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Editorial

SOIL AND WATER BIOENGINEERING IN A CHANGING CLIMATE*

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Abstract

The ecological crisis derived from the human activity and its risks push us to find solutions that go through the understanding of the laws of nature and its principles, to stop the ongoing degradation and the initiation of restoration mechanisms. As a society, we are experiencing a period of uncertainty, in which we perceive that the solutions could come from finding a balance within our environment based on the sustainable management of our ecosystems, the restoration of their functionality and services, and the use of nature-based construction systems such as soil- and water- bioengineering techniques. Soil and Water Bioengineering is a discipline that combines technology with biology, making use of native plants and plant communities as construction material and erosion control in degraded environments. The International Symposium on Soil- and Water- Bioengineering in a Changing Climate, held on the 7th and 8th of September 2017 has been organized by Glasgow Caledonian University (GCU) in collaboration with the European Federation of Soil and Water Bioengineering (EFIB) and with support from the ECOMED Erasmus+ project. During two days, participants from eleven countries presented and discussed the possibilities offered by the technical discipline of Soil- and Water- Bioengineering to the ecological, economic, and societal challenges faced within a changing climate. In this editorial article we present the principles of the discipline of Soil and Water Bioengineering, together with a summary of the event sessions including the concluding remarks.

Keywords: eco-engineering, ecological restoration, resilience, ecosystem services

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1. Introduction and background

Soil and Water Bioengineering is a discipline that combines technology with biology, making use of native plants and plant communities as living building material for construction and control erosion in degraded areas. Plants and parts of plants are used as living building materials, in such a way that, through their development in combination with soil, they ensure a significant contribution to the long-term protection against all forms of erosion (EFIB, 2014). The term "Engineering" refers to the use of technical and scientific data for constructive, stabilization and erosion control purposes and "bio" because the functions are related to living organisms, mainly native plants with biotechnical characteristics and with the purpose of restore ecosystems, the ecosystem services and increasing the biodiversity.

Soil and Water Bioengineering has its origin in the combination of forestry techniques with traditional engineering techniques and, although the techniques were known in remote times, as a discipline it is relatively recent and come from the hybridization between Civil engineering and Biology. Its development and application has been carried out mainly in Central Europe, although in recent years, it has also become a reality in Mediterranean areas. The scientific research of the last forty years, the incorporation of new industrial materials, the evolution of the criteria and the technical capacities led to the scientific consolidation of this discipline. In recent years, based on new social and cultural demands, and a change in the scale of values with emerging environmental awareness, it has become an operational tool, not only for the erosion control, but also for regeneration of the natural environment.

Bioengineering techniques must meet technical, ecological, landscape and socio-economic objectives such as:

a) Technical objectives: refer to the protection and stabilization of the soil through the radical system the control of surface erosion and for the stabilization and consolidation of slopes or river banks.

b) Ecological objectives: Bioengineering techniques use native pioneer species with biotechnical characteristics and the vegetation evolves towards more stable plant associations belonging to the vegetation series of the intervention area.

c) Landscape objectives: aimed at integrating the works in the landscape, reducing their visual impact and providing landscape functions.

d) Socio-economic objectives: Decrease in construction and energy costs. These are techniques that use local materials and are an important source of employment since they are very manual techniques.

The main areas of application of soil and water bioengineering are:

- river restoration (Fig. 1)
- interventions in mountain areas mainly in the stabilization of slopes (Fig. 2), in the construction of forest tracks and in the regeneration of ski slopes.
- linear infrastructures: roads, railways, gas pipelines
- re-naturation of mines, quarries, tailings, and landfills
- interventions for soil protection in areas affected by fire
- interventions in urban degraded areas

For its appropriate application, a multidisciplinary study must be carried out in which the characteristics of the reference territory are studied, be it a basin, a hillside or an urban environment. It is, therefore, in the territorial dimension where the bioengineering techniques acquire their true ecological, technical, social and landscape application.

Soil and Water Bioengineering is designed to take into account the concept of resilience of the system. The latter concept is the ability of a system to absorb a disturbance
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without significantly altering the characteristics of its structure and functionality, being able to return to its original state, once the disturbance has ceased. For this return to occur, the resilience threshold must not be exceeded. Landscape Bioengineering should be designed respecting the principle of minimum intervention to recover this threshold. This means intervening in those factors that allow the ecosystem to recover again on its own.

Fig. 1. River restoration - Artia Channel-Gobierno Vasco (photo: P. Sangalli)

Soil and Water Bioengineering works have a clear dynamic response: at first the initial rigidity is offered by the inert materials but, as time progresses, the indigenous vegetation plays an increasing role in the stabilization of the site. The general scheme of bioengineering works spins around the following axes:

- The use of indigenous species potential for the short- and long-term degraded land restoration.
- The use of the nearby materials for the project design. Bioengineering works have low-carbon project features.
- The improvement of the ecosystem resilience by fostering and triggering the site natural ecosystem evolution.

Fig. 2. Landslide stabilization with Soil and Water Bioengineering techniques (photo: P. Sangalli)

The Soil and Water Bioengineering techniques can be classified into two large groups: landslide techniques (used mainly on slopes) or riparian techniques (used on media with water). In watercourses, soil and water bioengineering techniques contribute to the protection of erosion-prone riverbanks, channel realignment, revitalization of non-natural watercourses and channels with the promotion of the ecological efficiency of the watercourses, the protection of land uses and the stabilization of dykes, dams and forelands.
Whether they are used on the slope or on the riverbank and according to the role of the plant, the Bioengineering techniques are classified into four categories (Zeh, 2017):

- **Surface protection techniques**: These are techniques used to control surface erosion and the consolidation of the topsoil stratum. They belong to these techniques the different types of sowings, hydro seeding, transplant of rhizomes, etc.
- **Stabilization techniques**: Techniques in which the plant part plays an important role in stabilization. Within this group are: cuttings, fascines, brush layers, mat of branches, etc.
- **Mixed techniques**: are consolidation techniques in which the plant material are combined with other materials (wood, stones, wire, geotextiles ...). In these techniques the materials initially assume the role of stabilization until the plant material has been properly developed. Within this group are the live wooden frameworks, the live palisades, the vegetated rip-rap, vegetated gabions, green walls, etc.
- **Complementary techniques**: they are techniques that, without having a binding or consolidation role, are necessary to make the work evolve towards a better ecological, landscape or socioeconomic status: Within these techniques we find plantations, niches for wildlife, anti-noise screens, ramps for fishes, etc.

2. **Soil and Water Bioengineering in a changing climate – The symposium**

The ecological crisis derived from the human activity and its risks push us to find solutions that go through the understanding of the laws of nature and its principles, the stop of the ongoing degradation and the initiation mechanisms of restoration. (Kabisch et al 2017). As a society, we are experiencing a period of uncertainty, in which we perceive that the solutions could come from finding a balance within our environment based on the sustainable management of our ecosystems, the restoration of their functionality and services, and the use of nature-based construction systems such as soil and water bioengineering techniques.

To address some of these challenges, the International Symposium on Soil- and Water- Bioengineering in a Changing Climate, held on the 7th and 8th of September 2017 was organized by Glasgow Caledonian University (GCU) in collaboration with the European Federation of Soil and Water Bioengineering (EFIB) and with financial support from the ECOMED Erasmus+ project. During two days, participants from eleven countries presented and discussed the possibilities offered by the technical discipline of Soil- and Water-Bioengineering to the ecological, economic, and societal challenges faced within a changing climate.

3. **Technical sessions of the symposium**

The first day of the symposium was dedicated to the presentation of works within four thematic areas that included urban challenges, slope stabilization, bioengineering as a discipline, and the fluvial environment.

The inauguration of the symposium was carried out by the GCU Pro Vice Chancellor for Research, who spoke about the importance of training in knowledge and values and in interdisciplinary and cross-disciplinary work and study methods. The Glasgow City Council welcomed the attendees, and referred to the challenge of the cities before the challenges that can pose the climate challenge, and more specifically how it is faced by the city of Glasgow, specifically in relation to the increase in water level, the risk of floods and, the island of urban heat.
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After the inauguration, the technical sessions began. The first session was chaired by Caroline Gallagher, from the GCU and it was dedicated to the challenges in urban areas. Paola Sangalli, as president of the EFIB and as a member of the organizing committee presented on the role of the Soil and Water Bioengineering in the fight against climate change. She highlighted that these techniques are nature based solutions based (NBSs) that have a fundamental role in the establishment of the necessary green infrastructures. She also presented a series of hillside stabilization projects and rivers restoration works. Anita Meldrum from Glasgow Caledonian University presented an example of the study of sustainable urban drainage of one of the most emblematic and central urban spaces of the city with nature-based solutions as strategies to mitigate the unwanted effects of climate change at the urban level. John Scott, from Forkers Ltd, presented an example sustainable use of waste from the refinery process for soil stabilization in abandoned mines with reference to circular economy.

The second session was dedicated to the techniques of Bioengineering, materials, modeling and design and was chaired by Rosmarie Stangl of the BOKU University in Vienna. Michael Obriejetan, of the Institute of Bioengineering and Landscape Construction (BOKU) showed examples of coating techniques for the restoration of the slopes of a hydroelectric power station, by using various mixtures and substrates with different seed mixtures and was evaluated in terms of vegetation development. Yamuna Giambatistini (Università degli Studi di Firenze, Italy) addressed the performance of different trees in root extraction tests. He demonstrated a simple static model that simulates the force of the wind. The stability of the tree depends on both the radius of the rooted soil zone and the total diameter of the root. Freddy Rey (IRSTEA, Grenoble, France) explained the need to update the standards and identify new approaches to the problems of ecological restoration, referring to French examples and a wide range of ecosystem services. In a joint presentation, Guillermo Tardio and José Luis Garcia-Rodriguez from the Polytechnic University of Madrid presented the ECOMED project strategy. The analysis of the needs of the sector in the Mediterranean area, including the training and development of a strategy of transfer of know-how between the company and the University are the main objectives of the project funded within the 2-year ERASMUS project. The second meeting of the project held in Glasgow, Scotland, represented a great opportunity to establish cooperation and joint conference with EFIB at the international level.

The session on Water Bionengineering, rivers, reservoirs, and coastal restoration projects were addressed. This session was chaired by Joao Paulo Fernandes of the University of Evora, Portugal. Albert Sorolla, from the Naturaleza Company (Spain), explained with several examples focused on Catalonia, the use of Bioengineering to manage the consequences of climate change. In particular, he has presented various examples of river restoration and the creation of rolling ponds and rainwater management. David Holland and Hamish Moir (Salix and cbec Eco-Engineering, UK; one of the sponsors of the symposium) showed numerous examples of interventions that have been carried out in the United Kingdom with the use of logs as elements of stabilization of river restoration. Klaus Peklo of ICE Engineering (France) showed several examples in the last twenty years in the south of France in fluvial restoration from the project to the execution and monitoring phase of the works (Fig 3.). Giuliano Sauli, President of AIPIN, (Italy) and Rosella Valentini of Maccaferri Italy, presented on the effect of mixed bioengineering techniques on carbon sequestration and the reconstruction of habitats in river restoration. Isaac Sanz, of ETSI Montes (Spain), presented a restoration project for the Saúca torrent, which highlighted the hydrological study and analysis of the basin as well as hydraulic modeling. Vladimir Robevski from Cadonia (Australia/Macedonia; sponsor of the symposium) presented on the design for sustainable use of vegetation and soil/water bioengineering techniques for the revitalisation of residential area in Bitola, Macedonia.
The next session on Water Bioengineering was chaired by Alejandro Gonzalez Ollauri from Glasgow Caledonian University. Valasia Iakovogloy (Emattech, Greece) presented a protocol based on field methods and GIS for the preliminary analysis of altered fluvial areas for the establishment of bioengineering techniques. Rodrigo Maroto (ETSI Montes, Spain) presented a project to restore the Eresma River in Coca, Segovia from a slope that is endangering a Mudéjar tower of the 12th century. Axel Bubholz (Erfurht University, Germany) presented the restoration project for the Gramme River and its floodplain as well as the hydraulic modeling including the analysis of isometric maps, regulation plans, and historical geological maps for the design the new channel.

The roundtable was chaired by Slobodan Mickovski from Glasgow Caledonian University. Here, the role of bioengineering in the strategy against climate change was discussed together with the sustainability benefits and the conclusions of the symposium were presented.

4. Symposium site visit

A site tour through Glasgow and Stirligshire was organized for the second day of the symposium in an attempt to showcase some of the soil and water engineering examples from Scotland. The participants had the opportunity to visit and discuss:

- The Glasgow Water Supply and the Town Planning System: the engineered system that supplies water from the Loch Katrine, 31 miles to the north of the city and was built in 1848. The focus in recent years is not water supply but the impact and mitigation of flooding. The Flood Risk Management Act 2009 introduced River Basin Management Plans produced by groups of planning authorities. Every significant development to have SUDS and separate foul and surface water sewers
- The Flanders Moss (Fig 4.), the single largest raised bog with primary active surface in Britain. In terms of peat land resource the moss accounts for about 14% of the British and the 3% of the EU primary raised bog resource. It is a remnant of a much larger raised bog that covered about 1500 ha. The restoration management works, carried out over the last 25 Years. Included raising of water table trough ditch blocking and bunding, removal of scrub and modifying surface vegetation before reintroducing of grazing.
- Falkirk Wheel and the Helix project: works on the Union and Forth and Clyde canals including bank protection, dredging, slope stability, vegetation and habitat creation and protection.
5. Concluding remarks

Nature-based approaches can offer sustainable solutions to cope with climate change mitigation and adaptation challenges. Soil and Water Bioengineering techniques form part of the above and were shown, through the presentations and site visits, to be effective not only in normal but also in extreme situations. There is growing recognition that nature can help to provide viable solutions that use and deploy the properties of natural ecosystems and the services that they provide in a smart, 'engineered' way.

The Soil and Water Bioengineering use the properties of the root systems to cohere and stabilize the soil in order to use the plants as building and living material. These nature-based solutions provide sustainable, cost-effective, multi-purpose and flexible alternatives for various objectives: technical, ecological, landscape integration and socio-economics. It can be summarized that the introduction of vegetation in the traditional civil engineering works is a powerful way of providing various ecosystem services such as erosion protection, aesthetic value, habitat provision, and balanced local climate without neglecting water management issues. Soil and Water Bioengineering interventions using combined methods even with an important inert component give a clear contribution to biodiversity and show a carbon sequestration rates similar to natural standards.

The advantages of soil and water bioengineering measures compared to conventional engineering methods were shown to include:

- Longer and sustained functional development due to the development and regeneration ability of plants and plant communities,
- Establishment of a more developed plant community in the frame of the natural vegetation succession,
- Increase in stability as the plants develop,
- Favourable response to disturbance through the natural ability of plants to adapt,
- Adaptation of plants to the forces to which they are subjected through their elasticity, resistance to pull-out and new succession lines,
- Increase in biodiversity and habitat functionality (ecology),
• Enhancement of landscape (landscape aesthetics),
• Support of socio-economic factors (tourism, local recreation),
• Low-impact, use of little energy and promotion of natural regeneration.

The process of developing a bioengineering strategy gives particular attention to try different work stages, in particular at the characterisation stage where not only the problem, the process, and the risk factors, but also all local characteristics are inventoried and evaluated. This evaluation conduct to the process of conception, that is followed by the construction and with particular relevance given to a long term maintenance. The process of conception of an intervention relies strongly on the use of adequate software to characterize and conceptualize the intervention.

Ecological engineering is a discipline that integrates the ecology and the engineering concerned with the management of ecosystems with a common goal to maximize the multitude of benefits to both man and the natural environment. Within this context, soil and water bioengineering is a specific discipline related to Eco-engineering, combines techniques that use plants as living building materials, for: (i) natural hazard control (e.g., soil erosion, torrential floods and landslides) and (ii) ecological restoration, rehabilitation or nature-based reintroduction of species on degraded land, river embankments and disturbed environments. The success of such a project requires both of these objectives to be reconciled: the natural hazard control with the ecological restoration.

In the Mediterranean Area, the aridity of the climate determines the particularities in the soil and water bioengineering related to the selection of both plant material and techniques. The ECOMED project is addressing the former challenges that will allow the Mediterranean soil and water bioengineering sector to achieve a higher specialization level by analysing the current sector needs, strengths, weaknesses and opportunities; by analysing existing soil and water bioengineering works; by improving the existing design routines and protocols; by reinforcing the sector by a know-how transfer strategy (generation of new interactional schemes and dynamics within the sector); as well as by generating an improved syllabus and sector specific training modules.

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References