METHODS GUIDE FOR THE INSTALLATION AND MAINTENANCE OF VEGETAL FILTERS

Life

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Prevención de la eutrofización por nitrógeno agrícola

PROJECT LIFE + "EUTROMED"

Project selected and funded by the European Union with the objective of improving the quality of our water and agricultural soil.

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ANNEXED:

Introduction

1. Introduction

Nitrate contamination of continental and coastal waters is one of the most extensive, continuous and more important phenomena affecting the environment, in particular the quality of natural water bodies, with consequent negative impact on health and environment (Hermosín, 2004). This contamination consists, mostly-in elevated nitrate concentrations in surface and groundwater, although eutrophication of dams, estuaries and coastal waters can be produced without these high concentrations (Figure 1).

Among the different factors causing nitrate contamination, agricultural contamination is of greater magnitude and severity, not only because it generates the biggest amount of nitrates, but also because of its diffuse type of origin, is more difficult to identify the direct cause of its occurrence and consequently, much more difficult to study it as well as to establish measures for its control and mitigation.

At the same time, the enrichment of waters with phosphates produces negative environmental effects, by provoking an excessive growth of aquatic plants, creating ecological disequilibrium in communities, as well as problems in channels and dams, which generates big expenses and periodical cleaning -besides water contamination with quality loss, sedimentation, degradation of the waters destined for recreational purposes and the declining health of aquatic ecosystems.

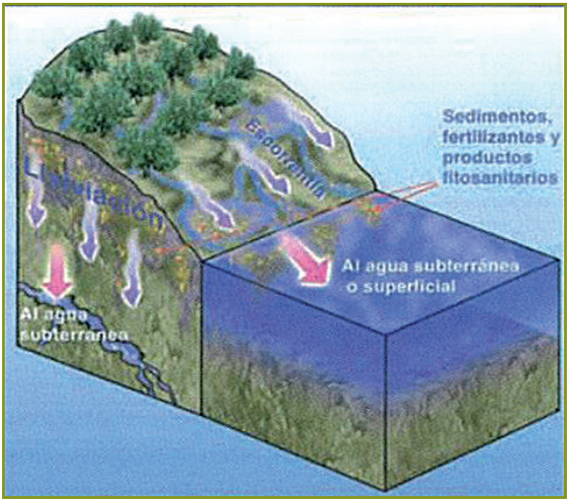

Figure 1: Movement of water and contaminants in soil (source: Consejería de Agricultura y Pesca, 2009).

In this manner, water quality at European scale is subject of preferential attention by environmental authorities of the EU. The Water Framework Directive and Nitrate Directive channel this interest through contamination prevention and control strategies, focused on guarantee a good chemical status of waters. By example, the Autonomous Community of Andalusia has established a number of zones vulnerable to contamination by nitrates from agricultural sources, specifically 24 zones, all of them described and detailed in the Decree 36/2008 of February 5th d (BOJA 36, 20/2/2008), modified by the Order of July 7th, 2009 (BOJA 157, 13/08/2009) as can be viewed in Figure 2.

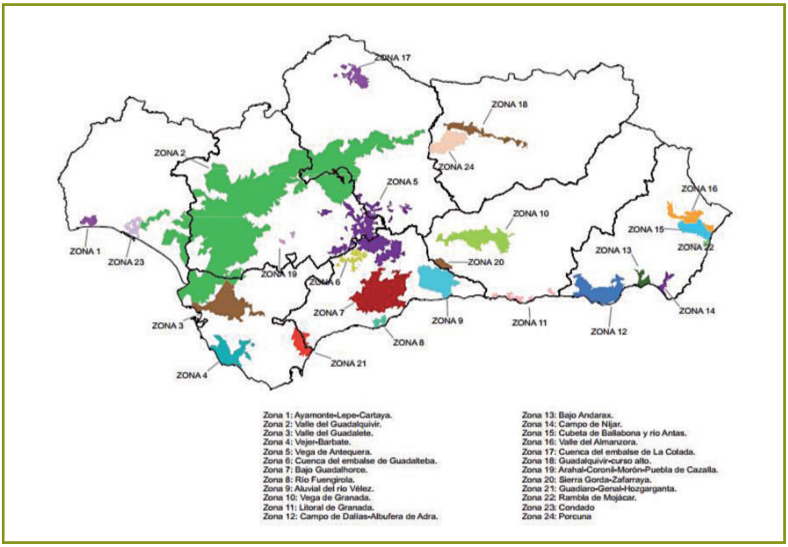

Figure 2: Zones Vulnerable to nitrate contamination from agricultural sources in Andalusian Autonomous Community.

Consequently and –as result of the eutrophication problem in the Mediterranean Basin-, the initiative of EUTROMED project has emerged, whose goal is to demonstrate, through a pilot experience, the efficiency of a technology focused on the reduction of nitrate concentrations in the surface water flow in agricultural lands of Mediterranean climate, such as the basin of Cubillas River (Granada Province), which pours its waters into the aquifer of the Zone 10 (Vega of Granada).

On the other side -in these same areas-, soil erosion occurs simultaneously as an environmental problem of the greatest importance (Catt et al, 1998). Such problem is present in different regions of the planet and in Spanish territory, with greater incidence on semiarid regions, where water resources are scarce. Erosion is a process that occurs spontaneously in nature, although its intensity varies across sceneries. Human intervention strongly increases the depth of this process.

The plough of lands and their implementation for cultivation involves an alteration of the dynamic equilibrium of the system. Soil, -protected under enough vegetation cover- can face direct exposure to rain, sun and wind. So, when vegetation is eliminated, the dynamic equilibrium of the system is altered, soil becomes unprotected from the action of climatic agents, it incorporates less supply of organic matter from cultivated plants, and human labor accelerates the soil mineralization processes. These new conditions are usually less favorable for the maintenance of soil structure, which makes it more vulnerable to erosion and prone to lose its ability to filtrate rainwater, which will diminish also the water availability for plants, even with the same amount of rainwater received.

The runoff water produced by rainfall events, together with the irregularities of the terrain, -facilitates the concentration of its flow, without the formation of multiple channels, others than the ones formed from the position where the cutting force of the water overcomes the resistance of the soil. Once the channel is formed, its growth is fast and it increases downstream, since the channeling enhances the flow speed in absence of vegetation that could stop it and facilitates its filtration.

Image 1. Rivulets transformed into gullies. Gully nº 51 of the EUTROMED demonstration area, before treatment.

Rivulets, gullies and gorges, in some cases, represent three degrees of development of the same process, without a well-defined boundary between them. They are usual companions in Andalusian landscapes across the Mediterranean slope.

For all these reasons, EUTROMED project assumes as one of its main challenges, to demonstrate the importance of the utilization of vegetal filters to prevent, reduce, mitigate and compensate (in that order) two environmental problems coexisting at the same time in the Guadalquivir River Basin and in the Mediterranean Basin, which are: **eutrophication** and **erosion**.

The vegetation is able to diminish the kinetic energy of the rain drop by intercepting it and reducing the volume -as well as the erosive force- of it, protecting the soil from the direct impact of rain drops and solar radiation, and by improving it physically, since the increase of vegetation cover causes an increase of organic matter. Besides, there is a decline in the runoff flow energy due to the surface roughness originated by the vegetation, increasing the volume of filtered water while the root systems are acting as a matrix that enhances soil resistance to shear stress.

It is also known that the utilization of vegetal filters with nitrophilous plants diminish the nitrate concentration in runoff waters that run across them, due to the nitrate retention in the soil through the sediments trapped in vegetal filters, by the presence of denitrifying bacteria and the assimilation capability of the nitrophilous vegetation itself.

Recent studies (Juan Vicente Giráldez et al, 2014), funded by the EU just like LIFE+ EUTROMED, demonstrate how the vegetation covers installed on naked soils in slope roads and other infrastructure works in Andalusia, (in the case of Mancha Real, Jaén using native loams of the Olive grove soil), diminish up to 98, 32 % the volume of runoff compared to the control, and up to 99, 50 % the amount of soil lost to erosion.

On the other hand, the high rates of erosion in agricultural fields left without vegetation cover are well known, as well as the high nitrate levels, -as a consequence of the contamination produced by agricultural activities- concentrated in ravines and streams. Thus, we are searching for a continuous solution to this problem, through a better understanding for the prevention of soil erosion and the water eutrophication, as well as applicable conservation techniques. In this way, vegetal filters used by EUTROMED project help to improve and enhance the knowledge of this technology for the control of eutrophication and erosion in the Mediterranean basins, showing its efficiency in the restoration of gullies and, indirectly, to the environmental conservation of rivers and streams.

Through this methods guide, we offer a practical tool for the selection of areas susceptible to treatment as proposed by EUTROMED, as well as the installation of vegetal filters in zones of particular runoff concentration. These filters are installed in zones where agricultural slope runoffs are concentrated, with insufficient vegetation cover in Mediterranean climate basins, which causes the formation of gorges and gullies -and the dragging of fertilizer excess dissolved in water, which end up reaching to streams, rivers, aquifers and dams, and bringing contamination to all of them.

Image 2. Predominant initial situation in Juncarón Stream (left) and Target situation with presence of gallery forest (right), currently existing in a single point of the stream

Selection of working area

2. Selection of working area

2.1. Actions carried out for the selection of the working area- EUTROMED.

The selected working area for the development of EUTROMED project was located in the basin of Cubillas River. This basin is tributary to the UNIT of Vega de Granada, which has been designated as "Zone vulnerable to nitrate contamination from agricultural sources" under the context of the NITRATE DIRECTIVE (Decree 261/1998, of December 15th).

To select this work area several steps were followed, detailed next:

1. **Search for a zone in compliance with the goals of the Project.**

   The "Zone 10: Vega of Granada" was selected as zone vulnerable to nitrate contamination from agricultural sources and, within it, one of its basins, Cubillas River, as field of action, because this basin presents eutrophication problems and constitutes a traditional and conventional zone for agricultural use within the Guadalquivir River Basin. Moreover, the zone is characterized by its Mediterranean climate and is affected by erosion as a consequence -among other factors- , of the lack of vegetal cover in a field of such great extension as the Olive grove. (Image 3).

Image 3. Olive grove located between the municipalities of Iznalloz and Deifontes, Granada.

2. Dissemination and information of EUTROMED Project.

With the goal of reaching out to the farmers of the locations where the parcels are located inside Cubillas River Basin, several workshops, conferences, press notes, meetings, round tables and field visits where programmed, -with the purpose of providing information and orientation regarding the objectives of EUTROMED Project, and how these actions could benefit the territory and the farmers at the same time.

3. Contact with cooperatives and other organizations located in the area of action.

In order to facilitate the dissemination among the farmers and get in touch with most of them, cooperatives near the zone were contacted, which provided information about the parcels identification and ownership records.

4. Selection of collaborative cooperatives and organizations.

In our case, since our project is just a pilot, we could not select but one cooperative, **San Isidro de Deifontes Cooperative** (Figure 3) due to the general interest shown by its associated farmers who own parcels with similar characteristics and with an accentuated problematic of eroded gullies and degradation of the streams where their waters are discharged. Besides, all the agricultural exploitations grouped in this cooperative constitute an irrigation community for the Olive grove located in Cubillas River Basin, which is a tributary of the Vulnerable Zone "Vega of Granada".

Figure 3: Geographic location of Deifontes district.

5. **Visit to the area of action and selection of the parcel or Pilot Basin Model.**

   The working area was visited with the goal of getting familiar with the characteristics of the terrain (soil, crop, slopes, gullies, gorges, accessibility, etc.) and to improve the understanding of the treatment required for the implementation of the Pilot Basin Model.

Following all these actions, it was determined that, within the Cubillas River Basin, the micro basin of Juncarón stream was a proper reflection of the environmental issue intended to be solved by the project, since it is characterized by its Mediterranean continent-like climate (Figure 4), poorly evolved soils (limestone, loams and dolomites), irregular topography and Olive predominance. The combination of these factors (stormy rains, scarcely consolidated soil, steep slopes, agricultural activities and low vegetal cover) accelerates soil erosion, favoring the formation of groves and gullies with a depth range of 0, 5 to 3 meters, triggering the dragging of nitrates into the runoff waters as a result of the excessive application of fertilizers to compensate the loss of organic matter of the soil.

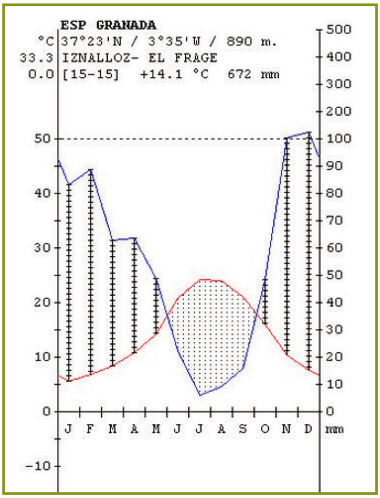

Figure 4: Ombrothermic Diagram of the selected area of action (source: Rivas-Martinez, 1996).

Besides, the traditional model of Olive cultivation in these territories, which imposes a scattered vegetal cover over poor soils, with low content of organic matter and scarce consolidation where the dragging of the surface layer is facilitated by the erosion and the formation of gullies (Image 4), has caused the destruction of the riparian vegetation of streams, ravines and gorges to avoid competition with the crops, to promote –if more of this negative impact is possible- the degradation of the slopes and their natural superficial drainage until the formation of big gullies, -whose remediation is difficult and expensive.

Image 4. Example of gully found Cubillas River Basin.

2.2. General criteria for the selection of areas for the installation of vegetal filters.

As general criteria to follow for the selection of other areas or regions with Mediterranean climate susceptible of treatment with vegetal filters developed by the EUTROMED project, we can cite the following:

1. Environmental problematic of lack of control of soil erosion and water contamination by the excess of nutrients from agricultural sources.

2. Areas with climatic characteristics similar to the Mediterranean type, characterized fundamentally by irregular precipitation rate (in terms of distribution and frequency): heavy rain seasons, as storms and tempests, followed by stern and prolonged drought.

3. Areas of similar orography and pedology: troughs with gorges and streams between steep sloped over soils of low permeability, poor in organic matter and poorly evolved, composed by limestone, clays, loams and dolomites.

4. Utilization of agricultural crops demanding an insufficient vegetal cover particularly in sloppy terrains.

5. Presence of gullies of depth ranging between 0, 5 and 3 meters, showing vertical or horizontal development, without dumping of debris, stones or branches, and the absence of landslide problems or movement of land masses.

6. Availability of citizens and neighbors to engage in restoration work and soil conservation in a proactive manner.

Thus, those farmers of the area, interested in participating in project similar to LIFE + EUTROMED must sign a Voluntary Agreement where specific actions and duties from both parts are listed. Among the commitments and benefits collected in the agreement with the EUTROMED project we can cite the following:

Commitments of the agreement for the farmer:

- Allow the installation of filter structures and the take of necessary measures in their ground of land utilization.
- Do not interfere with the filters installed throughout the whole project.
- Adopt good fertilization practices, following the indications of the project officers.
- Assist to the formative sessions organized in the framework of the project.

Benefits of the agreement for the farmer:

- Free specialized assessment regarding its agricultural activities, for the installation of filtering structures and its maintenance, and for the implementation of good agricultural practices

- Free training on several aspects regarding the control of erosion and the preservation of soil used for agricultural exploitation.

Image 5. Importance of farmer´s training.

Installation of vegetal filter models

3. Installation of vegetal filter models

3.1. Inventory and location of vegetal filters.

Once the area of action was chosen (Image 6), we proceeded to the selection and quantification of treatment types as a function of the slope and gully depth, applying different models developed by EUTROMED using stone or steel structures and vegetal fiber filters, as well as plants (vegetal filters), as described below.

For that purpose we implemented a topographic inventory of all the gullies using georerefenciation –by GPS-, and then writing down their coordinates in the field notebook (see sheet model in Annex 1), length, width and depth of each one. All these measures were taken in order to locate every gully in a geographic and administrative context -and to quantify every intervention to follow their evolution.

Image 6. Photo of the zone of action located in the Deifontes district.

3.2. Description of vegetal filters.

The vegetal filters used in the pilot constitute a soft technology of low cost based on the fixation of pre-fabricated systems using vegetal fibers from the zone, such as esparto, straw or others, over which the plants will be placed. These systems work by filtering runoff waters from the slopes, retaining solids dragged and suspended in water, which contain a big amount of nitrates, whereas the progressively planted vegetation will absorb other part of the nitrates dissolved in the water. This is the reason why there is a big interest in obtaining an extended vegetal cover within these runoff lines.

Moreover, prefabricated systems using vegetal fibers minimize the erosive processes by retaining a good part of the dragged solids, constituting the support and necessary enforcement to facilitate the vegetal cover -in zones where its setting up is particularly difficult due to the erosion-, by fixing the soil and seed particles or plant roots among its interstices, and using these structures as matrix and substrate at the same time.

We have established four models described in Tables 1 and 2, and their outlines in the Annex 2.

Table 1: Description of the vegetal filters based on four models -regarding the slope and depth of the terrain.

Model 1	Model 2	Model 3	Model 4
Slope <10%	**Slope 10-20**	**Slope >10%**	**Slope > 10%**
Depth <0,5m	**Depth 0,5-1,0 m**	**Depth >1,0 m**	**Depth >1,5m**
Description of the treatments			
Series of 4 biorolls of esparto, of 15 cm diameter and 3 meters in length will be placed transversally to the water flow every 5 m from each other, ending with a fifth esparto bioroll of 30 cm diameter,- supported by a flexible gabion of 2 -3m length, filled with stones of 30 cm diameter	series of 4 biorolls of esparto of 30 cm diameter and 3- 6 m length, fixed transversally to the water flow every 3 m from each other, ending with a fifth bioroll supported by a flexible gabion filled with stones of at least 30 cm diameter and variable length.	Over the gully previously filled and mechanically profiled, an organic layer will be placed, over which series of esparto biorolls of 30 cm. diameter and up to 6 me in length will be installed, transversally to the water flow, every 3 meters from each other, on the top of flexible gabions of variable length.	Series of steel palisades sheathed in reinforced organic layer, type E3R, of variable width and height, accompanied by biorolls over the margins, fixed through tensioners transversally to the water flow, joining this structure to any of the former models, and at most, - the maximum distance sedimentation filling.

These models will be applied to the gullies indistinctly along all their extent, since it can vary throughout their course regarding slope, terrain structure and accumulated flow, which affects the depth of the gully.

Image 7. Model 1 -using biorolls of 15 cm diameter over rivulets smaller than 15 cm.

Image 8. before and after model 2 using biorolls of 30 cm over flexible gabions in gullies wider than 50 cm.

Image 9. Model 3 using gully fill of 1 meter and cover of layer, biorolls and flexible gabions.

Image 10. Model 4 using steel palisades with closures of layers and biorolls over gullies wider than 1,5 m.

For the application of the first three models (models 1, 2 and 3), the absence of refills of debris, stones or branches is indispensable requisite, otherwise these refills would facilitate the cortical flow drainage causing dragging by the bagging of all the structures installed on top of them. In the development of model 4, only maximum stability is needed in the bottom as well in the margins of the gully, in the point where the fence is located.

Table 2. Schematic model of employed materials for the 4 models.

	Model 1	Model 2	Model 3	Model 4
Slope	**< 10 %**	**10 - 20 %**	**> 10 %**	**> 10%**
Depth of the gully	**< 0,5 m**	**0,5 – 1,0 m**	**> 1,0 m**	**> 1,5 m**
Series:				
Nº of biorolls in row	4	4	1	1
Diameter of bioroll	15 cm	30 cm	30 cm	15 cm
Length of bioroll	3 m	3- 6 m	3- 9 m	Variable
Organic layer (m2 minimum)			12 – 33 m2	Variable
Metallic fence				1
Distance between biorolls	5 m	3 m	3 m	Variable
Bioroll ending the series	Bioroll of 30 cm diameter over flexible gabion filled with stones of 30 cm. diameter.		Flexible gabion filled with stones.	

The cultivation of vegetal nitrophilous species is realized on top of these structures, in a ratio of 2 or 3 units per meter.

Image 11. Placing of the plants on top of the structures.

The selected vegetal species must comply with the following requirements:

- High fertilizer absorption-capability.
- Fast development, small size and good propagation rate, without becoming invasive or competing with the trees.

- Abundant secondary roots that contribute to its attachment to the soil, as well to the solid fixation and water percolation, without becoming competence for the crops
- Resistance or lack of feeding interest for rabbits or rodents, whose presence could significantly affect the vegetal development.
- Availability in the nursery-garden.

Plants proper for these purposes are numerous among the family labiatae and poaceae, such as:

- *Lavandula latifolia.*
- *Rosmarinum officinalis.*
- *Santolina chamaecyparisus.*
- *Thymus mastichina.*
- *Thymus zyggis.*
- *Stypa tenacissima.*
- *Lygeum spartyum.*
- *Cynodon dactilon.*

In our experience, Santolina chamaecyparisus has become very advantageous, because -aside its compliance with all the requirements described-, it shows very low appeal to the rabbits.

Image 12. Nitrophilous plants: ***Lavandula latifolia, Rosmarinum officinalis, Santolina chamaecyparisus.***

In a nutshell, the selection of nitrophilous species must be carried out following the phytosociological characteristics of the zone, cultivation requirements and characteristics of the soil (slope, soil, humidity, presence of rodents and rabbits, etc.), implementing their plantation or sowing on top of the filter structures and gullies.

As it is well known, the main cause of nutrients arriving to surface waters is the process of erosion-runoff (Alvarez-Benedi et al 2005). Diminishing these processes would not only –in principle- prevent the eutrophication but also preserve soil fertility. To achieve that, we will adopt the models described in Tables 1 and 2, with the installation and fixation of flexible gabions, biorolls and organic layers, in each case, with the help of machinery to plow the land and manpower.

Moreover, the growth of nitrophilous vegetation, with a good capability for development under the required conditions, increases the nitrate assimilation rate and favors the growth of root-associated denitrifying bacteria.

Thus, the runoff generated in the surface of the terrain due to precipitation, will dissolve and drag the nitrates present in the soil, where it will come across the vegetal filters, which will act by blocking the erosion and retaining the nutrients. The nitrophilous plants will remove or assimilate nitrates and other nutrients through two ways: during their own growth and development as nitrophilous vegetation, and because of the activity of the denitrifying bacteria, which transform nitrates into nitrogen gas.

Thanks to the proposed technology, the initial runoff -rich in nitrates and other nutrients- would be mitigated in regards of the quality and quantity of transported water, and also it would impact positively on the reduction of solids and sediments in suspension, and therefore its capability for terrain abrasion. Posterior sampling will determine, through proper data analysis, the efficiency of this process.

Image 13. Sampling points for the measurement of system efficiency over gully 51: treated sample to the right and control sample to the left.

3.3. Installation procedure for vegetal filters.

Once all the gullies are inventoried and all the descriptive outlines of the proposed models are followed, we can proceed to the treatment and installation of the vegetal filters. To achieve such purpose, first all the units of required materials will be quantified as follows: ml of biorolls, m^2 of organic layers, ml of flexible gabions, m^3 of stones, m^2 of metallic frame and nº of pikes or tensioners needed for its attachment. Also, most adequate vegetal species for that goal will be identified and its number, as explained above.

For the installation o vegetal filters on the terrain the procedure is as follows:

1. Natural vegetation will be taken into account and preserved as much as possible, as well as structural elements such as rocks or stumps, which can supply stability and biodiversity to the gully.

2. The installation will begin with the opening of fixation ditches or the attachment of biorolls and gabions, which will have a depth equal to at least half the diameter of the gabions or the biorolls, since the proper measurement of the depth and length of the ditches is mandatory, because it is very important that the tips of these structures stand higher than its medium points, in such manner that, in the concavity formed between both tips and its medium point there must be section enough to hold the maximum flow at this point. Anyways, these tips must no surpass the natural terrain, or surpass it at the minimum extent to avoid becoming an obstacle for the transit of machinery during agricultural labor.

Image 14. Installation of biorolls of 15 cm diameter (model 1) in tying ditches: importance of the maintenance of central drainage capacity.

3. It must be ensured that these structures will not become an obstacle for the water flow but in a slight level difference, which can be overcome by the water flow passing over the gabion or bioroll surface with a slight jump with minimum impact on its course.

Image 15 . Sediment retention in the bioroll-gabion structure in the watercourse.

4. In the case of the sections for the development of the model 3 the installation will begin with the filling of the gully, using the land from its margins by pushing it inwards, then compacting the soil removed and profiling the gully to dissipate the runoff by rolling it into a larger surface. Next, transversal tying ditches will be excavated, keeping a distance between them in function of the slope and location convenience. In our case the ditches were placed at a distance of 3 to 5 m.

Image 16. Filling and profiling of gullies in Model 3.

Image 17. Filling of flexible gabions.

5. In model 3, after the opening of tying ditches and the filling and profiling of gullies, and before the installation of biorolls and flexible gabions, the placing and fixation of organic layers will be carried on, provided –preferentially- with reinforced sun-resistant nets (Bonterra 2E3R or 2K3R types), whose characteristics are listed in Annex 2. These layers fulfill the function of fixing the bare mobilized soil, retaining fine particles and seeds permanently. During their installation the following steps must be take into account:

- All the layers must be in full contact with the soil without tension, by retiring from underneath them all the elements that can potentially prevent its adherence -such as stones, debris, branches, etc

- Water flow into the treatment must be secured; a small longitudinal ditch will be excavated in the margins of the treatment, on both sides of the gully, to attach a layer with small corrugated U-shaped steel staples of 6- 8 mm diameter and 15 cm length, and then covered with the excavated land.

- Also, while allowing water flow, special attention must be paid to the rivulets reaching the gully, to avoid water filtration beneath the layer.

- Finally, the whole surface covered with layer will be attached to the ground using the U-shaped steel staples above described, applying 1 staple per m^2.

Image 18. Installation of organic layers, biorolls and flexible gabions in ditches excavated in the filling of the gully (model 3).

6. Anyways, to attach the biorolls and flexible gabions, steel corrugated pikes will be used, -of 8 to 10 mm diameter and a length equal to at least double the size of these structures, i.e., for biorolls or gabions of 30 cm diameter, the pike must be longer than 60 cm. The pikes will be placed preferentially in pairs, on both sides of the structures, or on the top of them, wrapped up in galvanized wire which will provide them tension. .

7. In model 4, structures based on lattices of corrugated steel will be used, of 15 x15 cm and 12 – 14 mm diameter, with a height no bigger than 1 m, cut in situ in segments to suit the

section of the gully, which will be placed tilted on the ground with a slope of approximately 70º, in which center the dump will be cut, tailored to fit the maximum flow calculated for that point. On the base of that tilted structure, a lattice of the same characteristics will be placed, previous manual grading and leveling, cut in an unique segment not smaller than 2 m of length and of the same width as the graded surface, in order to serve as support and anchorage or the tilted structure through straps and pikes of the same type of steel.

Image 19 . Development of the metallic fence in model 4.

8. The whole aforementioned structure will be lined internally -as a bagging- with layers of the same type cited for model 3, then it will be attached to the tilted fence and to the walls of the gully, underneath the anchoring base structure. Over the vertices of the tilted structure, -right in the junction of the gully walls and the bottom- a bioroll of 15 cm diameter will be placed, which -by being extended over the tilted structure-, will enforce these points, preventing –in case of overflowing- the lateral and vertical undermining of the structure.

Image 20. Model 4 metal palisade built into the gully.

Maintenance of the vegetal filters

4. Maintenance of the vegetal filters

Before talking about the maintenance of the vegetal filter models applied to diminish the processes of eutrophication and soil erosion above described, it is important to explain the relevance of keeping and favoring the presence of vegetal cover as the first and essential filter to prevent surface runoff.

4.1. Development of vegetation cover.

The development of a vegetal cover in crops such as olives must be carried out at least over two third parts of the width between the trees, perpendicular to the slope of the terrain and forming strips of herbaceous plants. These strips will act as small barriers against the surface runoff, enhancing the filtering and rolling of runoff water and avoiding erosion processes and loss of fertile soils. Thus, in Olive groves or other crops with slopes bigger than 10%, the placing of vegetal covers becomes essential, as it can be deducted from the benefits listed in the following Table:

Table 3 . Comparative diagram of beneficial effects of the presence of vegetal covers in slopes.

OLIVE GROVES IN SLOPES WITHOUT VEGETAL COVER	OLIVES GROVES IN SLOPES WITH VEGETAL COVER
Rain drops impacting on the ground break soil structure and disaggregate soil in tiny particles.	Vegetation protects the soil from rain drops and enhances its structure preservation.
Water speed up in slopes and drags part of the disaggregated soil, which causes the **loss of the most fertile horizon of the land.**	The soil keeps its structure; it is well consolidated and **is not dragged by the water.** The root systems keep it together.
The soil **decays in organic matter content**, since the fertile layer is dragged by the water.	The soil **increases its organic matter and its organic nitrogen contents** when soil biodiversity is favored.
Water forms **rills and gullies** which become deeper, becoming an obstacle for agricultural labor.	Vegetation **favors water filtering into the soil and avoids the formation of rills and gullies**. This allows a higher availability of water for the Olive grove.

Although the development and conservation of the vegetal cover is essential to implement a good management which will allow us to obtain all the benefits listed. This, three types of vegetal covers can be established for the Olive grove:

1) Cover of spontaneous species. Consists in letting the spontaneous weeds grow, eliminating through a selective herbicide –or most recommendable, using a brush cutter- those species causing more problems to the crop, -as usually are the wide-leaf species-, in such way that the narrow-leaf grasses will remain.

2) Cover of sown species. Consists in the sowing of herbaceous plants in the Olive roads. It must be implemented during the fall, with the first rains. The more suited species for this purpose are:

- Grasses: *Hordeum vulgare* (barley), *Avena sativa* (oat), *Triticum spp.* (wheat).
- Legumes: *Vicia sativa* (vetch), *Vicia ervilia* (ervil), *Trifolium sp.* (shamrock).

The remaining species legumes are less durable -in the soil- than the grasses, but the legume covers present the advantage of fixing atmospheric nitrogen in the soil and they can be used as green compost.

3) Mulch (Inert cover). Consists in placing a cover with the debris generated during the agricultural activity (pruning previously chipped, wiped leaves, stones, etc.).

For all vegetal cover it must be taken into account the following:

- If the development reached by the vegetal cover alive represents competence for water, it must be eliminated in spring season (March-April). The removal can be done through chemical mowing (herbicides) or mechanical mowing (brush cutter), becoming necessary to leave the vegetal debris over the terrain to allow its role as mulch.

- It is not advisable the passing of harrow over an Olive grove located in a slope, because the topsoil layer would be removed and all the accumulated vegetal remains would be dragged, running under the risk of disappear with the first autumn rains causing the loss of the most fertile layer of the soil.

- If there are rill or gully formations, their control becomes indispensable, through the implementation of any of the already described models, which will work as obstacle or filter to diminish the speed of the water flow, increasing the sedimentation, and avoiding -at the same time- the increasing of their width and depth.

Image 21. Spontaneous vegetal cover and mulch composed mostly of crushed branches.

4.2. Conservation of installed vegetal filters.

The maintenance of the technology planted in the rills and gullies is so important as its installation, because it secures its correct functioning throughout time and the achieving of the intended goals: the mitigation and control of the loss of fertile soil and the retention of fertilizers.

To ensure the correct functioning of the vegetal filters, the following recommendations must be followed:

As general rule, it is advisable to interfere as little as possible in the gullies and vegetal filters planted, to keep their maximum hydraulic capacity and channel roughness, in order to laminate the runoff as much as possible, enhance the filtration and to progressively increase the sedimentation without affecting the growing biodiversity being planted until the sustainability of the new natural drainage system is reached.

Image 22. Example of filter structure planted in a gully without interference.

Due to the above explained, the new drainage system is considered very vulnerable to regular actions of agricultural activity such as the application of pesticides -which would affect the desirable proliferation of beneficial flora and wildlife-, or the agricultural labor and harvest -which would affect the restoration and consolidation of the drainage structure.

It is particularly advisable to avoid using heavy machinery, (vehicles, tractors, trailers, tanks, boogies, etc.) over the set bio-roll-gabion of stone and nitrophilous plants

It is emphatically recommended to avoid direct contact or contamination of the plants established on the top of the gullies, especially if they are located in the exterior surface of the structures, since the roots will constitute the permanent filtering matrix of the models.

Image 23. Impact of the herbicides over the planted and spontaneous vegetation during the development of a treated gully.

If brush cutters or grinders are used, they cannot be passed over the biorolls, although they can be passed over the vegetation of the rest of the gully if it does not alter its course neither it leaves the soil uncovered.

Image 24. Damage caused by the use of machinery over the filters in the gully.

- If branches are burnt, a safety distance should be taken from the gully and the biorolls, to avoid the burning of the established plants or the structures. We must keep in mind they are made of vegetal o synthetic fibers which are highly combustible.

- Do not pile up branches, stones or debris on the top of the gullies or filtering structures, since they affect their capacity to drainage, favoring the obstruction of the flow and side overflows in the pile up or spill points.

Image 25 . Piling up of branches on top of the filters is a very common example of malpractice.

After the installation of the filters, careful monitoring of their evolution will be carried on, after the first rains and successive downpours. If, by any chance, a structure would be moved o shifted away, the company responsible for its installation will be notified immediately; a guarantee period of at least two yeas must be stipulated during which the structures will be reinforced and secured, and the plants will be reseeded or replaced until reaching their definite stabilization to achieve their function of filtering.

Image 26. Reseeding grasses over unborn zones.

After the guarantee period – if there were any- or after the two years since its implementation, an -at least- annual periodical check should be implemented, to detect if there is pike loose or any structure shifted away. In that case, they will be reinstalled or reinforced until the plants and retained soil particles become intertwined with them.

For a better monitoring and control of the state of each filter structure, it is necessary to keep a field notebook (Annex 1), in which every defect or damage found will be annotated, its cause, repairmen done and its date, etc. with the goal of determining the incidence and recurrence to propose new solutions.

4.3. Management of field notebook for the control of installed vegetal filters.

To achieve a rational conservation of the installed filters its is advisable the use of a field notebook which can be done using the field sheet model shown in Annex 1, using one sheet for each gully under treatment.

The gullies will be inspected by a technician responsible of their installation and/or maintenance throughout the whole basin. In first place, the name of the land owner will be mentioned, whom having subscribed the cooperation agreement, is responsible for the management of the vegetal covers on the crop and correct application of the technical implementations over the gullies. At the same time, the name of the property and municipal cadastre (TM) will be annotated, in order to facilitate its administrative dependence.

For their initial geographic identification and status, every gully will be numbered and staked by recording its coordinates at the beginning and at the end of the gully, according to the direction of the trail,- if it is ascending or descending, to establish order and numbering for each treated point or point selected for treatment; in the latter case, the depth of the point will be measured previously to its treatment, and then the type of structure installed will be quantified (bioroll 15 or 30 cm. diameter, organic layer, flexible gabion or fence, etc.).

The same sheet offers the possibility of annotate 3 controls or follow ups, which are to be done during the next two years of minimum maintenance after installation: two inspections after the first heavy rains and after the winter or spring rains, and the third one, during the second year after the rain season.

The requirements or defects found during the inspections will be annotated in order to implement the corrections as follows:

- New installation (re-installation), which involves not only bringing new materials (in case the original materials were dragged away) but also the requirement for new structures.

- Replacement of any element detached or dragged away, for which is necessary to bring new materials for required enlargement, improvement or anchoring reinforcement.

- Broken elements or structures, which require replacement or repair.

- Detachment, for which only re-attachment of the structures is needed, or the insertion of some elements to prevent the detachment, such as stones, or pieces of layer to work as plugs.

- Bypass, produced often by the obturation of the draining capacity of the structures due to the dumping of branches or debris, which requires many times the relocation or enlargement of the structures.

- Lack of vegetation, which usually comes associated with agricultural malpractices regarding the control of applied herbicides or the appearance of rodents or rabbits which will block the consolidation of the vegetal filters and the decay of their filtering capacity and runoff water purification. A more strict control on herbicide application or the utilization of animal repellents must be implemented (by example predator feces), as well as a reseeding or replanting.

Agricultural malpractices on the gullies due to the indiscriminate use of herbicides or phytosanitaries, utilization of heavy machinery over the gullies -causing the filter destruction or the water course deviation, the dumping of branches, etc.

Remarks, in the first place regarding to the particulars of every structure, such as the advancement (A) of retreat (R) in the process of structure consolidation, or general comments regarding the need to communicate with the owner or tractor operator for the improvement of the agricultural labor or to establish new agricultural practices.

Image 27 . Monitoring of filters to test their adherence after the first rains.

Conclusions

5. Conclusions and proposals

With the adoption of good agricultural practices and the utilization of the models of vegetal filters developed by the LIFE+ EUTROMED project, the following can be achieved:

- The stabilization of the gullies until their naturalization as gorges and ravines.
- Soil conservation through the reduction of fertile soil losses.
- Savings in fertilizer application in the crops and the reduction of losses by runoff or percolation.
- The improvement of soil humidity content in the gully environment.
- Increased recharge of the aquifers (wells) of the environment.
- The reduction of sediments concentration and fertilizers in the troughs.
- Creation of points to facilitate the transit of machinery and avoid the fragmentation of the land.

- Promoting biodiversity through landscape formation and the increase of the presence of micro and macrofauna, particularly birds.

- Savings in costs of the agricultural activity and the maintenance of productive capacity.

In any case, conservation work of the treatments implemented will always be required until at least achieve a vegetal cover which represents minimal competition for the crops, adapted to these environments and protecting -at the same time- the bed and margins of the gully from soil erosion decisively.

For all these reasons, help-lines for public investment must be encouraged and taken advantage of-, for the restoration and conservation of agricultural drainage structures, such as gullies and ravines, since they improve the environmental quality where they are built, and above all, they prevent the risk of flooding of downstream populations. However, it is fundamental the creation of environmental awareness regarding the caring and conservation of our agricultural and natural environment by the farmers and inhabitants.

Glossary

6. Glossary

Bioroll: Cylindrical structure composed of a bag of coir net or polypropylene mesh, or polyamide with multifilament or not, filled with natural fibers (by example esparto, coir or straw) very compacted , of variable lengths and diameters, used fundamentally for the protection of the water flow margins and as fascines for the restoration of slopes. They are recommended for places under high and very high erosion pressures.

Erosion: Natural process of cyclical movement followed by surface soil materials caused by impact, disaggregation, dragging, abrasion and sedimentation, leading to the gradual loss of soil's original quality.

Eutrophication: Excessive nutrient enrichment in the water, accompanied of an elevated consumption of these nutrients by algae and aquatic plants, leading to oxygen depletion and loss of biodiversity.

Gabion flexible: Consists of a synthetic sack (polypropylene or polyamide) of multifilament weather-resistant, of variable diameter and length, which can be stitched to each other and, once is totally filled with gravel of grain-size fitted to the diameter of the net-, it is applied for the protection of margins and riverbeds in places under high erosion pressures, showing a great advantage due to its malleability and adaptation to irregular beds, as well as its adaptability to the undermining caused by vertical erosion.

Gorges or ravines: Natural drainage of varying depth with vegetation concentrated on a slope, which serves as eventual channel for rainwater; during its degradation it becomes a gully.

Gully: Incision produced on soil -bare or with scarce vegetation- due to the concentration o water flow, causing destabilization of the terrain and its surroundings.

Organic layer: Organic layers are flat structures made of natural fibers (esparto, straw, coir, etc.) inter stitched with synthetic (polypropylene) or natural (jute or coir) nets utilized to prevent erosion, by increasing the bed roughness and diminishing the flow rate, enhancing water filtration in the terrain, mitigating the runoff by working as vegetal cushion, and being incorporated by the soil thereafter, buffering soil's temperature, diminishing the evaporation of retained water, increasing microbial activity and cationic exchange, and promoting -through all this- the implantation of vegetation.

Rivulet: Gully of depth lesser than 50 cm.

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Annex

Annex 1. Model of field notebook sheet.

PROPERTY				LAND		TM			
GULLY		LENGTH		COORD. HEAD		COORD. BASE		Nº ORD. UP	Nº ORD. DOWN

TRANSVERSAL STRUCTURES

INSTALLATION	Nº Order	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Transversal Struct.	DEPTH																																								
B15	LENGTH																																								
B30	LENGTH																																								
G30	LENGTH																																								
E3R	m2 inst.																																								
Lattice	LENGTH																																								
	HEIGHT																																								
CONTROL	NEW INST.																																								
DATE	RESET																																								
	BROKEN																																								
	MSMTCH																																								
	DERIVATION																																								
	LCK VEG.																																								
	MALPRCT																																								
	OBSERV.																																								
CONTROL	NEW INST.																																								
DATE	RESET																																								
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CONTROL	NEW INST.																																								
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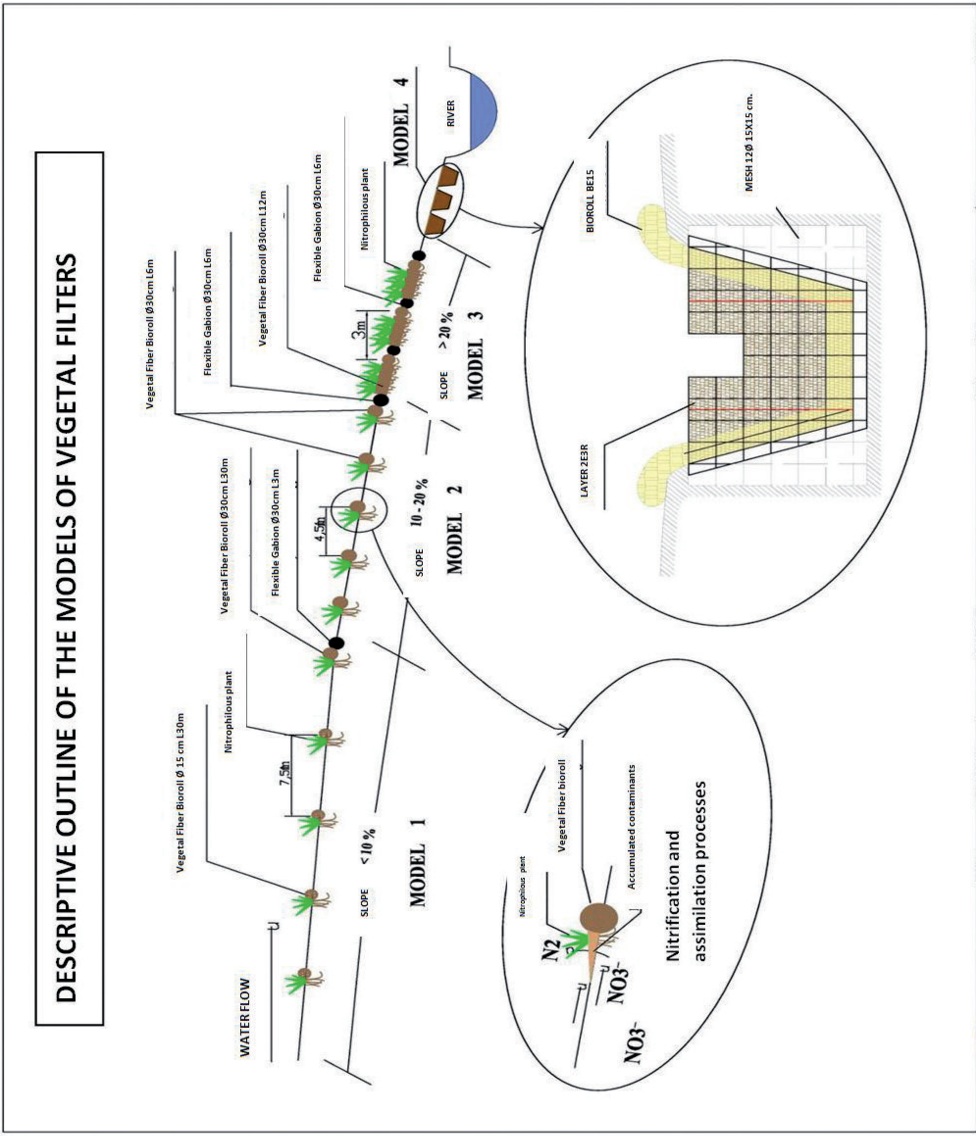
	MISMTCH.																																								
	DERIVAT.																																								
	LACK VEG.																																								
	MALPRCT.																																								
	OBSERV.																																								
ON CALL- OBSERV.																																									

Annex 2. Descriptive outline of the vegetal filter models.



Annex 3. Technical specifications of the employed products.

PRODUCT INDEX

BIOROLLS:

- **BONTERRA BE15.**
  - **Description.**
  - **Technical specifications.**
- **BONTERRA BE30.**
  - **Description.**
  - **Technical specifications.**

ORGANIC LAYERS FOR CONTROL OF EROSION:

- **BONTERRA 2E3R.**
  - **Description.**
  - **Technical specifications.**

BONTERRA BE15

BIOROLLS are cylindrical structures made of natural fibers wrapped up in coir or polypropylene nets. Biorolls enhance the implantation of species by direct planting into the bioroll structure, as well as the emergence of spontaneous riparian vegetation due to the control over erosion exerted by this type of structures on the riverbanks.

Biorolls offer very efficient solutions for the restoration of riverbanks and directional of water flow, such as fascines for the restoration of slopes and as flexible elements for sediment filtration.

Advantages of their utilization:

- They can hold water flows of higher energy (>1.5 m/s), surpassing 2.5 m/s when colonized by vegetation.
- They constitute an immediate work of biological engineering of intended ecological approach.
- They offer big tolerance to drought and flooding.
- Biorolls provide a refugee zone for mammals and invertebrates.
- Biorolls offer immediate embellishment of the landscape after their installation.

<table>
<tr><th colspan="4">BONTERRA BE15: Technical Specifications</th></tr>
<tr><td rowspan="3">APLICATION AND CONDITIONS</td><td rowspan="2">Riverbanks</td><td>- High erosion (v >1.5 m/s)</td><td rowspan="2"></td></tr>
<tr><td>- Very high erosion (v > 2.5 m/s)
- Colonized by vegetation</td></tr>
<tr><td colspan="3">Slopes higher than 1/3 o 1/2</td></tr>
<tr><td>COMPOSITION</td><td colspan="3">- 100% esparto fiber
- Polypropylene mesh</td></tr>
<tr><td>PRESENTATION</td><td colspan="2">Cylindrical pieces</td><td>Lentgh: 3 m
Diameter: 15 cm</td></tr>
<tr><td rowspan="2">STRUCTURE</td><td>Mesh or net (exterior)</td><td colspan="2">- Polypropylene
- Color: black
- Weigth: 13,5 g/m
- Resistance: 15 Kg/100 mm</td></tr>
<tr><td>Esparto fiber (int.)</td><td>Weight</td><td>Aprox. 3,5 Kg/ml.</td></tr>
</table>

BONTERRA BE30

BIOROLLS are cylindrical structures made of natural fibers wrapped up in coir or polypropylene nets. Biorolls enhance the implantation of species by direct planting into the bioroll structure, as well as the emergence of spontaneous riparian vegetation due to the control over erosion exerted by this type of structures on the riverbanks.

Biorolls offer very efficient solutions for the restoration of riverbanks and directional of water flow, such as fascines for the restoration of slopes and as flexible elements for sediment filtration.

Advantages of their utilization:

- They can hold water flows of higher energy (>1.5 m/s), surpassing 2.5 m/s when colonized by vegetation.
- They constitute an immediate work of biological engineering of intended ecological approach.
- They offer big tolerance to drought and flooding.
- Biorolls provide a refugee zone for mammals and invertebrates.
- Biorolls offer immediate embellishment of the landscape after their installation.

BONTERRA BE30: Technical Specifications			
APLICATION AND CONDITIONS	Riverbanks	- High erosion (v >1.5 m/s)	
		- Very high erosion (v > 2.5 m/s) - Colonized by vegetation	
	Slopes higher than 1/3 o 1/2		
COMPOSITION	- 100% esparto fiber - Polypropylene mesh		
PRESENTATION	Cylindrical pieces		Lentgh: 3 m Diameter: 30 cm
STRUCTURE	Mesh or net (exterior)	- Polypropylene - Color: black - Weigth: 33 g/m - Resistance: 24 Kg/100 mm	
	Esparto fiber (int.)	Weight	Aprox. 10 Kg/ml.

ORGANIC LAYERS FOR CONTROL OF EROSION

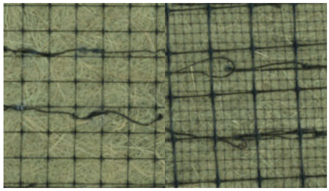
Organic layers absorb the energy coming from erosive particles such as rain drops, hail, snow or wind particles.

- They increase soil's ability for water retention by avoiding losses by evaporation.
- Regulate soil's temperature by buffering its exposure to cold-warm cycles.
- Within a period of time (T), organic layers are incorporated into the soil forming together with it an organic horizon.
- They work as complements of auxiliary elements on site such as curbs, gutters, pitchings, etc
- Organic layers reduce conservation costs by avoiding the grounding of gutters and drainages.
- OL allow to reach a finish level with a whole landscape integration
- Easy installation and reduced costs.

BONTERRA 2ER3

ESPARTO ORGANIC LAYER - DOUBLE DENSITY AND THREE REIFORCEMENT NETS

BONTERRA 2ER3: Technical Specifications

APLICATION AND CONDITIONS	- Coating of green fences - High erosion in rivulets (<2,5 m/s)		
COMPOSITION	- Natural: 100% Esparto (Approx. density: 800g/m2) - Synthetic: polypropylen (Density 89,74 g/m2)		
PRESENTATION	**Rolls**	Length: 50m Width: 2,40m Diameter (approx.): 0,50 m	
STRUCTURE	**Strand:** Polypropylene (PP) 1000 den. Treatment UV	Weight: 3,33g/m2. Color: black Tenacity: 4,12g/den	
	Mesh on both sides + intermediate mesh between the top mesh and the polypropylen fiber Treatment UV	Inferior mesh: Black polypropylen Weight: 19,53g/m2 Grid size: 19,54 mm x 19,54mm Longitudinal traction: 2,106 KN/m Transversal traction: 2,163 KN/m	
		Intermediate mesh: Black polypropylen Weight: 18,06g/m2 Grid size: 6,86 mm x 6,35mm Longitudinal traction: 2,062 KN/m Transversal traction: 1,810 KN/m	
		Top mesh: Polipropileno negro Weight: 48,82g/m2 Grid size: 31,75 mm x 31,75mm Longitudinal traction: 3,829 KN/m Transversal traction: 4,763 KN/m	
MEDIUM TRACTION	Longitudinal 9,34 KN/m		
	Transversal 8,14 KN/m		

TECHNICAL CHARACTERISTICS OF THE NET FOR MANUFACTURING GABIONS (1)

NOMENCLATURE: m2. High Tenacity Polyamide Net.

COMPOSITION: High- tenacity polyamide yarn with knots manufactured on frame-level, with strand thickness of 3 mm and net width of 35 mm knot to knot. It carries a polyester net of high tenacity of 8 mm, stitched throughout the whole perimeter.

TECHNICAL CHARACTERISTICS:

- Maximum anti-solar treatment.
- Outdoor durability: more than10 years
- Specific weight: 180 g/m2.
- Braid breaking strength: 210 Kg.
- Perimeter corde- breaking strength: 1.050 Kg.
- Melting point: 260 ºC.
- Water absorption: 0, 4 %.
- Resistant to oil, acid and organic solvents.
- Resistance to Sun Light: Excellent.
- Resistance to Abrasion: Excellent.
- Resistance to outdoors exposure: Excellent.
- Their properties do not vary under prolonged exposure to sun, water or other agents.

CHARACTERISTICS OF GABIONS

- Monotubular flexible gabion of High-tenacity Polyamide Net with technical characteristics above described. Diameter: 30 cm. Length: 2 and 3 m.

NET TECHNICAL CHARACTERISTICS FOR MANUFACTURING GABIONS (2)

Description: UD. NET W/KNOTS.

Construction: Net without Knots System Raschel Double Needle Bar.

Thickness of net strand: 3 mm.

Shape of grid: square.

Size of grid: 30 x 30 mm.

Perimetral configuration: Sewing Overlock composed by PPM rope- strand and polyester strand.

Raw material: High Tenacity Polypropylen Multifilament (PPM). 300 Kilo-langleys.

Properties of Polypropylen AT.

- Ecological. Recyclable 100%.
- Good thermal insulator.
- Specific weight: 0, 91 (lower than water).
- 100 % inert, anti-bacteria.
- Anti-allergic.
- It does not accumulate static electricity.
- Not edible by insects.
- Anti-absorbent fiber – Dust-resistant.
- UV ray- protected.
- Abrasion- resistant.
- Good electrical insulation.
- Acid-resistant (except boiling xylene).
- It retains its tenacity in humid and alkaline environments.

GABIONS CHARACTERISTICS

- Monotubular flexible gabion of PP multifilament mesh with the technical specifications above described. Diameter: 30 cm. Thickness of the strand: 3 mm. Grid size: 30 x 30 mm. Length: 2 and 3 m. Color black.

PARTNERS OF THE PROJECT

Coordinator:

Diputación de Granada

Granada es Provincia

Associates:

paisajes del sur

BonTerra® Ibérica S.L.

ugr | Universidad de Granada

Co-Sponsor:

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