MONITORING GROUND BIO-ENGINEERING STABILIZATION OF LANDSLIDES IN LAZIO REGION, ITALY

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Abstract

Latium, like most other Italian regions, is subject to numerous landslides and gravitational movements. These landslides have been registered and mapped by the Region of Latium. 16 sites were chosen for the monitoring of ground bio-engineering projects which are currently being carried out in collaboration between the Region of Latium and the Department GEMINI of the University of the Tuscia in Viterbo.

The monitoring activity was performed by completing a questionnaire for each site. The main data required, in order to have a complete vision of the site and its problems, concerned descriptions of the morphological, lithological and phytoclimatic aspects of the slope. This information was provided by the planners and contractors, who also gave a description of the ground bio-engineering techniques used to stabilize landslides. The aim of this study was to verify the effectiveness of using ground bio-engineering techniques in the Mediterranean climatic zone. In this zone, rooting of plants is especially complicated, but we could exploit the biotechnical characteristics of plants and adapt ground bio-engineering methods to this area. We can use information from this study to protect the territory, whilst minimizing the environmental impact, thus fostering and protecting the environment in areas where ground bio-engineering is carried out.

KEY WORDS: bio-engineering, landslide, monitoring form

Introduction

One of the main objectives of the Latium Region's territorial policy is to orient intervention and soil protection programmes toward criteria that respect the natural equilibrium of the territory in question. Therefore, the Region of Latium has in recent years promoted a series of technical and administrative measures aimed at encouraging the adoption and the spread of ground bio-engineering techniques. Although ground bio-engineering is not a new discipline, it has been re-evaluated in the last twenty years and has been applied in many different parts of the world. The most commonly used definition of ground bio-engineering is the following: "Bio-Engineering is a technical discipline that uses living plants in anti-erosive and consolidation operations together with other materials (wood, stones, straw, metallic nets, bio-mat, geo-fabrics, etc…) (Schiechtl, 1991).

In Latium, ground bio-engineering began with a decree issued in 1996 by the Region, which defined the criteria governing soil protection projects in this area. These criteria, which have been are innovative for this territory, aimed at enhancing the protection of the landscape and environment, with particular attention paid to the restoration of areas where risks related to hydraulics or landslides occur (Regione Lazio, 1999). A fundamental principle to always be applied was that any intervention must have the least possible environmental impact. All organisations and regional offices working for the Latium Region must adhere to this policy. The Region's Environmental Department has organized three collaborations to perform studies regarding the application and monitoring of ground bio-engineering in various fields i.e. hydraulic management, quarry and dump sites, revegetation of road embankments, protection of coastal sand dunes and the stabilization of slopes (Regione Lazio, 2003). Our study was carried out with regard to the third convention, between the Region of Latium and the GEMINI Department of the Tuscia-Viterbo University, entitled "Analysis and applicability of bio-engineering techniques related to slope stabilization inside the boundaries of risk areas in the territory of the Latium Region." (see figure 1)

In this research, we present the results from the monitoring of several field sites. These results show the present situation regarding the quality and efficacy of the operations performed on slope stability. The aim of this study was to verify the correct execution of bio-engineering activities, both in technical terms and also of their insertion within the landscape. We also assessed the effectiveness and feasibility of intervening with bio-engineering techniques in a Mediterranean climate and determined which techniques and species are most suitable in this type of climate. As a result of this study, we could identify the sort of training required for ground bio-engineering contractors and planners, and highlight the need to use native plants and inert materials of local origin.

Materials and methods

Site selection

Three operational phases were distinguished for the purposes of monitoring and data: *ante-operam* (before the implementation of works), *in opera* (during the implementation of works), *post-operam* (after implementation of works). 16 sites were chosen for the monitoring of ground bio-engineering projects (Figures 2 and 3). A monitoring form was made up to survey slope stability using information provided by a multidisciplinary group of engineers, forestry experts and geologists. Therefore, data should be complete with regard to the different types of problems which could be encountered on a slope.

The field sites were chosen following a series of criteria that would be able to represent all the regional territory, from both the administrative point of view, with sites distributed throughout all the provinces, and also with regard to climate. Having different climate types will also result in different types of vegetation. Urban, rural and protected areas were also represented. A wide selection of different ground bio-engineering methods was available and their cost calculated and compared with traditional civil engineering methods.

Monitoring Form

A questionnaire or monitoring form was written and consisted of three fundamental parts:

Part 1: This part indicates information related to the position of sites and the identification of the main professional figures involved i.e. the designer, operations manager and contractor. Some of the most important information that we collected in this part falls under the heading "years of activity in the bio-engineering sector". Previous experience has made clear the importance of adequate preparations on the part of contractors for the correct application of techniques in question. Furthermore, such information could provide an indication of state of the art in the ground bio-engineering field and could highlight if there is need for further training.

Part 2: the data to be collected serve to describe the area under consideration and its current condition e.g. "Vegetation aspects of the area". This makes it possible to ensure that correct plant varieties will be monitored in the work being planned. Other fundamental data are those related to lithology, geomorphology and landslide typology, which allow for the identification and description of any gravitational movements that may have occurred and their presumed causes. In order to collect such data, a geological form is used as described below. This form will also be used to evaluate the completion of the project.

Part 3: In part 3, the area in which a site has been planned or already set up is described. Therefore, the bio-engineering techniques used and the project scale is determined, with particular attention to the plant species to used and the criteria for planting, two elements which are fundamental for the success of the operation. Furthermore, costs are reported of all work related to ground bio-engineering techniques, as well as work done with "conventional" civil engineering techniques Some of these techniques remain fundamental for some typologies of landslide phenomena (De Antonis et al., 2003).

In the case of gravitational movements, geological parameters and geotechnical tests are particularly important, therefore, along with the above-mentioned form, a geological form was also used for this type of monitoring. This geological form was based on the official census form for landslide movements prepared by CNR (National Research Centre: National Group for Protection against Hydrogeological Catastrophes), for geological and morphological descriptions of landslides, with a special section dedicated to any geotechnical tests that might have been carried out in the course of preliminary fact-finding studies. This form allowed a more careful evaluation of the quality of the project itself, given that the parameters are essential from a geological point of view to tackle landslide problems.

The geological form contained information retrieved from individual projects. The following aspects were considered: geological, geomorphological, hydrogeological and seismic. Sites were also studied with particular attention to the type of material involved in the landslide movement and to the typology of the landslide movement itself. The recorded data have the dual aim of providing a summary of the current situation at these sites and highlighting, principally at the geotechnical level, which studies have been carried out both in the field and in the laboratory e.g. penetrometric tests, stability checks and structural analysis. In the section "mapping" we show which maps have been drawn and attached to the project e.g. a geomorphological map 1:500 scale.

In relation to the data collected, we designed a fact sheet, thus highlighting the most significant data. This enabled us to appreciate both the quality of the projects and the work which strongly conditions the effective success and efficiency of the ground bio-engineering methods. From an analysis of the parameters necessary, we tried to evaluate the training needs that can eventually arise not only at the project level but also from the civil servants who evaluate the projects and the contractors who actually carry out the operations.

Results and Discussion

The parameters that we chose to analyse from the data collected during monitoring were:

- species type used for cuttings;
- species type used for plantations;

· planting-out period;

· percentage of cuttings and rooted plants which rooted;

· planned and really implemented seeding;

· works planned with live material but carried out with dead material;

· the number of years of experience in the ground bio-engineering field declared by contractors;

· the typology of execution errors most often recorded

· the typology of landslide movements.

This scientific aspects were analyzed and the results presented in Tables 1 - 9.

Table 1 shows that the species most often used for cuttings belonged to the *Salix spp.* (87.5%). This was also true in gradient works, where the two main species used were *Salix alba* L. and *Salix purpurea* L. Some attempts to use incorrect alternative species were also evident: for example the use of Locust tree should be avoided as it is not native and is also an invasive species. These considerations highlight the need to try new species as cuttings for gradient works, where conditions for the survival of willows are not favourable. The necessity to use alternative species to willow is shown when we analyse the arboreal and shrubby species used as rooted plants (Table 2). It was observed that a wide variety of species were used and that apart from a few exceptions, these were native plants which, if planted in the proper period and treated with a minimum of care, give excellent results in terms of rooting. Such a result is to be considered positive, and can be implemented if three principal factors are respected:

1. phytoclimatological information is supplied by preliminary field studies (Blasi, 1996);

2. projects are supplied with a botanical report;

3. indications for the period of planting-out are respected, with works being put on hold when necessary.

Consequently, when these factors were respected, higher quality and more careful planning was observed, with live plants beginning to be considered as veritable construction material. Contractors planning to specialize in the ground bio-engineering sector were also more receptive to the suggestions provided during the monitoring phase.

When dealing with living plants, e.g. scion or rooted plants, the field site's needs must be calibrated with suitable periods for planting (Table 3). The summer period is usually excluded, but in certain cases, the planting-out of both cuttings and plants was done in May, when the growing season is fully underway. Such late timing often interferes with the rooting of cuttings, but plants have a higher probability of recovering from transplanting stress if watered. However, irrigation is rarely carried out on the work sites. The latest month for the planting-out of cuttings and plants should be April.

Another fundamental parameter which should be considered for successful practice of ground bio-engineering, is the percentage of rooting (Tables 4 and 5). This parameter is linked to those above i.e. a higher percentage of rooting will be gained for those plants chosen with regard to the environment in which they will grow and are also planted in the right period. Further factors that influence the percentage of rooting are e.g. seasonal climate (summer 2003 was particularly dry and many plants died that had rooted well at the beginning of the summer season), edaphic conditions, post planting care, choice of good quality nursery material and the correct size of vegetal material. It is the interaction between all these components that will determine the success of the work. The percentage of successful rooting in cuttings at the field sites was rather low and often only 0 – 20% successful rooting was observed (Table 4). *S. alba* was the species with the most successful rooting, and sometimes up to 80 % success was seen. However, in rooted plants, many plants show either very low rooting ability, or, on the contrary, very high rooting ability (Table 5).

The influence of hydroseeding was also determined (Table 6). Hydroseeding is often successful but is not often used (Regione Lazio, 2002). Table 6 shows that hydroseeding and/or seeding was planned for 12 out of 16 sites, but was only effectively carried out in 25% of the cases, and not done at all at 58% of sites. These data are very important because on denuded slopes, grass coverage is necessary to protect the soil from erosion whilst awaiting the development of tree and shrubby coverage. It is however, worth noting that in most cases, seeding was not carried out because there was an over-abundant development of natural grassy vegetation, a condition that can be determined in advance with a local situation study. Therefore, at the design stage, plans could be made in lieu of hydroseeding, for the maintenance of such vegetation. Natural grassy vegetation tends to out-compete cuttings, which usually have to take root in difficult situations, both from a climatic and edaphic point of view. It could be useful to mow this spontaneous vegetation, thereby encouraging the growth of cuttings.

Reinforced terrains are often designed with the intention of planting cuttings (Table 7). However, these cuttings are often not included and are replaced with hydroseeding.

Amongst the sites monitored, of the four reinforced terrains which according to plans were to be cultivated with cuttings, none were actually planted with the cuttings and only one of these was hydroseeded (Table 6).
These considerations are also important to an efficient management of project's economic resources.

Many errors can occur during the implementation of ground bio-engineering. Some errors can be quite serious and undermine the stability of the work itself (Table 8). The relationship between the number of errors carried out and the years of experience in bio-engineering techniques declared by the contractor was determined (Figure 4). It can be seen that contractors with considerable experience commit as many errors as contractors with little or no experience, which indicates that information was faulty and that the ongoing training of the contractors themselves is necessary. One should therefore arrange for more training through practice work sites.

The final data examined considered the management of landslides (Table 9). When dealing with landslides, it is often necessary to integrate conventional and ground bio-engineering techniques. In general, in the case of slippage, an underground and surface drainage system is combined with containment and consolidation works carried out with ground bio-engineering techniques.

Conclusion

From the analysis of our monitoring results in Latium, it is clear that many fundamental errors are still being made, especially in the execution stage. These data highlight the need for more training and for a special certification for contractors who have acquired specific qualifications in the field of ground bio-engineering.

The analysis of the species used and the percentage of rooting, indicates the need for further research to identify suitable species within the Mediterranean zone. Another important factor to be considered is the need to encourage local nurseries to furnish this new "construction material". Similar monitoring work has been carried out by the National Park of Vesuvio. For the implementation of ground bio-engineering, managers used rooted wild plants which were not reared in a nursery (Bifulco, 2001). In the future, it would be interesting to compare their data on percentage of rooting and the related success of bio-engineering techniques.

Monitoring serves both to determine methodology for gathering data and to create qualitative standards to serve as reference levels for the efficient planning of slope stability, in both technical and economic terms. For such projects, it is necessary to determine how much to supplement "classic" or “conventional” interventions with bio-engineering, the goal being to protect a territory in such a way as to minimize the environmental impact of these activities.

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References

Bifulco C 2001 Interventi di Ingegneria Naturalistica nel Parco Nazionale del Vesuvio. Ed. Ente Parco, Napoli.

Blasi C 1996, Regione Lazio Assessorato Agricoltura, Foreste, Caccia e Pesca, Usi Civici, Fitoclimatoligia del Lazio.

Civita M 1982 Classificazione tecnica e identificazione pratica dei movimenti franosi. Ed. Levrotto & Bella, Torino.

De Antonis L and Molinari V M 2003 Interventi di sistemazione del territorio con tecniche di Ingegneria Naturalistica. Ed. Regione Piemonte, Torino.

Regione Lazio 1999 Assessorato per le politiche dei trasporti e lavori pubblici, Università di Roma "La Sapienza" - Dipartimento Scienze della Terra Individuazione e perimetrazione delle aree in frana nel territorio della Regione Lazio.

Regione Lazio, Assessorato per l'Ambiente 2002 Manuale di Ingegneria Naturalistica applicabile al settore idraulico. Ed. Punto Stampa s.r.l., Roma. 421 pp.

Regione Lazio, Assessorato per l'Ambiente 2003 Manuale di Ingegneria Naturalistica applicabile ai settori delle strade, cave, discariche e coste sabbiose. Ed. Sdomatt Grafica G.S.I, Roma. 18-357 pp.

Schiechtl H M 1991 Bioingegneria Forestale - Biotecnica naturalistica - Basi - Materiali da costruzione vivi – Metodi. Ed. Castaldi, 2ª Edizione, Feltre (BL).

Regione Toscana 2000 Principi e linee guida per l'Ingegneria Naturalistica, Vol. 1: Processi territoriali e criteri metodologici. Ed. Regione Toscana, Firenze. 378 pp.

Zocca A 1999 La Propagazione di Alberi e Arbusti. Edagricole, Bologna. 429 pp.

Captions to figures

Figure 1: Position of field sites studied.

Figure 2: Number of ground bio-engineering works planned (in gray) and implemented (in lines) at the field sites.

Figure 3: Number of type of ground bio-engineering works planned (in gray) and implemented (hatched) at the field sites

Figure 4: Years of experience (solid line) in ground bio-engineering declared by the contractor compared with occurred errors (black bars).

Figure 1

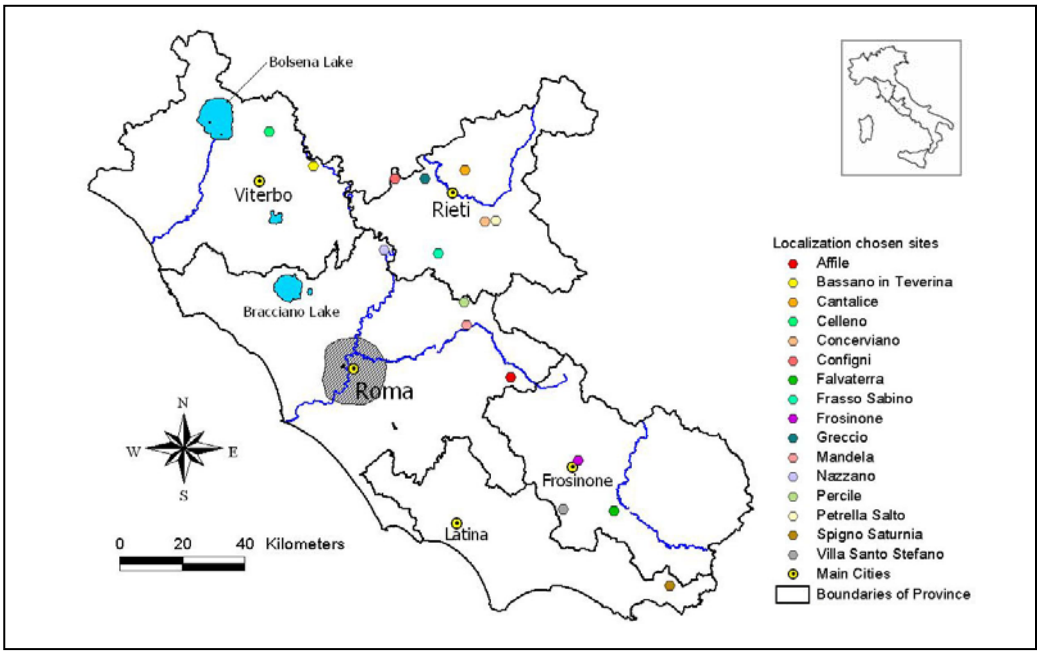


Figure 2

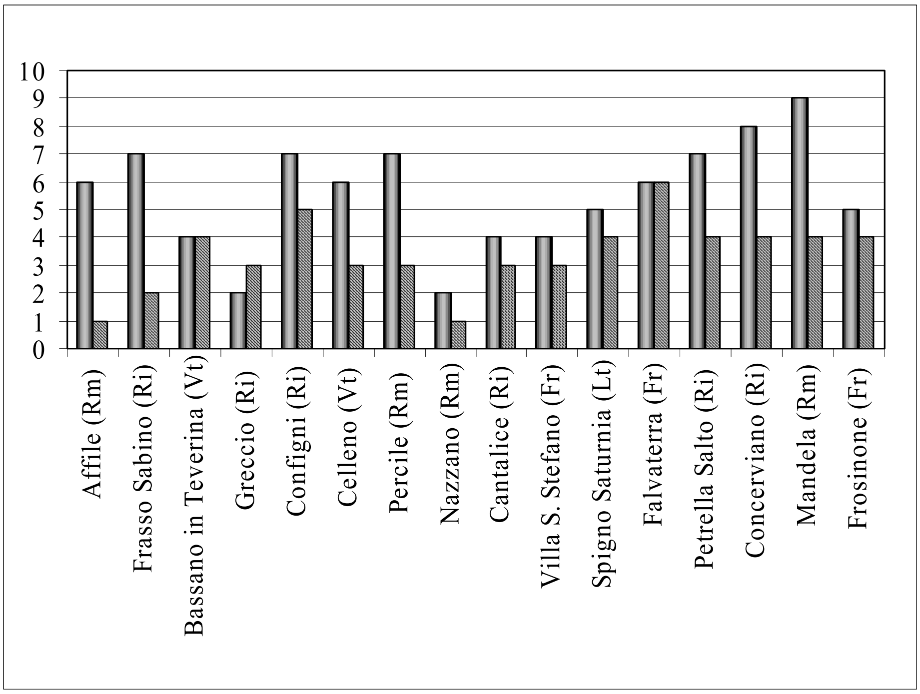


Figure 3

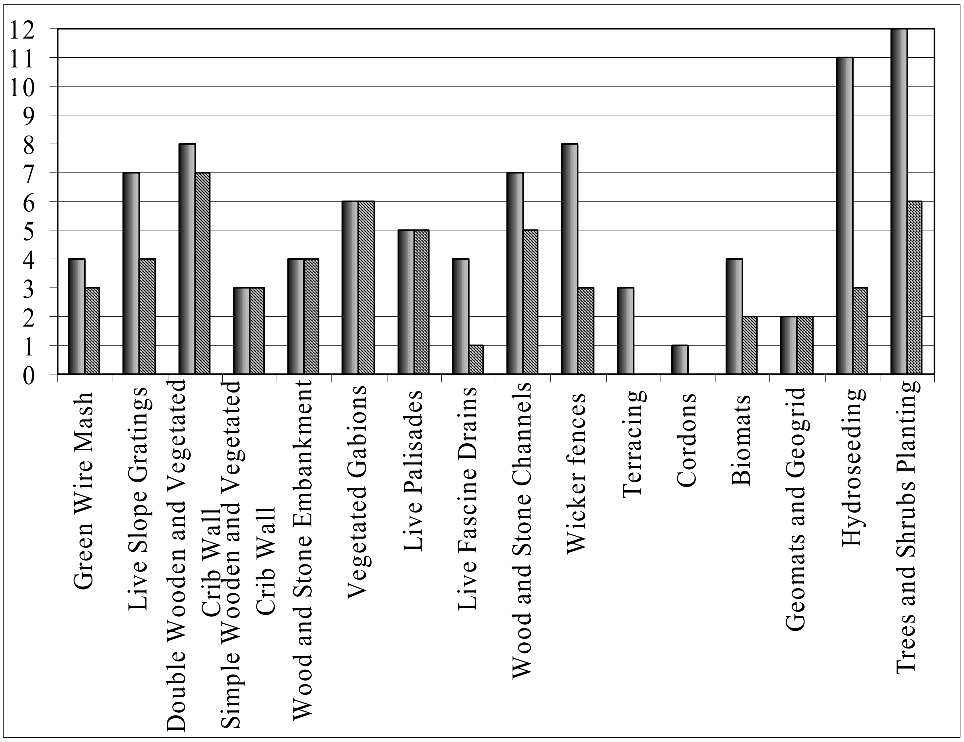
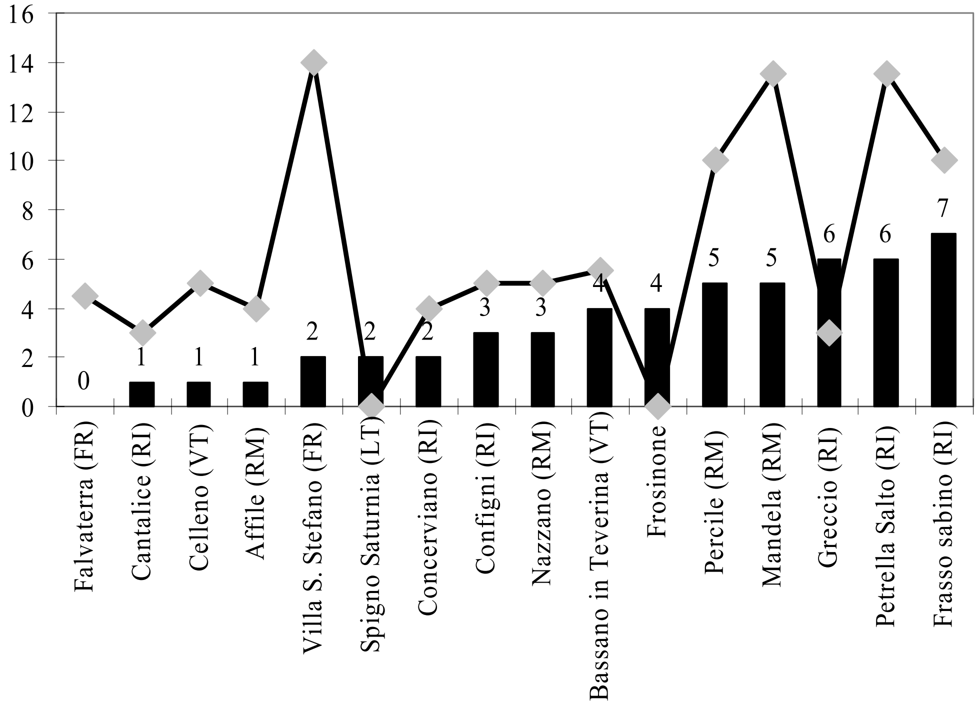


Figure 4



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Species used from cutting	**% of use**
Salix alba L.	37.50
Salix purpurea L.	37.50
Salix spp.	12.50
Robinia pseudoacacia L.	6.25
Populus alba L.	6.25
Tamarix africana Poir.	6.25
Fraxinus ornus L.	6.25
Ostrya carpinifolia Scop.	6.25

Table 2: Arboreal and shrubby species used in the ground bio-engineering studies

Rooted plant used	**% of use**
Cornus spp.	37.50
Prunus spinosa L.	25.00
Crataegus monogyna Jacq.	25.00
Quercus ilex L.	18.75
Euonymus europaeus L.	18.75
Spartium junceum L.	12.50
Ostrya carpinifolia Scop.	12.50
Olea europea L.	12.50
Myrtus communis L.	12.50
Rosa spp.	6.25
Pistacia lentiscus L.	6.25
Phillyrea latifolia L	6.25
Corylus avellana L.	6.25
Other species	6.25

Table 3: Planting-out period of rooted plants (P) and from cutting (C)

Sites	Months											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Celleno (VT)												
Bassano in Teverina (VT)						C					P	
Villa S. Stefano (FR)	P	P										P
Falvaterra (FR)										C/P		
Frasso Sabino (RI)		C/P	C/P	C	C							
Nazzano (RM)												
Percile (RM)			C	C								
Mandela (RM)		C	C/P	P								
Spigno Saturnia (LT)	C	C/P									C	C
Frosinone												
Configni (RI)				C/P	C/P							
Cantalice (RI)												
Concerviano (RI)											C	
Greccio (RI)	P	P	P	P	P						P	P
Affile (RM)					P							
Petrella Salto (RI)										P		

Table 4: Percentage of rooting in species used from cuttings

Species used from cuttings	**Percentage classes of successful rooting**				
	0-20%	21-40%	41-60%	61-80%	81-100%
Salix alba L.	3	3	0	1	0
Salix purpurea L. + other sp. of willow	3	1	0	2	1
Other species	3	2	0	0	0

Table 5: Percentage of rooting in arboreal and shrubby plant species

Species of rooted plant	**Percentage classes of successful rooting**				
	0-20%	21-40%	41-60%	61-80%	81-100%
Cornus spp.	2	0	0	0	3
Prunus spinosa L.	1	0	0	0	2
Crataegus monogyna Jacq.	1	0	0	0	2
Euonymus europaeus L.	1	0	0	0	1
Other species	4	0	0	0	2

Table 6: Implementation of hydroseeding (Regione Lazio, 2002) and other types of seeding

Hydroseeding and seeding planned	**Sites with planned seeding**
implemented	1
simple seeding	2
to be implemented	2
not implemented	7

Table 7: Ground bio-engineering works planned with live material but implemented with dead material.

Bio-engineering techique (Regione Lazio, 2002)	N° of works planned live	N° of works implemented dead
Green Wire Mash	4	3
Live Slope Gratings	7	3
Double Wooden and Vegetated Crib Wall	8	2
Simple Wooden and Vegetated Crib Wall	3	2
Wood and Stone Embankment	4	3
Vegetated Gabions	6	2
Live Palisades	5	4
Live Fascine Drains	4	0
Wood and Stone Channels	7	2
Wicker fences	8	2
Terracing	3	0
Cordons	1	0
Biomats + seeding	4	2
Geomat + seeding	2	1

Table 8: Most frequent errors occurring in the implementation of the ground bio-engineering works.

Most frequent errors	N° of errors
Work-slope connection	6
Inert material dimensions e.g. pole diameter	6
Works too vertical	5
Disposition of the poles crosspieces	2
Choice of the materials	8
Dimensions of species used from cuttings	9
Wrong joints	6
Wrong nailings	9

Table 9: Typology of gravitational movements (Civita, 1982) which occurred in the chosen sites.

Typology of Gravitational Movements	**N° of Sites**
Complex	3
Slump and Slide	8
Fall and Topple	4
Flow	1