SOIL BIOENGINEERING
APPROPRIATE AND SUSTAINABLE TECHNOLOGY TO REDUCE SOIL VULNERABILITY

IDEASS ITALIA

Innovation for Development and South-South Cooperation

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Presentation

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Soil Bioengineering ("slope and river bioengineering stabilization") is a branch of technical science that studies ways of using living plants, parts of plants or different plant associations as construction material, often in conjunction with nonliving material such as stone, earth, wood, and steel. It seeks to achieve hydro-geological soil consolidation by establishing a blanket of vegetation to retain rainfall, protect soil from wind erosion and provide it with efficient drainage. Bioengineering is primarily concerned with the stabilization and environmental regeneration of slopes and riverbanks subject to landslides. However, it also has an important added value: it respects the landscape and the ecosystem.

The origins and development of bioengineering are relatively recent, dating back to the first decades of the 1900s. The first documented experiences, including accounts, reports and publications, were produced by technicians in the German-speaking areas of the Alps, in Austria, Germany, and Switzerland. Forestry technicians and public administration inspectors began to experiment, evaluate and classify intervention typologies and criteria based on the use of living material, such as plants, and/or natural material, such as wood or stone.

Although from a scientific and bibliographical point of view this branch of engineering is relatively recent, in actual fact many of the techniques and the empirical bases for the use of living vegetable material in consolidating and regenerating unstable soils date back to much earlier times and probably represented, from the very beginning, efficient instruments for mountain economy and agriculture.

Another important function of bioengineering is the reduction of vulnerability in soil exposed to recurrent climatic disasters, such as landslides and flooding. These events have a disastrous impact on development, halting progress and obliging institutions to redirect available funds to deal with emergency situations. According to the International Federation of the Red Cross and Red Crescent Societies, in the 1990s the world was subject to three times as many natural disasters as in the 1960s, while over the last five years emergency funds have dwindled by 40%. More than 90% of all natural disaster victims in the world live in developing countries. These soil management techniques can, therefore, have a significant impact in areas exposed to natural disasters.

Bioengineering was first applied in the forestry sector but has subsequently been used to protect soil in mountain areas, blend infrastructure into the landscape, and regenerate quarries, waste disposal sites and other degraded areas. In the last few decades these techniques have been much promoted in Italy, at first in the Alps and then in the Apennines and Mediterranean areas. At present they represent a valid alternative to traditional engineering projects, even if, in some circumstances, classical civil engineering methods cannot be abandoned. Legislation has been introduced to provide incentives for this type of systemization, not only because it brings great ecological benefits and regenerates the landscape, but also because it is an economically viable alternative to traditional interventions.

In Italy, this branch of technical science has seen considerable development thanks to AIPIN, the Italian association for bioengineering, which promotes and disseminates these techniques through conferences, technical tours, capacity building courses in schools, publications, and research projects. Bioengineering has been extensively used in Austria, Germany, and Switzerland from the beginning of the century, and in Central and southern European countries from the 1980s.

What problem does it solve?

Bioengineering projects often lead to a rediscovery and modern reinterpretation of traditional methods. Techniques using living material for the systemization of unstable slopes and riverbanks data back to the earliest times and were of considerable importance for ancient rural civilisations, especially in mountain areas. These techniques became widespread precisely because of the empirical efficiency that plants have in resolving problems of soil instability and because there was an abundance of easily available material (plants, wood, and stone) in the rural environment.

During the 19th century, bioengineering methods used in the Alps were described in technical documents and manuals. Experience gained in mountain land reclamation by forestry administrations of the German-speaking areas of the Alps at the beginning of the 1900s consolidated the use of bioengineering techniques. In Italy, regulations issued by the Ministry of Public Works (1912) for the presentation of projects on hydrological forestry systemization of mountain basins included provisions for the use of plants and locally available natural material.

Bioengineering, which was first used in the forestry sector, has subsequently been used to protect mountain soil, blend infrastructure into the landscape, and regenerate quarries, waste disposal sites, and degraded areas in general

The aims of bioengineering interventions

AIMS	Technical	Ecological	Landscape	Economics
Interventions	Systemization of unstable slopes	Systemization of river banks	Environmental regeneration of degraded areas (e.g. quarries and waste disposal sites)	Blending infrastructure into the environment

Bioengineering interventions also have an important function in reducing the vulnerability of soil exposed to recurring natural disasters. The news is always full of increasingly frequent disasters, often made worse by 'global' hydro-geological instability, a problem common to various regions of the planet. Examples include Hurricane Mitch, which badly affected Nicaragua in 1998, annual floods in India, Nepal and Bangladesh, and the devastating floods during the summer of 2002 in the Danube regions of Europe. The year 1998 was the worst ever recorded for natural disasters caused by bad weather. Floods and storms brought

death to tens of thousands of people and uprooted millions of others. If we include earthquake victims, about 50,000 lives were lost because of natural disasters (Kofi Annan, "Facing the humanitarian challenge: towards a culture of prevention", 1999).

These catastrophic events, which are widespread throughout the world, have serious consequences on the living conditions of the people affected, especially in the poorest countries. Bioengineering interventions can, therefore, bring great benefits by reducing soil vulnerability and preventing the disastrous effects of natural calamities.

Bioengineering interventions can be easily incorporated into sustainable development strategies because they not only perform specific functions (preventative and emergency protection of the soil, regeneration of the habitat, etc.), but they are also economically viable and socially acceptable.

The following factors make this type of intervention particularly suitable:

- Reduced costs compared to traditional interventions, such as concrete walls or gabions;
- Large scale use of local workforce, which accounts for most of the expenditure, bringing economical benefits to the population concerned;
- Preference for locally available natural material, which reduces costs, boosts the local economy and guarantees that any work blends perfectly into the landscape;
- Involvement of local specialists.

These interventions, which are labour intensive, can prove expensive in countries where labour costs are high. In these contexts, bioengineering interventions are preferred to other typologies because of their capacity to regenerate the natural environment. On the other hand, in countries where labour is less expensive, the solutions offer not only all the ecological advantages described above, but also significant savings.

Bioengineering is primarily concerned with the systemization and environmental regeneration of slopes and riverbanks subject to landslides. However, it also has an important added value: it respects the landscape and the ecosystem. The basic guideline for a "bioengineer" is, in fact, to make any intervention as 'invisible' as possible. After an initial period of adaptation, the plants used to consolidate the soil, which must be strictly native and preferably obtained locally, should blend with the surrounding landscape in such a way that the work of man is no longer to be seen. For this reason bioengineering techniques are most suitable in areas of great environmental value, such as national parks and protected areas.

Bioengineering in practice

The basic functions of bioengineering are as follows:
- technical: e.g. reduce erosion and consolidate road embankments or river banks;
- naturalistic: it not only creates a simple blanket of vegetation but also regenerates or triggers off paranatural ecosystems through the use of native species;
- aesthetic: blends interventions with the surrounding natural landscape;
- economical: competitive alternative to traditional interventions, replacing walled embankments, for example, with soil reinforced by a blanket of vegetation.

Bioengineering projects are multi-disciplinary; apart from purely physical interventions many other factors come into play. Numerous criteria must also be taken into account since projects include social and environmental issues, which are ordinarily not taken into much consideration or if so only after the realization of works. These projects establish a close relationship with the land, which influences construction work and which, in turn, is influenced by the interventions.

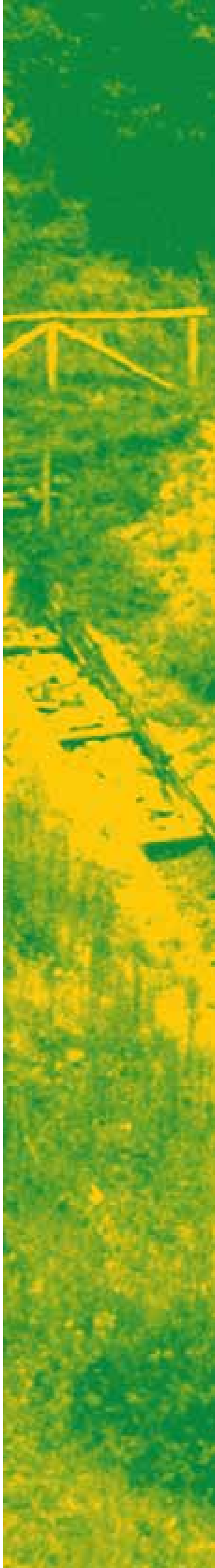
The basic principle behind optimal hydraulic and environmental systemisation is to implement protective measures only if they are really necessary. This depends on the extent of damage caused by certain phenomena (e.g. instability). An assessment has to be made to establish what degree of damage is acceptable and what isn't, taking into account economic factors (construction and management costs vis-à-vis the value of goods to be protected) and political factors (environment, landscape, use, etc.).

Environmental impact can be minimised by making every effort to avoid limiting natural forces. In fact, erosion or landslides are part of nature's dynamics and must not necessarily be limited.

In the same light, once the need for intervention has been established, a second important criterion is to reduce the problem by exploiting the capacity of the nature itself. In practice, this means leaving as much space as possible to natural dynamics.

Preliminary data needed in drawing up a project:
- Target area topography;
- Weather conditions;
- Pedological data;
- Hydrological data;
- Geological and geo-technical characterisation of the target area;
- Sampling of vegetation in the target area.

This information is then used to choose from a wide variety of interventions, commonly subdivided into four categories, three of which highlight functions (blanketing, consolidation and completion) and one construction material (combined materials).

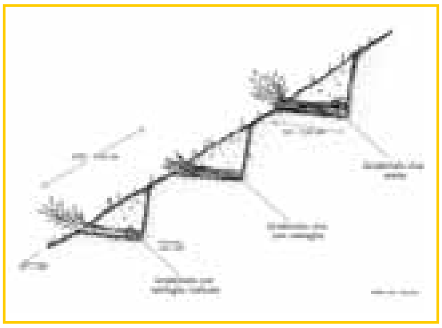


PROTECTIVE BLANKETS

Protective blankets are particularly useful when soil needs rapid protection. Its function is primarily to cover and protect, while deeper underground activity is less important. It involves sowing suitable grass species and laying turf.

STABILIZATION AND CONSOLIDATION

These operations are used to stabilise soils that are threatened with intense destabilising mechanical action, where consolidation is needed deep down (e.g. brushlayers and palisades)



A typical example of stabilization – "brushlayer" (Tuscany region, 2000-2001)

COMBINED INTERVENTIONS

Combined interventions involve both living and inert construction materials. Inert construction materials give an immediate effect while living plants take root and grow to increase stability.

Usually the application of inert material, which consolidates unstable embankments and slopes, is carried out before intervening with living material (stabilization, blanketing and complementary interventions).

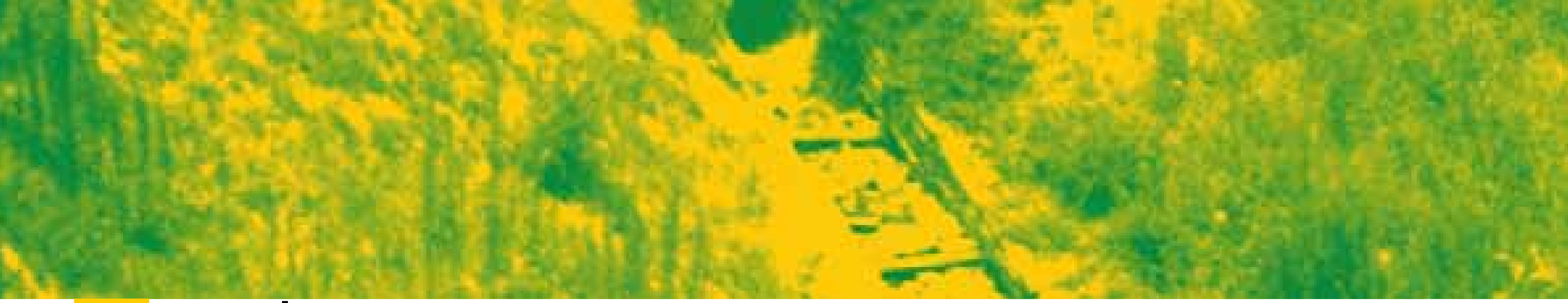
COMPLETION INTERVENTIONS

Completion interventions protect vegetation in the initial stages and promote further growth to secure preset goals.

A net made of jute completes work along a riverbank

COMPLEMENTARY INTERVENTIONS

Complementary interventions essentially involve planting various species of trees and bushes, and sowing different grasses. In effect, these interventions make use of classic reforestation techniques used in mountain valleys.



Results

Bioengineering techniques reflect a completely different perspective from typical civil engineering systemizations of landslides or river banks. These types of techniques, in fact, make every effort to limit the use of material that is extraneous to the target area's natural environment. The aim is to leave as few visible traces of the intervention as possible. These techniques, therefore, are not based on the idea that interventions should be clearly visible for everyone to admire so that the amount of money and effort that has gone into a project can be appreciated. The approach relies on the presence of a spirit of innovation among local institutions, which, however, often prefer to back solutions that are much more spectacular and seemingly more expendable in terms of consensus.

An important qualitative effect of bioengineering interventions is the promotion of scientific research through surveys and experimentation of native material, to see if it can be used in the project. Scientific research and work operations necessarily require the involvement of universities and specialists from local institutions (agronomists, forestry technicians and botanists, etc.), who play a vital role in collecting information and critically assessing any new solution.

The use of local workforce rather than sophisticated and expensive technologies makes a great impact in economical terms. Apart from encouraging the involvement and consensus of local communities, this aspect also produces considerable savings, especially in less industrialised nations.

This can be seen by comparing forecast costs for constructing double wooden live crib wall (one of the most used typologies in bioengineering), green gabions (rectangular metal nets filled with stones from which plants are grown), and classic cement walls in Guatemala, Nicaragua and Italy:

	Cost per m^3 in Italy (€)	Cost per m^3 in Nicaragua (€)	Cost per m^3 in Guatemala (€)
Double wooden live crib wall	125.90	5.00	4.25
Green gabions	214.50	37.50	27.30

These figures highlight the viability of constructions such as double wooden live crib wall in Nicaragua and Guatemala, which maximise the use of local workforce and at the same time reduce the need to buy materials such as metallic gabions and cement. The cost of an intervention of this type has very positive repercussions on the population involved in the construction work.

	Cost per m^3 in Italy (€)	Cost per m^3 in Nicaragua (€)	Cost per m^3 in Guatemala (€)
Double wooden live crib wall	125.90	5.00	4.25
	Cost per m^2 in Nicaragua (€)	Cost per m^2 in Nicaragua (€)	Cost per m^2 in Guatemala (€)
Cement wall	80.00	60.40	81.10

International interest

Bioengineering interventions are widespread in all European countries. In particular, the European Union has activated the following funds.

- INTERREG III Programme, which is designed "to foster cross-border, transnational and interregional cooperation and balanced development of the European territory". In particular (section C) aims to encourage "interregional cooperation, to improve the effectiveness of policies and instruments for regional development, mainly through large-scale exchange of experience, know-how and information".
- LIFE Programme, which "contributes to the implementation, development and enhancement of the Community environmental policy and legislation as well as the integration of the environment into other EU policies".
- programmes in support of rural development plans.

Construction site in León, Nicaragua 2004

Plant growth the following month

Results

Numerous European regions are using these funds for bioengineering interventions and could be willing to take part in transnational initiatives with interested countries.

In the United States, there has been considerable interest in bioengineering methodologies for decades. Back in 1972 the "National Erosion Control Association" was founded. Now known as the "International Erosion Control Association" (IECA), it typically connects producers of erosion prevention materials and technologies.

Bioengineering interventions have been carried out in Brazil, Nicaragua and Nepal.

A bioengineering project in the Department of León, Nicaragua, was promoted by the Tuscany Region in association with numerous territorial stakeholders. The University of Florence guaranteed preliminary research activity in Nicaragua and Guatemala. In particular, it carried out studies on the availability and costs of necessary materials, with encouraging results. In 2004, the city of León (Nicaragua) staged a theoretical and practical capacity building course for 20 local technicians and students. Participants were then directly involved in construction work on the banks of the Rio Chiquito. The municipality of León actively contributed to the operations, providing logistical support, vehicles and equipment. The University of León took charge of scientific aspects, selecting potentially suitable plant species and identifying the best time to start work.

Using Soil Bioengineering in other countries

Usually bioengineering interventions are promoted by local administrations: regions, provinces, mountain communities. Bioengineering interventions, despite their particular nature, are still classified as public works and therefore subject to the same laws and regulations, which vary from country to country. In general, authorisations from competent local authorities are needed to start work, which normally entails presentation of a draft project together with any other necessary documents.

The very nature of bioengineering systemizations, which involves specialists from various fields of activity, means that it is vital to establish collaboration with:

- Universities (especially the faculties of Engineering, Agriculture, Biology, and Geology)
- Land protection authorities, to exchange information, conduct experimentations and carry out interventions.

These interventions are especially useful on land where bad management and excessive exploitation of environmental resources have caused serious degradation, affecting people's daily lives. They are particularly suitable when deforestation has reached worrying proportions, causing slope instability, which can provoke landslides that spill into rivers, increasing the likelihood of floods down valley. They are, therefore, carried out in areas subject to frequent natural disasters, where the population and local administrations are concerned with land protection.

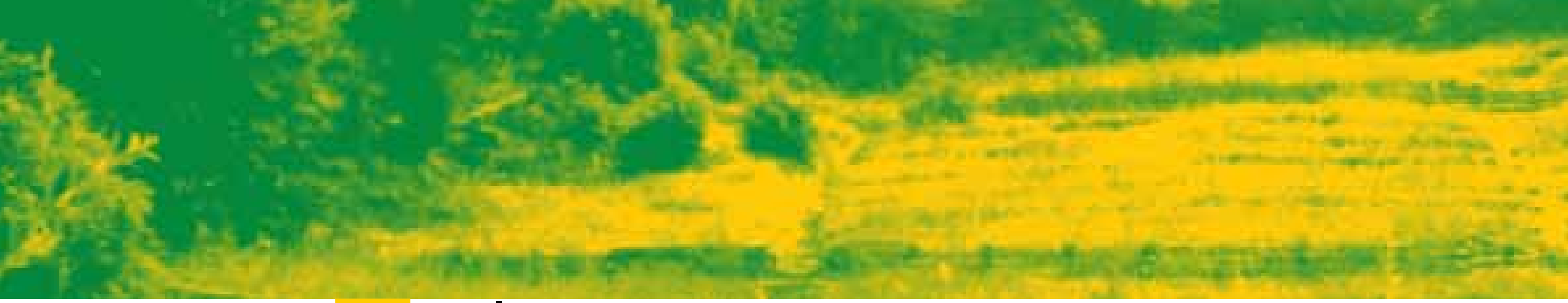
Bioengineering works best in areas where the local population lives in close relation with nature, understood as an essential element for sustenance. Interest in protecting the soil for agrarian purposes and widespread manual skills also facilitate the success of these types of interventions.

Finally, bioengineering work relies on the presence of a variety of specialists (engineers, agronomists, forestry workers, botanists), who, with their specific skills can help to devise and carry out the interventions.

Unfortunately, in both industrialised and developing nations, there is a widespread tendency to favour solutions which are technically sophisticated to the detriment of the environment and, often, also the landscape. Many engineers are over enthusiastic about technologically advanced and costly operations, where manpower is used to the minimum. This mentality undoubtedly leads them to downgrade work that, because of its very nature, must be as invisible as possible, favouring operations that create a visual impression. Very often not only technicians, but also public administrations favour ostentation. Bearing in mind these considerations, the promotion of bioengineering seems all the more appropriate, and must necessarily involve the widest range of institutional interlocutors, politicians, technicians, and associations in the countries and territories involved.

There is no doubt that technical conditions for bioengineering work can be found everywhere, since requirements are minimal compared to other typologies:

- **material:** durable wooden poles, cuttings, and biomaterials such as jute nets and coco fibre;
- **qualified personnel:** lumberjacks and building workers to start with, but specific skilled labour is fundamental if interventions are to be successful; therefore special capacity building courses are needed;
- **equipment:** no special equipment is required; the most expensive are long drills and chainsaws;
- **vehicles:** generally, trucks to transport material, and excavators, which provide significant savings in time, although work can also be carried out manually, as in the past.



To learn more

Further information on the different aspects of bioengineering can be found in the web pages of the following qualified institutions.

A.I.P.I.N. (Italian association for bioengineering)
www.aipin.it
CIRF (Italian Centre for the regeneration of rivers)
www.cirf.org
Comunità Montana del Casentino (Tuscany region)
www.cm-casentino.toscana.it
Comunità Montana Alta Versilia (Tuscany region)
www.cm-altaversilia.it
International Erosion Control Association, IECA
www.ieca.org
International Erosion Control Systems, IECS
www.iecs.com
Institute of Soil Bioengineering and Landscape Construction - Vienna, Austria
www.boku.ac.at/iblb/englforschhome.html
Cooperativa TUA (Terra Uomini e Ambiente)
www.tua.it

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- Tuscany Region 'Principi e linee guida per l'Ingegneria Naturalistica- Part 1 & 2 Processi territoriali e criteri metodologici'- Series: "Fiumi e Territorio", Tuscany region, 2000-2001.
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Contacts

The following institutions can provide technical assistance in designing and carrying out bioengineering projects in interested countries. They can also organise capacity building courses involving didactic construction sites and demos.

DIAF (Department of Agriculture and Forestry Engineering) - University of Florence (Italy)

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