

PRATI ARMATI® TECHNOLOGY - TECHNICAL PAPER

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PRATI ARMATI® technology to fight erosion and favour renaturation

PRATI ARMATI® technology is an innovative green system which uses only seeds of particular herbaceous perennial plants with special physiological characteristics coupled to a deep and durable rooting structure. This technology is used to contrast erosion of slopes along roads, highways and railways, river and stream banks and for the recovery and re-naturalization of degraded areas such as quarries, mines and landfills. The most interesting aspect of the use of these plants is that, thanks to their rusticity and adaptability, it is possible to use them alone to stop erosion, without any topsoil nor other materials, plastic products, etc. The resulting herbaceous protection is natural, rustic and perennial, therefore it does not require continuous remakes nor periodic maintenance.



Sicily – Hillside affected by erosion with strong environmental impact



Sicily – The same hillside renaturalized only by seeding deep rooting perennial herbaceous plants

What are PRATI ARMATI®

They are seeds of deep rooting and perennial herbaceous plants suitable for any rock types and all climates, used for erosion contrast, renaturation, soil conservation, protection of infrastructures and for restoration of polluted areas.

Where to use them

- on slopes and embankments of roads, highways and railways;
- to the shores of lakes, rivers, streams, canals;
- on sea-facing slopes;
- in quarries, mines, landfills and contaminated sites.

The implantation technique

The implantation technique of PRATI ARMATI® varies depending on the installation sites. The seeding is accomplished by manual broadcasting or with mechanical or hydraulic machines, depending on the evaluation local situation. The seeding method does not affect the success of the intervention. The hydraulic seeding (also called hydroseeding) consists in distributing a mixture of water, fertilizers, natural glues and PRATI ARMATI® seeds on the surface to be treated, using hydroseeding machines with tanks from 1,000 to 10,000 litres, mounted on wheeled or tracked vehicles. In very large areas (greater than 20,000 m²) or in locations not accessible in other ways, the use of helicopters with particular bucket mixers may be considered.



Sowing by hand



Hydroseeding in easily accessible areas



Hydroseeding by hosepipes handled by rock climbers



Hydroseeding by helicopters in large or inaccessible areas

What is included in the treatment with PRATI ARMATI®

The treatment with PRATI ARMATI® includes seeding (or hydroseeding) and fertilization, with a guarantee of at least 80% of grass-coverable surface (excluding rocky outcrops, walls, paved surfaces etc.) and guarantee of erosion-blocking. Reseeding and fertilizing are also included for the warranty period of 3 years. The final sale price includes all materials (seeds, fertilizers, etc.), all the workers and the means necessary to perform the intervention.

The mixture used for seeding/hydroseeding

The seeds mixture is not a standard, but it is defined on the base of the vegetational, climatic and soil characteristics of the area to be treated. The mixture used includes technical seeds of PRATI ARMATI®, natural fertilizers, adhesives for hydroseeding derived from vegetable waste and possibly soil improvers. The types of materials, the quantities and proportions are also defined according to the vegetation, climatic and soil conditions of the site.

The used seeds:

- come from perennial herbaceous plants, especially native, found in nature;
- mainly belong to the botanical families of grasses and leguminosae;
- are specifically selected according to the vegetation and climatic characteristics of the site to be treated;
- upon request of the Customer, they may be integrated with flower seeds, shrubs and native trees to favour the re-naturalization.

Some characteristics of herbaceous plants

- perennial;
- rustic;
- pioneer;
- good fodder;
- non-GMO;
- not weeds;
- withstand long lasting flooding;
- easily sprout after a blaze;
- show rapid growth even in prohibitive climatic conditions;
- do possess a root system with:
 - high growth speed;
 - high depth and density;
 - thin and homogeneous roots;
 - high average tensile strength (up to 205 MPa).

What PRATI ARMATI® can do

- contrast erosion and desertification, succeeding in grassing even the most sterile rock types (compact clays, fractured rocks, soils contaminated by hydrocarbons or admixed with lime etc.) without using any topsoil or other materials or products, synthetic or natural (geonets, geocells, biomats, mulch, bonded wood-fibre matrices, and so on);
- if the above materials and plastic products are already on site, they will be masked with obvious advantages for landscaping, furthermore improving their functionality and durability;
- mitigate the environmental impact of civil works;
- improve performance, functionality and durability of traditional works while reducing their maintenance needs;
- accelerate the renaturation;
- remove large quantities of CO₂ from the atmosphere contributing to the credits foreseen in Kyoto Protocol;
- increase the soil shear resistance and the Safety Factor;
- protect and waterproof the slopes in case of heavy rainfall;
- protect the soil from cracks and crevices due to shrinkage, thanks to the ability of shading, moisture retention and reduction of thermal shocks;
- decrease the saturation of soils;
- transform a fragile soil in a plastic system "soil-roots".



Italian motorway A6 - Old geonets remained barren for 15 years



Italian motorway A6 after intervention with PRATI ARMATI®: erosion has been stopped, slope is renaturalized and black geonets are masked by a thick vegetal blanket

What PRATI ARMATI® cannot do

They do NOT consolidate unstable slopes from the geotechnical point of view (that is, those with a safety factor SF < 1) that first must be consolidated (the safety factor must be SF > 1.3) with works of civil and environmental engineering (poles, reinforced soil, gabions, reinforced concrete walls, etc.) and then treated with PRATI ARMATI® to fight erosion and favour soil re-naturalization.

Application limits

The areas on which the intervention with PRATI ARMATI® will be carried out should therefore:

- be stable from the geotechnical point of view (SF > 1.3) and therefore, if necessary, they need to be stabilized with traditional civil works;
- have a maximum slope steepness of 60° and therefore, if necessary, they will have to be re-profiled;
- have a surface with coarse finish;
- be provided with appropriate works of regimentation and catching of surface and subsurface waters.

Which pedoclimatic conditions PRATI ARMATI® can withstand

- temperatures between -40 °C and +60 °C;
- arid to very wet climates;
- soils with pH between 4 and 10;
- any lithotype, even the most barren clay, silt, gravel, sand, flysch, lime admixed embankments, road and railway embankments in arid material, etc.;
- soils polluted by hydrocarbons and heavy metals;
- salty soils

Advantages

- very fast planting process (several hectares per day);
- they do not need:
 - top soil to promote rooting (they actually vegetate even on barren soils);
 - additional products such as geotextiles, geomats, geocells, biomats;
- safe installation process;
- all used materials are harmless and natural, machines are simple and safe;
- no need of maintenance works such as irrigation, fertilization, mowing;
- protection from clogging of water catching systems (eg. ditches and gutters), that are kept clean and efficient and will not need maintenance works;
- anti-erosion efficiency improved over time;
- slope finishing not required: surfaces may be left rough and coarse;
- the energy spent to fight erosion and favour the re-naturalization of 1 hectare of slope or embankment using only PRATI ARMATI® is about 100 times lower than using any other traditional technique;
- efficiency of CO2 capturing from the atmosphere is up to 5 times the one of herbaceous plants used in traditional hydroseeding

They are not weeds

Weeds are defined as those species without utility that spread uncontrollably.

The non-weeding behaviour of PRATI ARMATI® is demonstrated on all interventions.



Motorway A1 Milan-Naples (Fabro): there is a clear separation between the area sown with PRATI ARMATI® and the original soil condition



Sardinia (Florinas): the area sown with PRATI ARMATI® is quite defined and the deep rooting herbaceous plants have not invaded the surrounding areas

They require no maintenance

Once gone operational, PRATI ARMATI® plants do not need any maintenance, not even mowing, zeroing thereby the ownership costs.

There is no need of irrigation, as the used plant species are very resistant to drought and aridity.

They do not require fertilizer, thanks to the special mix used, which also includes seeds of nitrogen-fixing deep rooting species.

No mowing is required: even when the vegetal blanket becomes seasonally dry it will protect the slope from precipitation, such as the roof of a hut.

They tolerate saline soils and vegetate even at seaside



Genova Voltri, deep rooting plants installation by the seaside



Alghero (Sardinia): thick PRATI ARMATI® blanket along the coast

They withstand long lasting flooding



Noncello river (northeast Italy): flood of 2002 - The plants withstood the flooding lasted many days. Note on the trees the deposited silt indicating the level reached by the water

Deep rooting herbaceous plants may withstand submersion even for prolonged periods. This characteristic makes them particularly suitable for creating anti-erosion systems and protective banks along rivers and streams, and for covering with a vegetable blanket irrigation canals etc.

They sprout after fire events



Florinas-Muros road (Sardinia): a slope treated with PRATI ARMATI® underwent a fire



PRATI ARMATI® plants sprouting after the fire event

Deep rooting herbaceous plants are capable to sprout again after a fire event. Therefore, it will be not necessary to intervene with a new sowing after a blaze, with remarkable economic savings. Moreover, some of the species used are green in summer, thus counteracting the development and spread of fires.

They subtract huge amounts of CO₂ from the atmosphere

Deep rooting herbaceous plants use the high efficiency C₄ photosynthesis mechanism, capable of absorbing CO₂ from the atmosphere up to 400% more than common plants.

TYPE OF VEGETATION	TONS OF CO ₂ ABSORBED PER HECTARE EVERY YEAR (t ha ⁻¹ year ⁻¹)
Temperate deciduous forest	20
Temperate grassland	8
<i>Annual</i> corn crop	41.5
<i>Perennial</i> anti-erosion installation of PRATI ARMATI®	<u>Up to 40</u>

Ability to absorb CO₂ from different plant types in tons per hectare per year

Advantages with respect to common plants

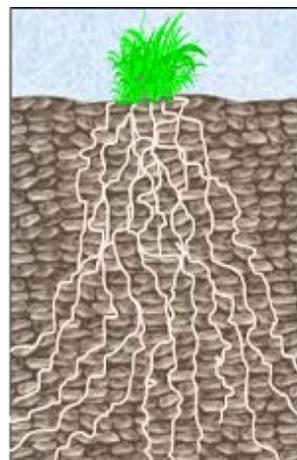
1. On equal age, PRATI ARMATI® show a much deeper rooting system, more collated and resistant than common herbaceous plants.
2. The herbaceous species of PRATI ARMATI®, unlike the trees, do not overload the soil with their weight and do not trigger phenomena of instability (the so-called "*sail effect*") due to the action of the winds.
3. PRATI ARMATI® have deep, thin, homogeneous and resistant roots that do not create bulges in the ground, as is the case of some tree and shrub species.



The comparison between the roots of a deep rooting perennial herbaceous plant and a traditional herbaceous plant, three months after sowing on excavated inert materials



The roots of the trees are growing over time both in depth and diameter, causing swelling and fractures in the soil



The diameter of PRATI ARMATI® roots remains instead constant along their entire span without causing cracks and bulges in the ground



Vegetal mantle development

The vegetation mantle of PRATI ARMATI® appears initially patchy, attaining complete coverage of the soil as soon as the plants reach full performance, usually after 12-24 months.

This type of development is not a peculiarity of PRATI ARMATI® but is typical of all vegetal covers, even in the urban context.



Villa d'Adda (northern Italy) – Development of PRATI ARMATI® vegetal blanket during 11 months from sowing

Seasonal changes

The appearance of deep rooting herbaceous plants changes with the seasons, conforming to the surrounding vegetation.

The plants used are perennial and follow the natural cycle: turn yellow in unfavourable periods and vegetate again when conditions become favourable. Although their aerial parts appear yellow and dry, the plants do not die, but enter the vegetative stasis. This phase generally occurs in summer for *microthermic* species, while for *macrotherms* it can be observed during the winter.



Road slopes by Florinas (Sardinia) – How PRATI ARMATI® and local plants look as seasons change

Renaturation

PRATI ARMATI® may favour the renaturation process. They actually behave as pioneer organisms vegetating barren lands and blocking erosion: soil conditions thus improve, making it suitable for colonization by more demanding plant species such as shrubs and trees.

Based on the needs of the customer, it is possible to:

1. maintain and enhance in time the sole herbaceous deep rooting plants of PRATI ARMATI®

2. speed up the spontaneous renaturation process by sowing along with seeds of PRATI ARMATI® also seeds of flowering species, shrubs and trees of the local flora: for example, mastic, broom, myrtle, cistus, etc. in the Mediterranean area; larches, firs, pines, stones, etc. in alpine areas. Through this integrated solution it can be achieved an anti-erosion and re-naturalization system that:

- avoids the long lasting and expensive transplantation operations of trees and shrubs that are often part of traditional interventions to block erosion
- avoids the typical effect "geometric" and unnatural which results by transplanting arboreal plants and/or shrubs seedlings in parallel rows
- avoids the continuous remakes due to heavy mortalities (failed areas) following transplantation
- drastically reduces the working times
- drastically reduces energy costs of planting
- drastically reduces installation risks
- allows the installation at any time of the year, granting optimal planning and site preparation
- cancels any maintenance
- provides a warranty of 10 years, something that no other green technology offers
- corresponds to the spontaneous process of renaturation
- avoids transplant geometries that are not typical of the nature
- leaves to the local pedoclimatic conditions the selection of the best appropriate species



Noncello river (northeast Italy) – Renaturation of the area treated with PRATI ARMATI®

Comparison with traditional anti-erosion techniques

On a surface of one hectare a typical intervention with traditional anti-erosion techniques (three-dimensional geonet, 10cm of topsoil, hydroseeding of various type with or without mulch) implies the transport and deployment of 1300 tons of materials and many weeks of processing; an anti-erosion intervention with perennial deep rooting herbaceous plants involves the use of 12 tons of materials (seeds, fertilizers and glues) and a single working day.

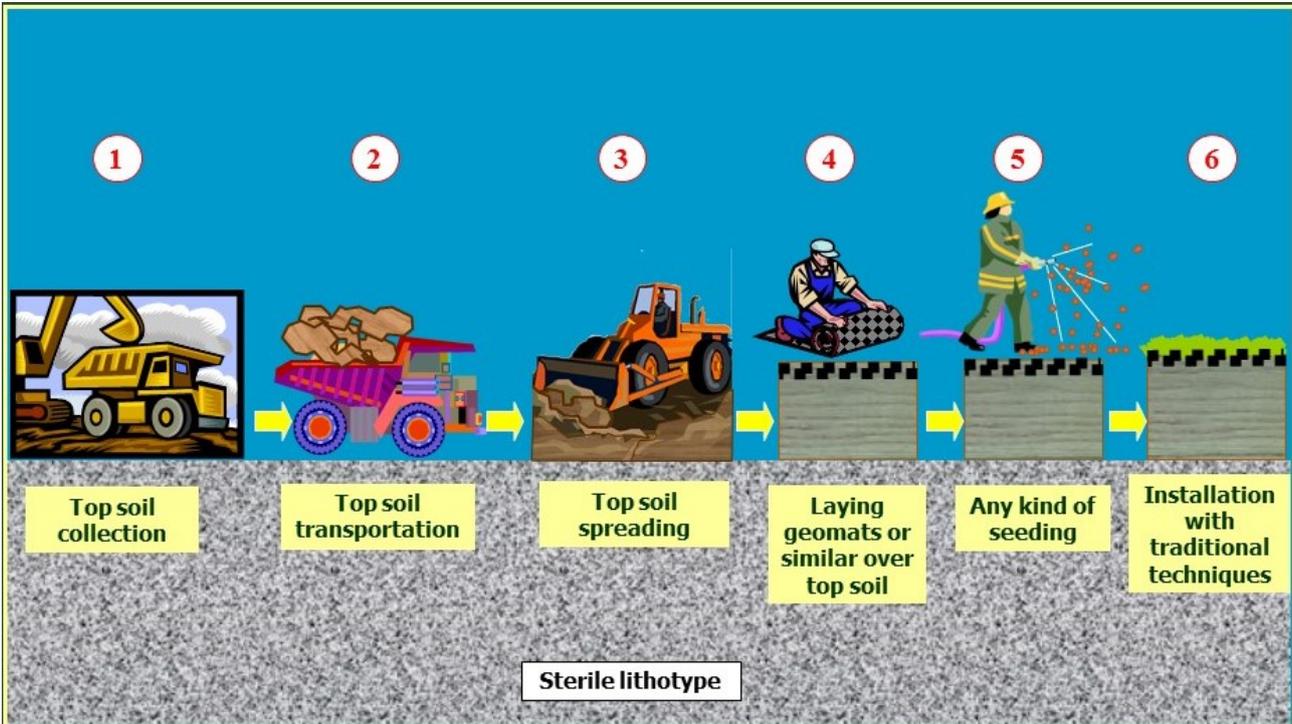
The traditional anti-erosion techniques involve the use of synthetic products (geocells, geotextiles, etc.), biomats, as well as vegetal topsoil to provide a fertile substrate for the rooting of vegetation. A typical anti-erosion system is for example obtained by the following steps:

1. deploying over the slope subject to erosion a geonet in plastic material and fixing it to the ground with suitable metal stakes
2. covering the geonet with a layer of topsoil of variable thickness intended to provide a fertile substrate for the rooting of vegetation (sometimes the geonet is deployed over the topsoil layer rather than below).
3. sowing traditional herbaceous plants (ryegrass etc.) and often transplanting shrub and tree species to favour the re-naturalization.

Especially the laying of topsoil (step 2) involves lengthy and expensive processing operations and a very high energy consumption.

With traditional solutions the costs are very high, the performances poor, the processing times lengthy and the risks significant. The processing steps are numerous: topsoil loading from very distant sites,

transportation to the construction site, deployment over the embankments of the collected material, installation of geomat or the like over the topsoil and finally hydroseeding of any type, simple or enhanced.



Traditional solutions, several work phases: for 10,000 m² and 10 cm of topsoil various working weeks and 1,300 tons of materials are needed

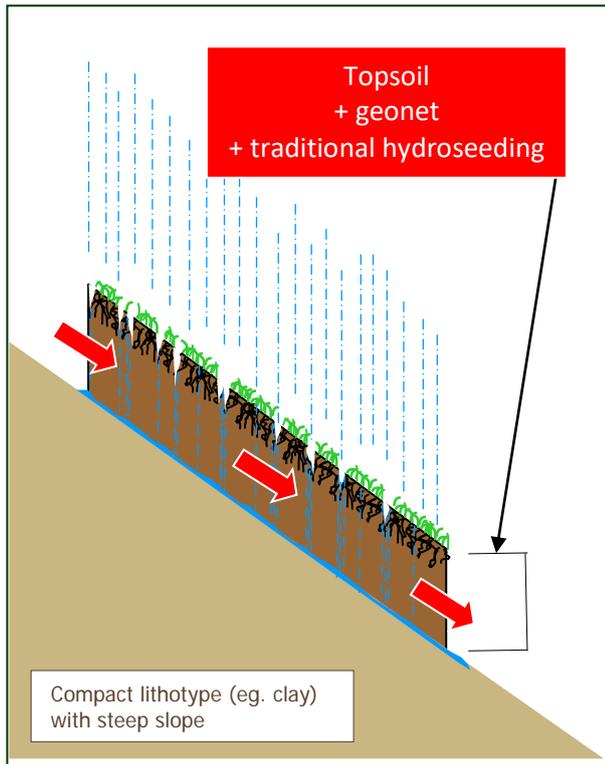
The topsoil is often not native and may contain seeds, rhizomes, weeds, pests, and even harmful and infesting microorganisms that in an environment different than the original may become very virulent. Moreover, this material is often characterized by poor geomechanical parameters and the entire anti-erosion system thus produced turns out unstable, collapses and slips downstream during heavy rainfall. Continuous, complex and burdensome maintenance works are therefore required.



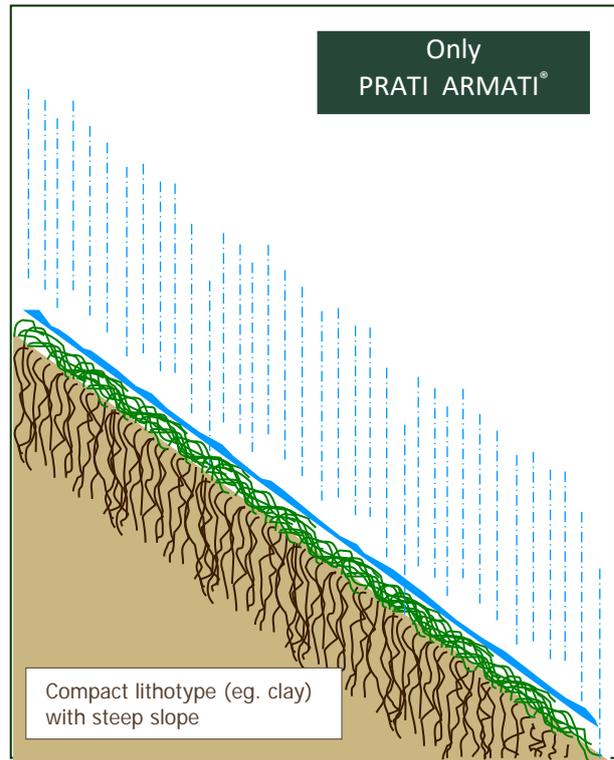
Collapse of an anti-erosion installation consisting of topsoil + plastics geonets + traditional hydroseeding + metal networks + deep nails



Collapsed anti-erosion installation based on wickerwork structures



The topsoil, in case of strong water saturation, may slip downstream



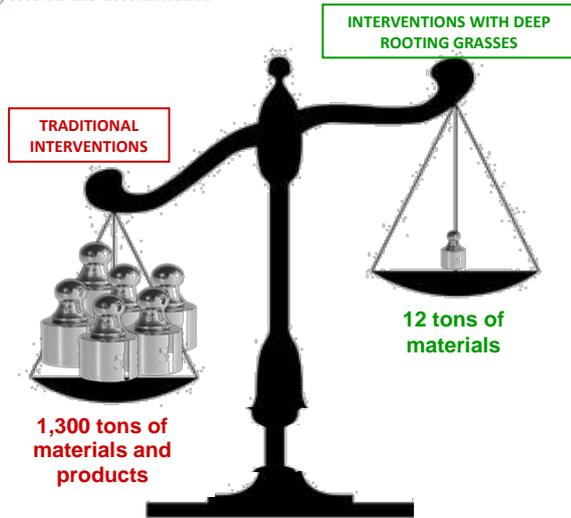
PRATI ARMATI® deeply anchor to the original lithotype irrespective of its inclination, sterility and compactness: they are not removed even by heavy rains and protect the slope

Using only deep rooting herbaceous plants it will be possible to drastically reduce costs of the anti-erosion intervention, the total volume of materials, the energy involved, the necessary time and the processing risks. As an example, the treatment of 10,000 m² (1 hectare) of soil with a classic traditional solution (eg. plastic geonet + 10 cm of topsoil + hydroseeding with traditional seeds) requires:

- 10 cm of topsoil (corresponding approximately to 1,300 tons)
- 12,000 m² of geomat polypropylene (24 tons including scraps and stakes for anchoring),
- about 10 tons of materials for traditional hydroseeding (water, seeds, adhesives, fertilizers etc.)

totalizing more than 1,300 tons of materials and products (would require about 70 trucks to transport them) and several weeks of work. Furthermore, it is often required an irrigation system and the transplantation of forest plants that make the operation even more expensive, long lasting, complex.

By contrast, the treatment of 10,000 m² of soil with deep rooting herbaceous plants, requires only about 12 tons of materials (water, seeds, natural glues, fertilizers) and 1 working day.



Materials needed for an anti-erosion intervention on 10000 m²
On the left, in red traditional interventions: over 1300 tons of materials (topsoil + geonets or geocells or similar + seeds + fertilizers).
On the right, in green: interventions with deep rooting grasses: only 12 tons of materials (water, seeds, fertilizers)

The ground temperature due to the black colour of geomats may reach 80 °C and cause burns to plants

Plastic materials used in traditional anti-erosion techniques are pollutants and not biodegradable: they will eventually deteriorate under the action of atmospheric agents giving rise to polymer fragments which mix with the soil, ending up in groundwater or ingested by wildlife or by grazing cattle. Instead, the use of solely deep rooting herbaceous plants to control erosion (like with PRATI ARMATI® technology) renders the anti-erosion interventions completely natural and environmentally friendly, moreover integrating them perfectly with the surrounding environment.

In addition, the black colour of geomats may cause the ground temperature to reach 80 °C, causing burns to the plants.



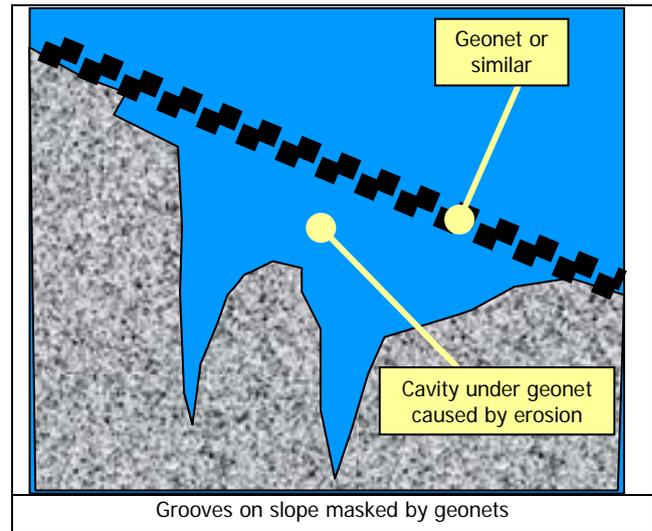
Plastic geonets 2 years after installation, degraded by atmospheric agents



PRATI ARMATI® installation 2 years after sowing

Benefits during inspection activities

Geonets, biomats and the like, stretched out on a slope prone to erosion, may mask possible cavities present on the soil, making almost impossible to detect the presence of ongoing structural failures that, if not fixed, can evolve giving rise to landslides phenomena or mudflows and debris: this is particularly important for the Inspection and Control Services of the road and motorway network. Geonets and biomats mask these problems and do not allow the inspection and maintenance services to early detect any failure in place below the geonets. By contrast, the realization of an anti-erosion intervention based on deep rooting perennial herbaceous plants does not involve problems of this type as the grassy layer perfectly follows the contours of the ground without masking any failure, which are therefore perfectly and immediately visible to the Inspection and Control Services.



Combination with traditional products

PRATI ARMATI® technology may be combined with all the environmental and civil engineering works used for slope stabilization (eg. gabions, piling, reinforced soils, rockfall netting, etc.) to improve their environmental impact and performance.

Such works for slope stabilization become immediately operating after installation, but begin to deteriorate from that moment and lose their functionality with time.

Deep rooting herbaceous plants need instead more time to develop their anti-erosion and renaturation action, but gradually increase their effectiveness over time.

The combination of the two types of products can therefore guarantee:

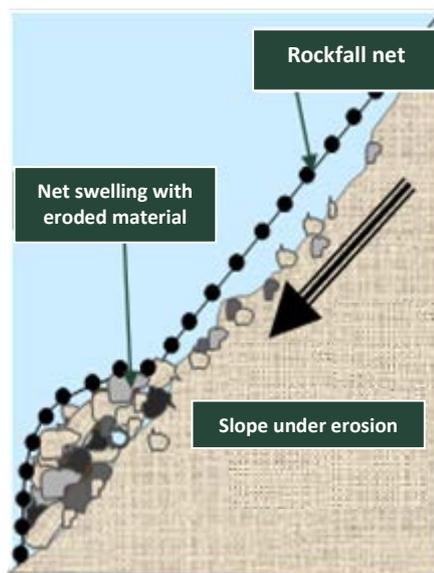
- immediate results;
- efficacy over time;
- synergy of results.

Protection of rockfall metal nets

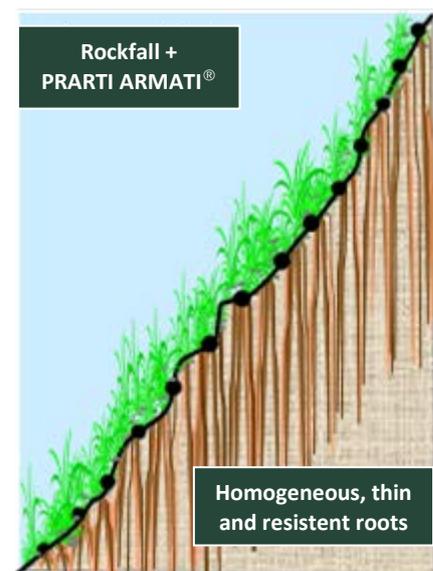
Contact rockfall nets are used to block the fall of boulders but are useless against erosion of the finer materials whose continuous loss caused by rain, wind, snow and freezing-thawing, undermines at their foot larger boulders that are detached and fall downstream, bulging the nets which thus loses its functionality.

The swelling nets must therefore be periodically emptied by the accumulated material and then put back, with high maintenance costs and risks. Sometimes they ruin irretrievably and must be replaced.

PRATI ARMATI® sown over metal networks block erosion of the finer



The continuous detachment of escarpment material may create debris accumulations that disengage and deform the contact rockfall nets, which thus lose their functionality



Contact rockfall protected by PRATI ARMATI® stay attached to the escarpment

materials, creating, thanks to the thick and thin roots bundle and the aboveground leaves blanket, a sort of "natural seal" that prevents the erosion and the bulging of the network due to the daily and seasonal fluctuations, and therefore the detachment of the biggest boulders and any type of resulting maintenance. The engraftment is guaranteed on rocky surfaces of any nature, provided they are altered and/or fractured, such as to enable the development and deepening of the root system. The thin and homogeneous roots avoid bulges in the underlying lithotypes, do not weigh the slope down and prevent the wedge effect typically triggered by shrub and tree vegetation. The thick leaves blanket, in addition to the masking effect of the metal nets, reduces the water infiltration, thus creating during the critical meteorological event a protection shield, particularly important for the slopes at risk.



Orvieto (Central Italy) – Aggressive erosion on a slope protected only by rockfall protection netting.



Orvieto (Central Italy) – The same area after PRATI ARMATI® installation. The erosion is stopped and the slope is renaturalized. The rockfall protection netting is hidden and protected from detachment: the deep rooting herbaceous plants anchor, thanks to their roots, the rockfall nets to the soil

Protection of works for water collection and control

Erosion causes clogging of the works of water collection and control: ditches, gutters, drainage traps, and so on. When these water uptake works are clogged, undermined or damaged, they become inefficient and favour the infiltration of water in the slopes, causing in turn instability and even deeper subsidence. It becomes therefore necessary to plan a continuous maintenance to restore the damaged ducts or to empty them from clogging mud and debris, with high costs, time and risk.

PRATI ARMATI® are deep rooting herbaceous plants that block the erosion across the slope thus preventing the eroded material from clogging gutters, ditches and wells, keeping them clean and efficient and eliminating maintenance costs



Yielding gutters made with tiles on road embankments



Drainage channels made with concrete modules on embankments protected by deep rooting herbaceous plants



Motorway A1 Milan-Naples. Ditches were frequently clogged up and a continuous maintenance activity was necessary to keep them clean and efficient.



Ditches are perfectly clean after PRATI ARMATI® installation. The erosion is stopped and the efficiency is guaranteed, zeroing maintenance costs.

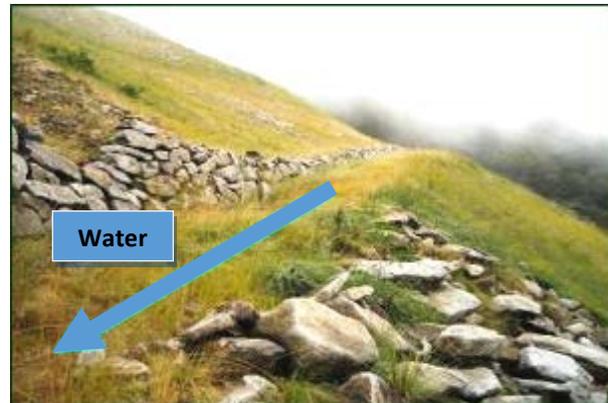
Realization of waters catchment and regimentation works lined with perennial deep rooting herbaceous plants

With PRATI ARMATI® it is possible to create simple channels for the regimentation of rainwater. They offer several advantages:

- they avoid expensive works with cemented stones, tiles or other traditional solutions to control the waters;
- the structures are not rigid and adapt to the settling of the ground without suffering damages, as is the case for structures made of cemented boulders or other traditional works;
- they reduce the flow speed of water through the thick and strong epigeous barrier of PRATI ARMATI®. This also prevents the clogging of drain wells that receive the ditches water.



Oropa (Northern Italy) – Drain channels directly created on the ground as is



The gutters are created on the ground as is and are grassed with PRATI ARMATI® that reduce the speed of runoff water.

Protection and greening of reinforced soil

The reinforced soil structures are works that can contain the slope thrusts. The thin roots of PRATI ARMATI® deeply penetrate their structure without compromising the functionality. Thanks to their root length they manage to catch deep water, surviving even in very arid conditions. The vegetable blanket protects the reinforced soil and masks the structure, which perfectly harmonizes with the landscape.



Reinforced soils in Alghero (Sardinia)



Alghero (Sardinia) – Reinforced soils protected and visually masked by PRATI ARMATI®

Combination with riverbank protection works

PRATI ARMATI® may be used for protection of river banks, lakes, streams and irrigation canals and the construction of simple ditches and drainage channels, either alone or in combination with other protective structures, improving performance and ensuring rapid and lasting results.



Meduna river (Northeast Italy): riverbank protection made with rock boulders in the lower part



Same point of Meduna river with upper banks protected by PRATI ARMATI®

Combination with gabions

The gabions have the purpose of containing the thrusts and lock the foot of the escarpment. PRATI ARMATI® block erosion and prevent the gabions clogging by eroded soil. Stone, iron and PRATI ARMATI® are a perfect and lasting combination.



Castelviscardo (Central Italy), construction of the new ring road



The new ring road with gabions protected upstream by herbaceous deep rooting plants

Combination with palisades

PRATI ARMATI® may be used to improve the performance of fences and to achieve a rapid re-naturalization of the treated surfaces.



Municipality of Bernalda (Southern Italy) - A flood Collapsed the palisades in an untreated area



The area treated with PRATI ARMATI® could weather the flood

Renaturation of quarries and mines

PRATI ARMATI® can be effectively used for the environmental recovery of quarries and mines in that:

- they provide in the short term coverage and protection of slopes from water and wind erosion
- they vegetate even on soils poor and contaminated by hydrocarbons heavy metals, etc .
- they favour the subsequent establishment of shrubs and local trees



Limestone quarry in the town of Spoleto (Central Italy)



Environmental recovery of same quarry using PRATI ARMATI®

Naturalization and securing of slope landfills

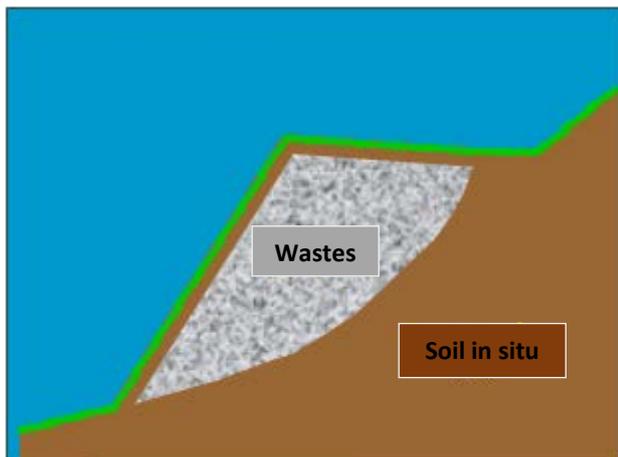
Slope landfills are usually created close to hills, in abandoned quarries, in ravines or watersheds. They are characterized by steep escarpments and waste outcrops often mixed with soil. For the implementation of emergency safety of this type of landfill, the commonly adopted covers (mineral solution with clay or waterproof membranes) are not convenient: interventions take time, are expensive, dangerous, complex, if not impossible, especially when working on steep slopes.

PRATI ARMATI® do not replace the remediation, but they can provide a quick and inexpensive solution to implement emergency safety of these landfills. Moreover, these interventions (see. Min. Decree 471/99) fall within the technical category "*in situ*", i.e. without movement or removal of the polluted soil and waste.

PRATI ARMATI® Technology actually guarantees the rapid and widespread development of a powerful root system and a thick vegetation blanket that:

- limit the infiltration of rainwater with sharp reduction of leachate, the main pollution factor in this type of landfill;
- reduce water erosion and therefore the loss of soil caused by water runoff;
- reduce the downstream drag of outcropping wastes which will be incorporated in the plant cover;

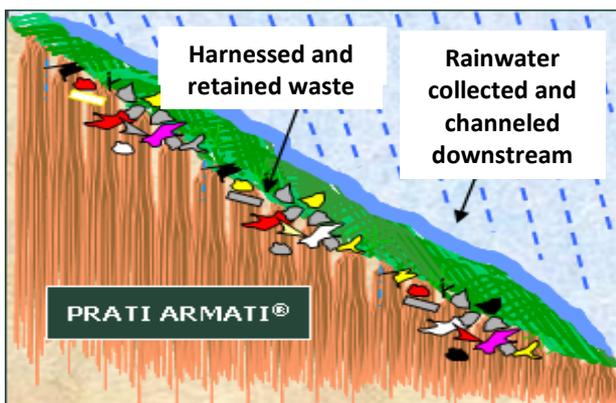
- reduce wind erosion which generates clouds of dust and pollutants, and removal and transport of light material (plastic films, paper, aluminium foil, etc.);
- isolate the waste from the environment;
- it gives a green and natural look to the landfill, improving its visual impact.



Sketch of a landfill slope



Example of a landfill slope



Cover with PRATI ARMATI®: the slope is sealed and leachate is reduced



Typical aspect of a landfill protected with PRATI ARMATI®

PRATI ARMATI® for grassing embankments of roads and railways

Following to experience gained and thanks to the results obtained by applying the technology PRATI ARMATI® on any lithotype, our company developed a "new dedicated product", always with performance targets, specific for the protection of embankments slopes (PRATI ARMATI® FOR EMBANKMENTS) that provides considerable economic, technical and environmental advantages, compared to traditional solutions. Given the impossibility of grassing with traditional hydroseeding the barren material of the embankments, it is customary to complete the preparation of embankments with a topsoil layer of variable thickness intended to provide a fertile soil for the roots of the plants.

This operation involves lengthy and costly processing steps: collect the topsoil from very distant sites, transport it to the construction site, deposit and distribute the material on the embankment surfaces. Unfortunately, the topsoil is often characterized by very poor geomechanical parameters and hardly presents stable conditions capable of providing a secure base for the growth of vegetation blanket destined to revive and protect from erosion.

Moreover, it seems clear the impossibility of laying the topsoil in place according to the best practice on the embankment since the inclined surface does not allow to roll and properly moisten the material, which is then simply compressed with the back of the bucket of mechanical excavators, if the height of embankments is not excessive for the size and type of the available mechanical means.

The final result is a clear contrast between the barren well compacted underlying surface and a layer of variable thickness of topsoil, unstable and not properly compacted, with an intermediate surface of potential

slipping which is activated on the occasion of persistent raining events. These events in fact tend to increase the weight of the topsoil layer, to decrease the cohesion and facilitate the lubrication of the contact surfaces between the two materials, triggering, in very short times, erosive phenomena.

At the same time cases of detachment and diffuse surface instability may occur, endangering not only the anti-erosion and greening process, but also the functionality of the works of hydraulic control of rainwater



Strong erosion on topsoil deposited over the embankments

(eg. discharges with concrete tiles), products that usually are placed above the embankments.

Alternatively, the package of traditional solutions for preventing erosion (eg. topsoil + plastic geonet or biomats + hydroseeding with traditional seeds, mulch, bonded wood fiber matrices, etc.) may be replaced by a new product, quickly and simply applicable: PRATI ARMATI® FOR EMBANKMENTS. The seed mixture was formulated after over 15 years of tests and research, and is specific for the treatment of road and railway embankments. It is directly applied on the barren material of the embankments body as such, without any addition of topsoil nor use of other materials such as geotextiles, geocells, biomats, mulch, bonded fiber matrices, etc.

It is therefore possible to obtain excellent results to stop erosion and renaturation in a single processing step.

The treatment allows to guarantee by means of a simple hydroseeding intervention:

- a durable anti-erosion protection;
- a reduction in the infiltration of rainwater;
- a complete re-naturalization of the embankment;
- an action of "topping up" in support of the works of water regulation (discharges in concrete tiles, Finsider pipes, etc.).

In case of fire or long periods of drought, the investment is not lost: PRATI ARMATI® FOR EMBANKMENTS show a good capacity of sprouting after fire and are capable to withstand periods of extreme drought.



Tuscany. The embankment made of large size barren material of before intervention



Tuscany. The railway embankments (50.000 m²) after intervention with PRATI ARMATI® FOR EMBANKMENTS

Perennial deep rooting herbaceous plants

Herbaceous plants used are perennial (therefore they do not have to be replanted every year), mainly indigenous, and mostly belong to the botanical families of gramineae and leguminosae.

They count on a highly developed root system that characterizes them with respect to all other common herbaceous plants used in traditional hydroseeding.

At the same age, PRATI ARMATI® plants compared to common herbaceous plants show a much deeper, collated and resistant root system characterized by:

- high growth speed;
- high depth and density;
- thin and homogeneous roots;
- high average tensile strength (up to 205 MPa), certified by Universities.

Perennial deep rooting herbaceous plants have deep, thin, homogeneous and resistant roots that do not create bulges in the ground which may trigger detachments and sagging, as is the case of some tree and shrub species.



By the time the roots of the trees are growing both in depth and diameter, causing swelling and fractures in the soil



The diameter of PRATI ARMATI® roots remains instead constant along their entire span without causing cracks and bulges in the ground

Soil reinforcement by the root system

The Safety Factor (SF) is a dimensionless value defined as the ratio of the forces/moments resisting movement (Fa) by the destabilizing forces driving movement (Fb).

In the case of soil reinforced with roots it is therefore the relationship between anything that contributes to sustain the slope (cohesion, friction, resistance of the roots, the component of the weight force normal to the sliding surface), and all that helps instead to create instability (saturation, the component of the weight force tangential to the sliding surface).

The greater the SF, the more stable is the ground. We recall that the PRATI ARMATI® may be used to block erosion only on stable slopes with SF > 1.3.

$$SF = \frac{Fa}{Fb} \quad \text{where } \begin{array}{l} \mathbf{Fa} \text{ stabilizing forces} \\ \mathbf{Fb} \text{ destabilizing forces} \end{array}$$

On a slope stable from the geotechnical point of view (SF > 1.3) a dense and resistant radical system transfers to the soil its resistance to traction: the shear strength increases, which results in an increase of the overall stability and therefore also of the Safety Factor (SF).

The roots of PRATI ARMATI®, thin and homogeneous, work exactly in traction and thus make the most of their mechanical strength.

Tensile tests and mathematical model

To evaluate the roots tensile strength of various species PRATI ARMATI®, tensile tests were conducted at the Department of Hydraulics by the Agricultural University of Milan, using a special device that could measure the roots breaking load (referred to the root diameter) together with the relevant elongation.

The tensile strength values increase with decreasing diameter of the roots.

Particularly high values of resistance to traction were found on the roots of PRATI ARMATI®, with average values exceeding 205 MPa and peaks of 468 MPa, comparable to that of a medium-quality steel.

Similar tests conducted on common plants (willows, birches, maples, etc.) gave average values about 3 times lower.

Plasticity of the soil-root system

The intertwining of the roots along the slope creates a linkage effect that helps to increase the surface stability of the slope. For this reason, the correct design must foresee the use of PRATI ARMATI® not only on the slopes, but also on the berms.

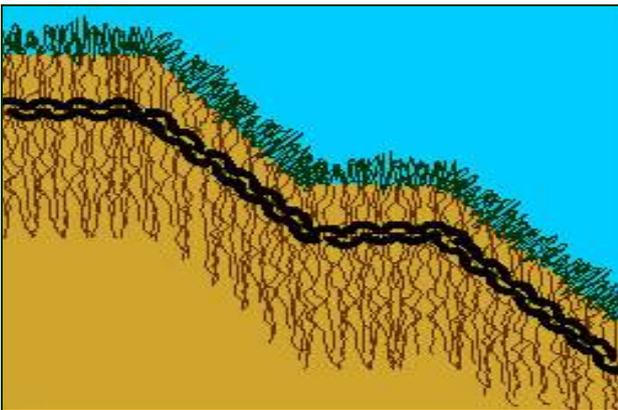
The soil-root system of PRATI ARMATI® is able to plastically deform as a result of mechanical stress. The plastic deformation absorbs stresses without giving rise to brittle failures of the soil.



PRATI ARMATI® installation by Volterra (central Italy) on clay ground



The deformed soil-root system resist the pressures of liquefied clays



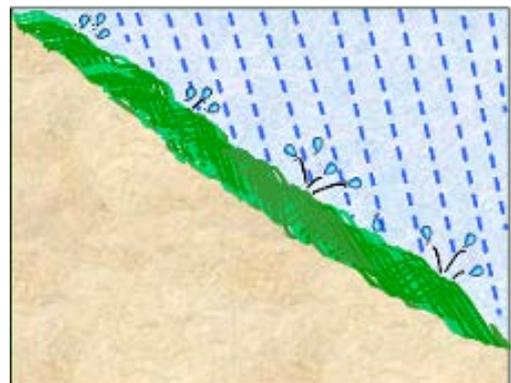
The chaining effect created by PRATI ARMATI® roots



Ozieri (Sardinia) – Urban waste disposal site

PRATI ARMATI® reduce the erosive power of rainfall

The vegetation absorbs most of the kinetic energy of the rain drops, so the impact on the ground and the resulting erosive power of rain are very attenuated.



Reduction of the impact energy (and therefore of the erosive force) of the rain thanks to the presence of vegetation

Slope waterproofing

In case of heavy rainfall events, the waterproofing effect of herbaceous vegetation is very different depending on the inclination of the slope:

1. if the slope is steep, a major fraction of the rain runs over bedridden leaves, even when the vegetation is dried up, as it happens on the roof of a thatched hut. A dense herbaceous plant blanket, placed on a steep slope, may isolate it very well during heavy and prolonged rainfalls;
2. if the slope steepness is mild (or even flat), the herbaceous vegetation only decreases the kinetic energy of the drops, however much of the water will reach, sooner or later, the soil.



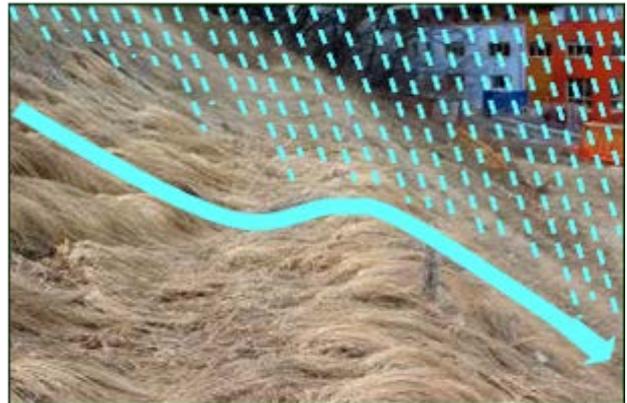
Orvieto (Central Italy) - Hillside before PRATI ARMATI® installation. The escarpment, without the protective vegetal blanket, is very exposed to the erosive action of water, especially in case of heavy rainstorm



Hillside after PRATI ARMATI® installation. When the slope is steep, in case of heavy rainfall events, a major fraction of the rain runs over bedridden leaves, even when the vegetation is dried up, waterproofing the slope and protecting it from the erosive action of water.



The blanket of PRATI ARMATI®, either green or dried, in case of heavy rainstorm allow to waterproof the underlying area as if it was the roof of a hut, precisely made with dry leaves



Slowing the speed of runoff on the ground

The presence of herbaceous vegetation, if characterized by special features of the aboveground part such as elasticity, resilience (low fragility) and high density, behaves as a vegetal filter, reducing the water speed at ground level.

The flowing speed of the water and the relevant transport capacity on a ground covered with vegetation are much lower than those found on soil barren or covered by plant species either arboreal, shrub or herbaceous, lacking the features above described.



Filter effect of the vegetable blanket slowing down the flow of water

Reduction of water saturation of soils

In some soils (eg. cohesive soils) an excess of water causes an increase in interstitial pressure resulting in decreased shear resistance and therefore lower stability of the slope.

The plants absorb, through their root system, water from the soil and disperse it into the atmosphere in form of vapour through the surface of the plant (the perspiration phenomenon), thus contributing to increase the shear resistance and therefore the stability of the slope.

The presence of vegetation determines a reduction of the saturation of the soil and the interstitial pressure, both due to the sealing effect of the slope and to the water transfer - via the root system - from soil to atmosphere.

The sucking of water from the soil operated by the plants determines an increase of the shear resistance of the ground and therefore a greater overall stability of the slope.

Only by way of example, an adult plant of corn transpires up to 7 liter / m² / day.

The transpiration of a traditional gramineae lawn 12 cm high, with roots depth of some tens of centimetres amounts to about 5 liter / m² / day in summertime in the Po Valley (equivalent to 50 tons of water per hectare per day).

Transpiration of PRATI ARMATI® is not only greater than the above, but it removes water along a larger vertical profile and in a more distributed and widespread manner. This phenomenon is particularly important in materials such as clays where the hydraulic conductivity coefficient is very low, from 10⁻⁷ to about 10⁻⁹ cm/s.

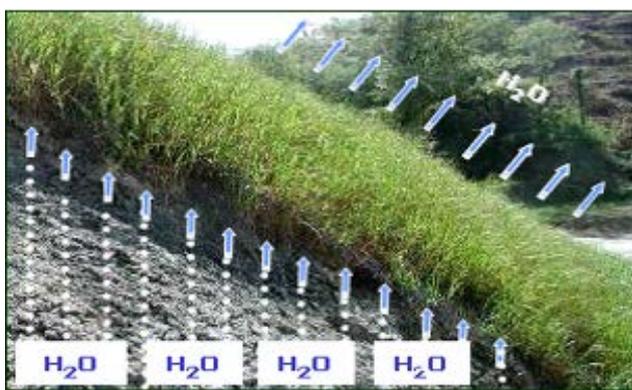
Moreover, this allows the plant to survive even in persisting drought conditions.

In this case, the better performances of PRATI ARMATI® are also due to:

- a **foliage much more developed** (up to 50-150 cm high) and therefore a wider transpiring surface;
- a **greater depth, amount and density of the roots**: even some meters of depth against the 30-40 cm of a traditional lawn;
- **physiology particularly efficient**, typical of plants with C4 photosynthesis: high photosynthetic efficiency and survival capacity even in very arid conditions.



Land sliding due to excessive slope inclination and to erroneous collecting water, which resulted in a strong soaking clay soil



Transpiration: the water absorbed by the roots is transferred to the atmosphere through the surface as steam plant

Protection from cracking and fractures

On sloping hillsides, the forces and the destabilizing moments make deformations increasingly large and irreversible.

The soil cracks, opens in depth and tends - as a result of the destabilizing forces - to slip downstream, giving rise to macroscopic phenomena such as landslides.

The presence of a plant blanket limits the thermal excursions at soil level that cause cracks, fractures and crevices associated to the typical shrinkage of clay sediments.

Reduction in erosion and stones rolling

Plants trap the sediment with roots, stems and leaves, reducing soil loss by erosion. A PRATI ARMATI® installation on the escarpment upstream of drainage channels, ditches and gutters prevents their clogging.

PRATI ARMATI® plants actually block the erosion on the slope and thus prevent the eroded material from being transported downstream, creating blockages. The hydraulic works are thus clean and efficient and will not need any maintenance.

The bridling action exerted by the aerial part extends as well to pebbles of various sizes. These are held by plants also indirectly, because the block of the erosion prevents the lacking of support at the foot and the consequent downhill rolling.

Obviously where the rolling phenomenon of pebbles and boulders is intense and dangerous, PRATI ARMATI® cannot replace the rockfall nets, but may be effectively combined with them enhancing the protective effects and efficacy over time.

On which types of lithotype is it possible the application of PRATI ARMATI®

The lithotypes treatable with PRATI ARMATI® comprise all loose rocks (soils) and stone rocks (rocks) provided that, thanks to cracking, macro-structure, texture, grain size, compaction, etc. they allow the engraftment and development of a root system, that is:

- SOILS: clays, silts, sands, gravels, alone or mixed in different proportions
- ROCKS: conglomerates (weakly cemented), marls (altered), calcarenites (weakly cemented), flysch,



Sciacca (Sicily) - On a sample slope previously treated, the area left without vegetation is prone to cracks and crevices



Pebbles harnessed by the thick and rugged vegetation blanket of PRATI ARMATI®

pyroclastics, shale, acidic or basic rocks altered or intensely fractured.

The engraftment may also be achieved on soils that, in pedological terms, appear totally sterile.

PRATI ARMATI® take even roots on soils with lime additives up to 5% by weight.

The rocks must be altered or more or less fractured and the percentage of engraftment is proportional to the degree of alteration and fracturing.

On compact and unaltered rocks, taking roots is not possible.