For this reason the reading should, on principle, only be taken after 50 min have elapsed. The electrode is to be checked from time to time (i.e. calibration with adequate buffer solutions) and cleaned, if necessary.

CEC: After Chapman (1965). The soil sample is mixed with an excess of sodium acetate solution, resulting in an exchange of the added sodium cations for the matrix cations. Subsequently, the sample is washed with isopropyl alcohol. An ammonium acetate solution is then added, which replaces the adsorbed sodium with ammonium. The concentration of displaced sodium is then determined by atomic absorption, emission spectroscopy, or an equivalent means.

REAGENTS: (i) Sodium acetate (NaOAc), 1.0 N: Dissolve 136 g of $NaC_2H_2O_2$ @$3H_2O$ in water and dilute it to 1,000 mL. The pH of this solution should be 8.2. If needed, add a few drops of acetic acid or NaOH solution to bring the reaction of the solution to pH 8.2; (ii) Ammonium acetate (NH_4OAc), 1 N: Dilute 114 mL of glacial acetic acid (99.5%) with water to a volume of approximately 1 liter. Then add 138 mL of concentrated ammonium hydroxide (NH_4OH) and add water to obtain a volume of about 1,980 mL. Check the pH of the resulting solution, add more NH_4OH, as needed, to obtain a pH of 7, and dilute the solution to a volume of 2 liters with water.

PROCEDURE (i) Weigh 4 g of medium- or fine-textured soil or 6 g of coarse-textured soil and transfer the sample to a 50-mL, round-bottom, narrow-neck centrifuge tube; (ii) Add 33 mL of 1.0 N NaOAc solution, stopper the tube, shake it in a mechanical shaker for 5 min, and centrifuge it until the supernatant liquid is clear; (iii) Decant the liquid, and repeat it three more times; (iv) Add 33 mL of 99% isopropyl alcohol, stopper the tube, shake it in a mechanical shaker for 5 min, and centrifuge it until the supernatant liquid is clear; (v) Repeat the procedure described in iv two more times; (vi) Add 33 mL of

NH4OAc solution, stopper the tube, shake it in a mechanical shaker for 5 min, and centrifuge it until the supernatant liquid is clear. Decant the washing into a 100-mL volumetric flask; (vii) Repeat the procedure described in vi two more times; (viii) Dilute the combined washing to the 100-mL mark with ammonium acetate solution and determine the sodium concentration by atomic absorption, emission spectroscopy, or an equivalent method.

8.6 Undrained and effective shear strength & Root strength

Undrained shear test: it will be measured with a vane shear test (EN 1997-2, Eurocode 7 part 2; https://www.iso.org/obp/ui/#iso:std:iso:22476:-9:dis:ed-1:v1:en).

Root reinforcement is only apparent when soil samples are tested both with and without roots. The following gives a brief description of the commonly used direct shear test.

Effective shear strength without root reinforcement

Equipment: Direct shear apparatus and shear box; soil sieved 2mm and lower.

Method: A detailed description of the direct shear test can be found in Head and Epps (2011), or national standards such as BS1377. The aim of the direct shear test is the determination of the soil cohesion and friction angle. Several test runs carried out at different normal loads are required (a minimum of three soil samples must be tested) to portray the so-called Mohr-Coulomb failure envelope, in which the intercept stands for the cohesion, and the slope angle stands for the angle of internal friction. Undisturbed samples for direct shear tests are usually saturated in advance. This test can be performed under drained or undrained conditions, depending on the shear apparatus employed. The same test can be implemented to evaluate the soil-root reinforcement under laboratory conditions (see below).

Root reinforcement:

In situ shear test. *It will depend upon the availability of the in situ shear test equipment. Vane can be used or in situ shearbox (e.g. Mickovski and van Beek, 2009).*

Direct shear tests in the laboratory should only be used to characterise the contribution of the smaller root systems (root diameters up to 2 mm).

8.7 Aggregate stability

Equipment: sieves with 2.8 mm, 4mm and 5 mm mesh diameter, droplets generating apparatus, 1.0 pF tray

Method: An adapted method of Low is used, as described by Imeson and Vis, (1984). It is important that 0.1 g drops are used and that the fall height is standardised at 1 m. A set of 40 aggregates of a size ranging between 4 to 5 mm is used. These can be separated during the aggregate size distribution analysis. It is very important that they are analysed as quickly as possible after sampling as aggregate stability changes during storage. Alternatively, soil samples can be stored in a refrigerator at 4^0C prior testing. A comparison of pre-wetted and dry aggregates is recommended. One set of 20 aggregates is pre-wetted during 24 hours at pF= 1.0. The other set of 20 is used after being air-dried. Each aggregate is positioned on the 2.8 mm mesh sieve. Let drops of water fall exactly on the middle of the aggregate until its falls apart, and it is washed down through the mesh. Count the number of drops until the aggregate is falling apart. Repeat this analyses for the two sets of 20 aggregates (air-dry and at pF= 1.0).

8.8 Estimation of slope soil erosion

A common way to measure soil erosion can be accomplish by using the Gerlach method (Morgan, 1986). In this method, small plots with boundaries (called troughs) are used. They consist of a small collecting gutter which is let into the soil surface and connected to a small collecting container on the downstream side

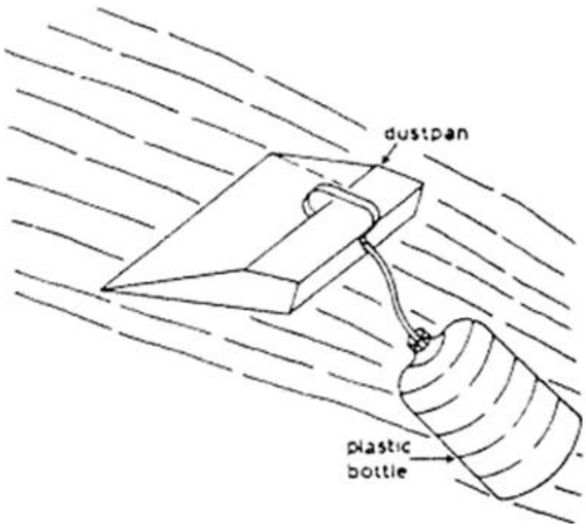


Figure 1 Gerlach method (from Morgan, 1986)

Figure 3 Example of installation of collecting boxes (from de Assunçao Alho, 2006)

The size of the plots is related to the purpose of the trial. In the bioengineering field work case, microplots of one or two square meters may be appropriate because the objective is a simple comparison of two treatments and the treatments are not influenced by scale. The two scenarios to compare are the bioengineered slope and the pre-restored scenario (represented by a similar area without bioengineering techniques). By performing several replications (e.g., 10) it is possible to attain useful comparisons of the effects/benefits of the bioengineering techniques in the intervention area.

Soil erosion can also be measured by using stainless steel rods or pins (Hudson, 1982). In case the selected site had those elements installed, the methodology for calculating the soil loss rate is explained in the following paragraphs. If an extra field work is planned to be done in the pilot site within the Ecomed project length, these elements could also be installed for collecting erosion measurements.

Soil erosion by the continual (gradual or intense) loss of topsoil may eventually lead to the inhibition of plant growth as well as to deterioration of the slope stabilisation structure. The importance of soil erosion has been pronounced in numerous occasions since it often goes undetected for long periods of time. The measurement/estimation of topsoil loss (in mm/year) for each site will yield valuable information when comparing different eco-engineering approaches within the slope scenario.

The use of erosion pins in measuring soil erosion rates has been extensively practiced as indicated by Boardman & Favis-Mortlock (2016). The technique is based on simple insertion of a thin metal pin (preferably a number of pins) into the ground with the top of the pin being exposed above ground. Upon insertion, the aboveground exposed length of the pin is measured, this being the starting point of the measurement. After a period of time the exposed length is again measured, and the increase in this length indicates erosion whereas the decrease indicates deposition. These measurement can be performed repeatedly and frequently over e fixed period of time. Boardman & Favis-Mortlock (2016) furthermore point out that this is a simple and a rather inexpensive method which can also be easily adapted in relation to the aim of the project.

There are no geographical restraints for the applicability of the technique. The method of erosion pins for the measurement of erosion rates has also been used in the Mediterranean climatic region as well (Scoging 1982, Benito et al. 1991, Sirvent et al. 1997).

Equipment: Mild steel or stainless steel rods, usually 300 mm long and 5 mm in diameter. Painted rods may be used for and ease in localisation after a period of time.

Vernier calliper, Vernier depth gage or a Depth micrometer gauge for precise measurement of the exposed length of the pin (in mm).

Method: The methodology follows in great detail Hancock & Lowry (2015). The pins can be located in a linear transect/s along the slope or within a grid (which will be representative of the area studied). Depending on the area of the site the pins can be located at 1 m distance within the transect and the transects distanced 2-3 m from each other. The pins should be inserted into soil between gaps in the surface armour.

The pins can be inserted into the ground by placing a wooden block on top and then hammered down. The height of the exposed length should be measured for reference. Usually this height is 50 mm.

Measurement of the exposed length of the pins can be performed every month (for a period of three months, six months, a year). In every case more reliable results are more likely to be obtained with longer time periods of measurement. Two measurements can be taken at each pin to avoid measurement bias. Hancock & Lowry (2015) give details on how the measurements should be performed.

Figure 4 Example of installation of collecting boxes (from de Assunçao Alho, 2006)

Calculation: The result for each pin will be the average of the two measurements performed. The arithmetic mean of the measured change in the exposed length of the pins is then used to quantify the net erosion or net deposition on the site. The changes in the exposed length of all pins are summed and divided by the duration of the observations, giving an average rate of net erosion or net deposition (in mm/year) for the area covered by the pins and for the period of measurement.

As an alternative method, a geodetic laser measurement can be utilised for an extremely precise measurement of topsoil loss. Leica Scanstation is commonly used for such measurements, which is characterised with a precision of ± 2.00 mm

8.9 Assessment of the deterioration of the wooden elements

The purpose of assessing the current state of the wooden elements is for retrieving information about the way the wooden material will evolve with time in the conditions present in the intervention area. Being able to foresee this process will improve the capacity for both designing the wooden structures and erring on the safe side in the internal stability checks (Tardio and Mickovski, 2016).

The first stage will consist in collecting information about:

- the tree species used in the work
- the natural durability of the tree species.
- Were the trunks debarked when used in the work? Is it treated or untreated timber the one used in the work?
- The age of the trunks used in the intervention. Depending on the age the percentage of sapwood will be lower or higher. Generally juvenile wood has a higher sapwood percentage and therefore a lower natural durability (higher deterioration rates can be assumed).
- the initial diameters used in the work
- gathering information about the most common fungi and insect attacks in the intervention area will be very valuable as well. Sometimes the attack is not from outside to the inside but the other way around.

As with the assessment of wooden girders and columns of old structures, the following methodology will be used:

1. Use a bodkin for a general check of the wooden elements. Use the bodkin to try to find weak zones over the wooden structure.

2. In case of detecting some weak areas (with lower rigidity), use a penetrometer (e.g. pylodin) for having a first assessment of the damage. See Giuriani and Gubana (1994) for the pylodin use.
3. If the depth of the affected area is longer than the penetrometer range (generally 40 mm) then use the resistograph for analysing the extent of the rot area. See Ouis (2003) for the resistograph use.

   With the preceding information, an assessment of the cross sectional loss of the wooden element will be calculated. Based on the latter, the deterioration rate will be calculated according to:

   $r = \frac{\frac{(d_{initial} - d_{current})}{2}}{t}$ (mm/year) (see below figure)

   Where:
   $d_{initial}$ = initial diameter of the wooden piece
   $d_{current}$= equivalent diameter after t years; current equivalent diameter of the wooden piece (take two perpendicular measurement of the diameters and make an arithmetic average)
   t = time lag (in years)

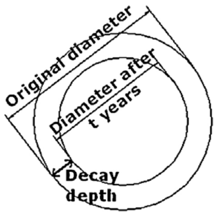


Figure 5 Example of decay process in a log used in a bioengineering work (from Tardio and Mickovski, 2016)

4. If available, use a microsecond timer for assessing the general state of the wooden element
5. Take a slice of the affected area in order to both analyse and study the type of pathology that affected the wooden elements. A sewing machine or a saw will be used for this purpose

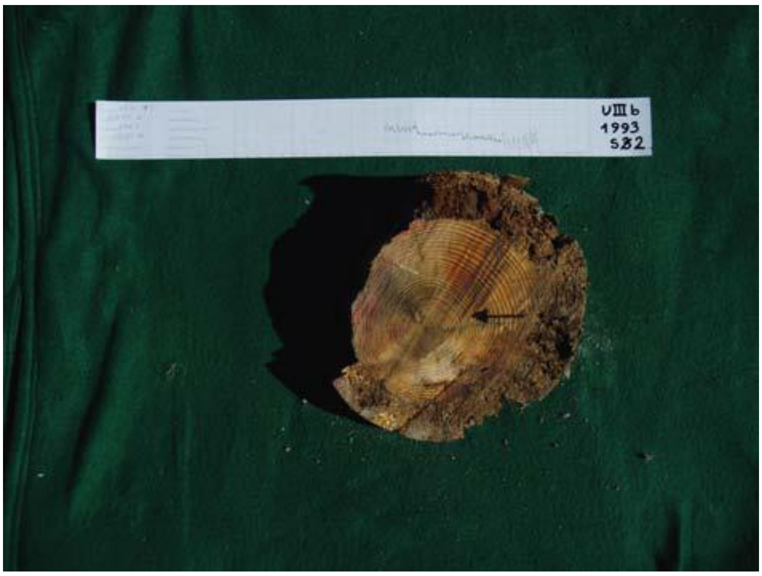


Figure 6 Slice of a wooden element. The resistograph reading is placed on the top of the wooden piece

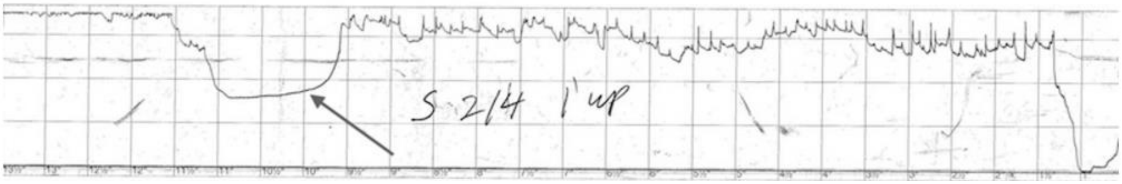


Figure 7 Resistograph reading. The dip in the line shows a zone with decay deep in a trunk

The unaffected cross sectional area will be assumed to keep its original mechanical properties. The latter maybe updated according to the current level of moisture of the wooden elements according to EN 384:2010. The moisture will be measured by using a wood hygrometer.

In the case of failed works, the following approaches will be analysed:

- Did the work fail because of a bad design (e.g., a wrong calculation of the necessary diameters to withstand the existing forces, a wrong choice of the bioengineering technique, etc.?)
- Did the work fail because of the loss of cross sectional area of the wooden elements (intense fungi or insect attack)?
- A combination of the preceding two approaches

The necessary apparatus and tools will be:

- a measuring tape (for measuring diameters)
- a bodkin
- a penetrometer (e.g. pylodin)
- a resistograph
- a driller: use this tool only if a resistograph or a microsecond timer is not available. You will have to detect when the drilling resistance increases, then you will stop drilling and measure the depth. Do this in different directions around the detected weak zone.
- a microsecond timer (use it when a resistograph is not available)
- a wood hygrometer

Figure 8 Wood hygrometer

Figure 9 Microsecond timer. The device is designed to measure stress wave propagation time in trees

Special attention will be paid in the analysis near the junctions since these are usually weak points (pathogens have a better access to inner parts of the wooden pieces).

9. DETAILED CHARACTERIZATION OF THE VEGETATION

The vegetation analysis will allow us to characterise the vegetation structure and its floristic composition. For the former, variables such as ground over, heights and diameter will be used while for the latter, variables such as number of species, seedling, etc will be utilised.

9.1 Vegetation cover per unit area of ground and vegetation height ($m^2.m^2$); (m)

The determination of the vegetation cover can be carried out using a stratified haphazard design (Gonzalez-Ollauri and Mickovski, 2017). This protocol consists of dividing the slope section into different strata (e.g. slope toe, slope middle, slope crest) and collecting random samples of vegetation by throwing randomly a 0.5/1.0 m2 quadrat. All the vegetation found within the frame is either harvested for further processing (e.g. dry biomass determination by drying the collected vegetation at 70C until constant mass) or counted in terms of individuals (i.e. density; number of individuals per unit area of ground). On zones where vegetation cover is sparse, the fraction of the frame covered by vegetation can be estimated. In this case, vegetation cover scales can be used (e.g. Domin scale). The following categories provide a rapid assessment of the vegetation cover, which provide an average value for each quadrat from grids (e.g. 5x5 cm; 10x10cm) established within a given quadrat.

A minimum of 30 repeats per stratum is recommended. Please, note that the former protocol is for herbaceous vegetation. For woody vegetation, the size of the quadrat must increase –e.g. 10x10 m. For the later, aerial images can be used and processed in a GIS software

Estimates of vegetation cover per grid square
0%
Around 25%
Around 50%
Around 75%
100%

The area without vegetation is either bare or covered by litter. Here, a further distinction can be made (note that the classes should be established per quadrant):

- Bare soil: no cover of dead or living vegetation or canopy and hence fully exposed to the sky;
- No litter present but sheltered by overhanging canopy
- Litter covered without canopy
- Litter covered with canopy

9.2 Plant species

Plant species will be identified for trees, shrubs and herbaceous vegetation. Invasive plant species present in the intervention area will be indicated in the study case report.

9.3 Vegetation height estimation

Estimate heights per plant species using manual measurements (http://www.wikihow.com/Measure-the-Height-of-a-Tree), clinometer, laser measure (e.g. Leica Disto) or smartphone (https://gabrielhemery.com/2011/05/15/how-to-calculate-tree-height-using-a-smartphone/). These measurements are based on trigonometric and Pythagoras principles.

For the case of herbaceous vegetation, plant height measurements can be obtained using rulers, sticks or meter tapes, starting the measurements from the ground level always

9.4 Tree location and dimensions

When trees are present on a site, it is important to map their position. Common tree traits measurements are tree height (see above), projected canopy area and diameter at breast height (DBH) must be measured. In the case of coppiced trees, the stump position, maximum height and diameter of the newly re-sprouted crown, should also be measured. It is vital to obtain information about the stand history (tree age, planting regime, year of coppicing etcetera). The compilation of measuring protocols compiled by Blozan (2006) is recommended.

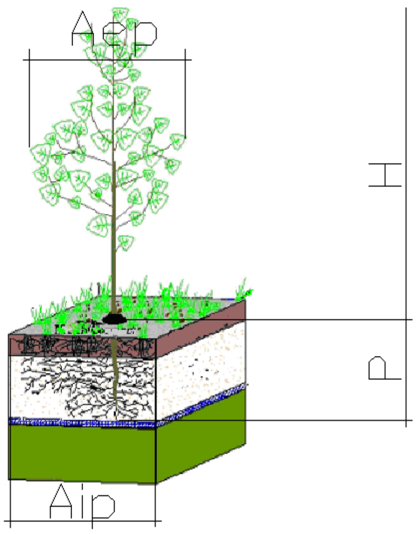
Equipment: Tachymeter or GPS, measuring tapes (2), Abney level or Vertex instrument, ranging staff, 4 pegs and poles, rope

Procedure: Map tree locations using either a tachymeter or a high resolution GPS system. X, Y, and Z-co-ordinates of each tree should be recorded.

Measure the circumference of the tree (DBH, [m]) at breast height (1.5 m). If the shape of the tree trunk is very irregular, measure three times, at 1.5 m and at a small distance above and below this height, and average. Alternatively, LiDAR-based methods can be used to geolocate and measure the above mentioned tree features (https://www.e-education.psu.edu/geog481/l8_p4.html).

9.5 Synthetic parameters (Cornelini et al., 2008)

The following parameters are based on the next figure:



Adimensional index of root architecture:

Index of root semi-sphericity:

A=1/2*(P/Aip) = 1/2*(root depth/root amplitude)

Adimensional indexes of stability and solidity

Index of relative stability: S=P/H = root depth/height above ground

Index of potential stablity: Sp=L/H = (length of main root / height above ground)

Index of relative solidity: s= Aip/Aep = Root amplitude / Plant amplitude above ground

Global stability indexes

Index of root stability: R=S*s = relative stability*relative solidity

Index of global stability: P = S*s^2 = (relative stability)*(relative solidity^2)

NOTE:

Comparisons of vegetation structure and floristic composition between the pilot area and both the pre-operational situation and a reference site (endpoint condition) will be very valuable for assessing the overall performance and progress of the bioengineering intervention.

GENERAL NOTE:

For the assessment of the overall intervention performance, the assessment should also be done in the following scenarios:

- Pre-restored conditions: In case of lacking the pre-restored information of the intervention area, a nearby area with similar conditions and similar instabilities can be used.

- Reference site: this is a study area similar to the project area, but not in need of stabilisation. This site represents the study area if it were undisturbed or stable. Conditions at the reference site represent the conditions that are the goals of the intervention.

Pre- and post-construction evaluations can measure the change or impact from the project, but the level of success can be judged only relative to reference system (NRCS, 2007).

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11. APPENDIX 1: RAPID ASSESSMENT FORM FOR WATER BIOENGINEERING ASSESSMENT

Project title:

Date of construction:

Date of repairs (if any):

Primary goal of the project:

Secondary goal of the project:

Other goal (s):

Please indicate if the detected problems were solved and to what extent:

Description of stream prior to construction (if available):

<u>Evaluation information:</u>

Date of assessment:

Assessment team:

List of materials tools used for the assessment:

RAPID ASSESSMENT METHOD

For qualitative assessments rate the variable from 1 to 5 (where 1 is the worst condition).

Landscape context:

- Landscape connectivity: riparian corridor connectivity
- Buffer width: average with in meters
- Buffer condition: degree of disturbance, quality of buffer

Hydrology:

- Water source: anthropogenic inputs.
- Channel stability: equilibrium, aggradation or degradation
- Hydrologic connectivity. Connection to floodplain

Physical structure:

- Physical patch richness. Richness of habitat structures:
  - Spawning gravel
  - Instream cover
  - Shade
  - Pool/riffle ratio
  - Amount and size of distribution of large woody debris
- Topographic complexity. Variation in elevation and moisture gradients.

Biotic structure:

Plant community:

- Number of plant layers. Number of height classes.
- Species richness. Number of co-dominant species
- % Invasion. % of co-dominants that are invasive
- Horizontal interspersion and zonation. Inter-fingering of plant community zones in plan view.
- Vertical Biotic structure. Degree of vertical overlap of plant height classes.

For a rapid assessment of the overall intervention performance, the rapid assessment should be also done in the following scenarios:

- Pre-restored conditions: In case of lacking the pre-restored information of the intervention area, a nearby area with similar conditions and similar original problems can be used.
- Reference site: this is a study area similar to the project area, but not in need of stabilisation. This site represents the study area if it were undisturbed or stable. Conditions at the reference site represent the conditions that are the goals of the intervention.

Pre- and post-construction evaluations can measure the change or impact from the project, but the level of success can be judged only relative to reference system (NRCS, 2007).

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ECOMED is an ERASMUS+ co-founded programme promoted by Universidad Politecnica Madrid which aims to improve the specialisation level of the ecoengineering sector in Mediterranean areas and within this context, this project offers to provide a sound and practical knowledge based on the accumulated experience in order to offer to the next generation of practitioners and managers a solid and well suited training in ecoengineering restoration techniques in Mediterranean scenarios.

For further information

www.ecomedbio.eu