SPECIALISATION PROCESS
FOR THE BIOENGINEERING SECTOR IN THE
MEDITERRANEAN ECOREGION: STRATEGY
FOLLOWED IN THE ECOMED EUROPEAN PROJECT*

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Abstract

The soil and water bioengineering sector is gaining presence into the riverbank and slope stabilization works and projects. This situation is also true for the Mediterranean ecoregion case. The bioengineering sector particularities can be classified as either general for the whole sector or particular for the Mediterranean ecoregion case. Within the former ones are those features related to the use of both plants (living material) and inert biodegradable materials (e.g non-treated wood). Within the latter ones, the particularities of the bioengineering sector are related to the aridity of the climate and the selection of both plant material and planting techniques. The Ecomed project strategy is addressing all the preceding challenges from different perspectives by:
- analysing the sector current needs, strengths, weaknesses and opportunities
- analysing existing soil and water bioengineering works
- improving the existing design routines and protocols
- reinforcing the sector by a know-how transfer strategy (generation of new interactional schemes and dynamics within the sector)
- generating an improved syllabus and sector specific training modules

Hence, the Ecomed project will be the basis for a long term continuous improvement dynamic that will allow the Mediterranean bioengineering sector to achieve a higher specialization level. The preceding approach is readily transferable to other ecoregions and hence the usefulness of the project from the circular economy point of view.

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1. Introduction

Soil loss and degradation are considered major threats worldwide because they have many negative implications on humans, their society and the environment (Yang et al., 2003; Zaimes et al., 2016). Specifically, soil loss affects the productivity of land and ecosystem’s dynamics. While it is a natural phenomenon, anthropogenic activities such as agriculture, deforestation and urbanization have accelerated soil loss rates (Bakker et al., 2008; Montgomery, 2007). Accelerated soil loss leads to decreased soil quality and significant land degradation and this is the reason why many scientists consider it a threat as important as climate change. Preventing soil loss and degradation is a worldwide priority thus numerous soil conservation efforts have and are being developed and implemented to achieve soil sustainability (Ananda and Herath, 2003; Baumhardt et al., 2015; Panagos et al., 2016).

The most common natural processes that lead to soil loss and land degradation are soil erosion, landslides and floods. Soil erosion occurs more frequently than landslides and floods. In contrast, landslides and floods are more episodic and typically very catastrophic (Chen and Wang, 2007).

Climate change is expected to add additional pressures on soil loss because of the variations in temperature, sea level rise, rainfall amounts and intensities, number of days of precipitation, ratio of rain to snow, that will impact plant biomass production, plant residue decomposition rates, soil microbial activity, evapotranspiration rates and potentially cause shifts in land-uses (Nearing et al., 2004). The many changes due to climate change make it difficult to predict the exact impacts but the expected increase in extreme weather events, particularly the increased rainfall intensity and extended drought periods compared to past conditions (Giupponi and Shechter, 2003), should increase water runoff and consequently soil erosion, floods and landslides (Routshek et al., 2014).

The increased occurrence of soil erosion, landslides and floods along with potential impacts of climate change and the exponential increase in the human population and their needs will put more pressure on the soil resources making soil loss and degradation mitigation an even greater priority (Rosenzweig and Hillel, 2000). The EU trough the Directive 2004/35/CE and the "Soil Thematic Strategy" ((COM(2006) 231); (COM(2006) 232) and (COM(2012) 46) as well as the 2012 report ‘The State of Soil in Europe’ (Report EUR 25186 EN from the EEA)) has been developing a strategic policy for soil protection and damage recovery, clearly stressing the importance of the preservation and the sustainable management of soil resources (Panagos et al., 2012). The growing perception in the scientific community is to move towards solutions that are more eco-friendly based on ecosystem approaches.

2. Soil and water bioengineering strategies for protecting the soil

Ground bio-engineering, also termed eco-engineering, is the use of living plants or cut plant material, either alone or in combination with inert structures, to control soil erosion and the mass movement of land in order to fulfill engineering functions (Schiechtl, 1988). Soil bioengineering is currently developing worldwide, as regulatory frameworks (including the European Water Framework Directive or more recently the European Green Infrastructure Strategy) are introducing the need to implement “soft” techniques for natural hazard control instead of “hard” techniques (engineered concrete and steel structures such as check dams), in the pursuit of restoring degraded environments or preventing further degradation during new constructions. The International Union for the Conservation of Nature (IUCN) is
proactively endorsing the use of ecological engineering for disaster risk reduction (EcoDRR), and includes ground bioengineering as a technique for protecting against landslides (Furuta et al., 2016; Renaud et al., 2016). Soil and water bioengineering techniques and strategies can help promote cost-effective and sustainable ways to reduce soil loss and land degradation.

2.1. Soil and water bioengineering particularities

The use of living and biodegradable materials in the ecological restoration and rehabilitation projects and works include some particularities into the intervention strategy, design, evolution and performance:

- the main reinforcing element, at least in the mid and long term, is the plant roots
- the living material (the plants and their roots) evolve with time.
- the biodegradable materials used in the work (e.g., untreated wood) change their mechanical properties with time (because of the deterioration processes).
- there is a stress transfer process of the stabilizing role between the initial inert materials used in the work and the living material (the plants). The soil and water bioengineering approach aims at achieving a final stage of the intervention where most (if not all) of the stabilizing/reinforcing function is developed by plants.
- soil and water bioengineering solutions are Nature Based Solutions (NBS) and therefore, the generated systems are both complex and self-organized.
- the design process cannot be explicitly complete at the outset of the intervention. Feedback loops are necessary to keep the intervention strategy and performance informed. A monitoring and maintenance stage is essential.

Therefore, for a bioengineering work design, the time and elements durability must be considered more explicitly throughout the design life of the work (Tardio and Mickovski, 2016).

2.2. Giving answer to soil and water bioengineering particularities

As stated before, the use of living material (plants) at the bioengineering design stage involves some complexities that must be addressed for a suitable simulation and justification of the bioengineering intervention. For this purpose, the following topics and questions must be attended:

**Question A:** How to incorporate the role of the vegetation into the system overall stability (slope, riverbank, etc).

**Question B:** How to design the bioengineering works given its clear dynamic and changing nature. In order to reflect this particularity into design procedures and routines, the following points must be incorporated:

- Question B1: The stress transfer process between the inert material and the evolving living material (plants).
- Question B2: Deterioration processes of biodegradable materials used in the work (e.g. non treated wood).
- Question B3: The stabilizing role transfer process between the different elements used in the work (stabilizing role transfer between the initial inert materials used in the work and the evolving vegetation).

**Question C:** Given the semi-empirical nature of this type of works, useful and effective feedbacks for allowing a fine tuning process over the work service life is essential. In this point, different approaches are possible:

- Question C1: Implementing a monitoring stage throughout the work service life producing continuous feedback information to calibrate the bioengineering work design and performance.
Question C2: Know how transfer strategies between sector stakeholders and the analysis of similar works from a similar ecoregion. A circular economy approach expressed as sector accumulated experiences analysis and exploitation tools have a great potential within the bioengineering sector.

Question D: The Mediterranean ecoregion involves particular challenges related to the lack of water and the aridity which represent the main limitation for soil and water bioengineering strategy implementation in those environments.

3. The Ecomed project strategy and design. Soil and water bioengineering in the Mediterranean ecoregion

The particularities faced by bioengineering works in a Mediterranean climate that are related to the aridity of the climate and the selection of both plant material and plantation techniques, demand a highly specialized and new knowledge triangle (new processes, methods and services) within the sector. Besides, as stated before, the bioengineering sector also needs new tools for making allowance for the complexities triggered by the use of both living and biodegradable material. All the changes occurring within the lifespan of an bioengineering work require a scheme that examines the entire work lifespan in order to verify the successes and errors of the intervention and justify potential corrective actions. The Ecomed project gives answer to those needs by developing protocols for the entire lifespan of bioengineering works. The project strategy collects information from all the stages of the work service life which are:

- **the design stage**: by analyzing projects and preliminary studies associated to bioengineering works
- **the construction stage**: by analyzing existing works (its current state, overall performance and, effectiveness)
- **the monitoring stage**: by analyzing both the monitoring works developed in existing works and analyzing the useful feedback loops generated throughout the monitoring stage development.
- **the training stage**: by analyzing existing syllabus and detecting training gaps to be filled if we were to support the specialization level of the bioengineering sector.
- **the sector strategy as a whole**: by improving and fostering the interactions and know how transfer between the sector vested stakeholders.

The preceding strategy is shown in Fig. 1.

![Fig. 1. Tools and information sources supporting the sector specialization level improvement strategy within the Ecomed project](image-url)
The selection and analysis of a set of bioengineering interventions is a featured element of the Ecomed project strategy. The criteria to select representative bioengineering works within the Mediterranean ecoregion were determined. These criteria looked at characteristics such as the amount of available information associated to the work and the variety of the materials used. Furthermore, the final set of the selected works are representative of four scenarios: slope, fluvial, coastal and failed eco-engineering works. Currently, existing works are being examined in Italy, France, Greece, Macedonia, Portugal, Spain and Turkey. The final set of selected works will be analyzed and will provide new insights in regards to the applications of bioengineering in the Mediterranean ecoregion. The analysis of the selected bioengineering works represent an essential source of information for developing more effective theoretical-practical tools and syllabus to support the specialisation process of the bioengineering sector.

Protocols for performing effective and efficient bioengineering field work were developed. These protocols are applicable and adopted for the entire Mediterranean region. The three protocols developed (see Fig. 1) are: a) Protocol 1 - bioengineering Work Selection Criteria, b) Protocol 2 - bioengineering Work Analysis Definition and c) Protocol 3 - Field Work Protocol. Protocol 1 provides information about the criteria to be followed for selecting bioengineering work examples in such a way that their analyses will effectively feed the sector specific toolkit generation process. Protocol 2 describes the structure, variables and stages that need to be included when analyzing each selected bioengineering work. It provides guidelines for analysing the work in such a way that the generated information will effectively support the sector specialisation process. Finally, protocol 3 defines all the procedures and methodologies for analyzing field work parameters and variables. In addition, different templates for analyzing the overall and particular work performance and effectiveness are also provided.

For the assessment of the overall intervention performance, the following scenarios were considered:
- **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 characteristics, 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.

This is carried since 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). With the preceding operational scheme, the sector specific tool generation will be well informed. Particularly, the following outcomes will be produced:
- adapted design routines and protocols
- tools for analysing the work effectiveness and detecting flaws affecting the bioengineering work performance
- tools for monitoring the work and generating feedback loops connected to the work design, fine tuning processes.
- an interactional scheme within the sector including know how transfer network and information exchange processes.
- an improved and sector specific training syllabus addressing the sector necessary level of specialisation and the Mediterranean sector particularities.

The overall project strategy is shown in Fig. 2.
Regarding the sector needs analysis work package, it is worth noting that more than 110 practitioners in bioengineering answered the questionnaires from 11 different countries. An analysis for each country but also for the entire Euro-Mediterranean ecoregion is being performed with the aim of gaining insights in regards to the sector needs and existing gaps to improve the design, construction, maintenance stages of works but also to enhance the educational and professional expertise. Different workshops organised within the sector analysis work package are being used to discuss and compare the soil and water bioengineering state of art in each country. This will be the foundation for the design of the long term alliance strategy and cooperation within the Mediterranean bioengineering sector which is, in turn, another outcome of the Ecomed project.

Fig. 3. Example of results obtained during the sector needs analysis. Particularly, the pie chart shows the answers received to the question “Do you currently use any software for soil-water bioengineering design?”
4. Conclusions

The Ecomed project addresses the particularities and needs of the bioengineering sector in the Mediterranean ecoregion. The increase of the specialization level of the Mediterranean bioengineering sector is achieved by means of the development of sector specific tools which are: new adapted design routines, an enhanced syllabus offered in HE centers, new monitoring protocols for construction sites, and improved monitoring tools for assessing the overall work performance and effectiveness. Within this context, the consortium of this project will provide 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 bioengineering restoration techniques in Mediterranean scenarios.

The strategy of the Ecomed project includes the following points: a) taking advantage of both the accumulated experience and the analysis of a set of case studies, b) generating new dynamics within the sector allowing for an enriching and effective know-how transfer between the stakeholders and c) offering a new set of sector specific tools to the Mediterranean bioengineering sector for the practitioners and the Academia (e.g. protocols and training syllabus). Hence, the Ecomed project will be the basis for long term fine tuning tools that will allow the Mediterranean bioengineering sector to improve its specialisation level and grow in reliability and acceptance. Finally the preceding approach is readily transferable to other ecoregions and this shows the usefulness of the project from the circular economy point of view. Giving that Ecomed is just a two year project, other projects and initiatives will be necessary to strengthen and complete the Ecomed project outcomes.

References
