Thematic Areas: BIOENGINEERING OF SOIL

NEW SCENARIOS FROM ECOLOGICAL RESTORATION WORK TO CONTAIN THE RISK OF DESERTIFICATION IN CUSTONACI

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Resumen

The first interventions aimed at limiting the risk of desertification has been an opportunity for more related approaches to the ecology and the circular economy. In particular, the techniques have been applied with innovative variations to fit the best in the ecological context. The choice of native species is fundamental: they recolonized the area decreasing the risk of the prevalent invasive species. The terracing has recovered the considerable volumes of cyclopean stones. The positioning of the biomat in jute, has blocked volumes of biomass from pruning in order to enhance, for the soils, the organic content. In addition, coupled with the bio-rollers with vine shoots, it has evolved the traditional technique of pre-seeded fascine. The hydroseeding operations have added seeds of the local germplasm, while those of hydromulching have reused posidonia stabilized on site Multidisciplinary monitoring (botanical, ecological, erosive, pedological, already started during construction) and maintenance have been ongoing for over 3 years. All the interventions have been perfectly successful: the area now has a very high plant cover and better floristic quality and the ecosystem approach opens up new scenarios (technosoils, mulch from posidonia, bio-rollers, etc.) of research and with possible interactions for the marble, vine and bathing industries.

Abstract

The realization (2014) of the "First interventions aimed at limiting the risk of desertification in the sub-urban Portella del Cerriolo Park" (Custonaci, TP) has been an opportunity for more related approaches to the ecology of the site and of the circular economy. In particular, the techniques (Dry Sowing of Seed & infructescences, Hydroseeding, Hydromulching, Slope Fascine & Biorollers, Branch Layering of Gullies, Planting, Slope Protection Biomat & Organic Pillows, Vegetasted stone walls and Cyclophoidal walls) have been applied with innovative variations and in order to fit the best in the ecological context. The choice of native species, identified thanks to an accurate floristic study, is of fundamental importance; they recolonized the area, decreasing the risk of the first prevalent invasive species. The terracing has recovered the considerable volumes of stone, even cyclopean, deriving from the overlying quarries. The positioning of the biomat in jute, has blocked volumes of biomass

from pruning in order to enhance, for the soils, the organic content. In addition, coupled with the bio-rollers with vine shoots, it has evolved the traditional technique of pre-seeded fascine. The hydroseeding operations have added seeds and flowers from the collection of the local germplasm, while those of hydromulching have reused posidonia stabilized on site for at least 14 months with low salt content. To the posidonia residues have been added pruning lawns from the maintenance of urban green and citrus. Multidisciplinary monitoring (botanical, ecological, erosive, pedological, already started during construction) and maintenance have been ongoing for over 3 years. All the interventions have been perfectly successful: the area now has a very high plant cover and better floristic quality and the ecosystem approach opens up new scenarios (technosoils, mulch from posidonia, bio-rollers, etc.) of research and with possible interactions for the marble, vine and bathing industries.

1. Introduction

The Anthropocene and Climate Change accelerates the severity of soil loss due to erosion and the advancement of desertification risk. In fact, among the 17 objectives of sustainable development OSS (*Sustainable Development Goals SDGs*) of the Agenda 2030 signed in 2015 by the 193 member countries of the ONU, the sub objective 15.3 is “fight desertification, restore degraded lands, including those affected by desertification, droughts and floods, and fight for a world without soil degradation”. The concept of desertification has progressively evolved over the last few years, trying to define a process that, although characterized by local causes, assumes a connotation of a global problem. The UNCCD (*United Nations Convention to Combat Desertification,* 1996), describes desertification in terms of degradation, attributable to climatic variations and human activities (deforestation, unsustainable agricultural practices, overpopulation, pollution, overgrazing, etc It derives from it the DDLD (*Desertification Land Degradation & Drought*): a set of methodologies to assess the different social impacts of soil degradation, including concepts related to migratory pressures, biodiversity, ecosystem services, conflicts over scarce natural resources, socio-economic stability and sustainable development, representing an evolution of the concept, exclusively physical, of the model MEDALUS (*Mediterranean Desertification And Land Use).* This approach has so far tried to quantify this phenomenon in

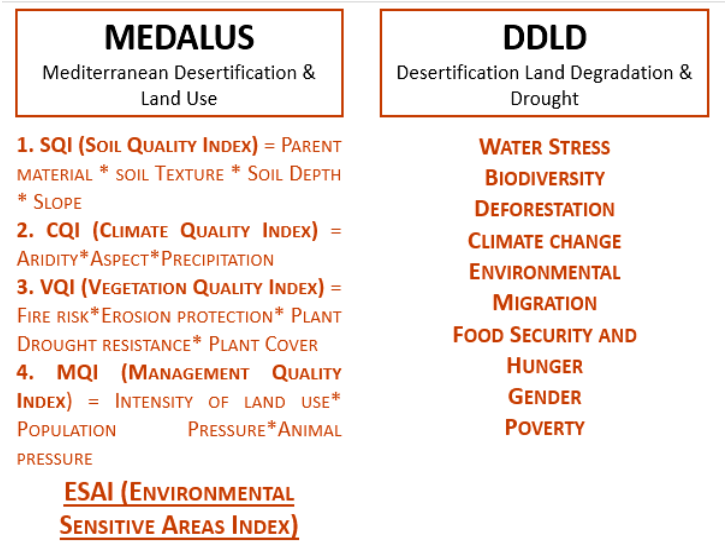

Fig.1 MEDALUS vs DDLD

the Mediterranean area by combining Soil indexes (6 indicators), Climate (3 indicators), Vegetation (4 indicators), Land management (2 indicators) from which the synthetic index ESAI (Environmental Sensitive Areas Index).
The project "First interventions aimed at limiting the risk of desertification in the sub-urban Portella del Cerriolo Park" in Custonaci (Trapani, Italy), although realized in 2014 with POR SICILIA 2007/2013 funds (Measure 2.3.1.B) it is already projected in this direction. It employs techniques related to soil bioengineering, but with a help that comes from the sea for the realization of technosoils, now our researched object to combat desertification. Different methods and mixtures have been studied and tested for use in degraded and soil-poor areas (quarries, landfills, etc.) with antrhopogenic soils, derived from beached biomass of Posidonia oceanica, vegetable wastes, urban pruning, vermicompost and, in the future, digestate, excavation lands, and FORSU (Organic Fraction of Urban Solid Waste).

2. Objectives of the case study at Portella del Cerriolo.

Custonaci is, according to the MEDALUS model, the second municipality at risk of desertification in Sicily, which is the region at greatest risk in Europe. Since prehistoric times, today it has a physiognomy of the plant landscape and a floristic composition profoundly influenced by anthropic activities: in particular agriculture and marble extraction. In addition, the coast is affected by considerable strandings of posidonia on the beach; these are a positive factor for the natural defense against coastal erosion, but, on the contrary, represent a problem for tourism and consequent onerous removals, temporary shifts and disposal. The case study, also for the near Monte Cofano Reserve, is important for the conservation of the floristic and vegetational biodiversity in the province of Trapani. The objectives of the intervention are:

Fig.2 Vineyards and quarries at Custonaci

Fig.3 Accumulations of Posidonia beached in Cornino

1. Improvement of the vegetable landscape in coherence with the surrounding landscape and the historical values of the area;
2. Increase of plant cover with a progression of about 10% per year;
3. Increase in the degree of biodiversity (n° rooted species and n° present species) starting from the species with higher resilience (*Chamaeropsis humilis L.*, etc) with a progression of at least one species stabilized per year;

4. "Forced deep rooting" of the planted shrubs with up to 80% improvement in the percentages of rooting with traditional planting (thanks also to the introduction of natural additives in the holes under the plantation hole);
5. Return to the site of non-implanted species autopropagated from outside the area.

3. Employed techniques and innovations

- Dry Sowing: was carried out with seeds of local indigenous species (*Artemisia arborescens, Ruta chalepensis L., Hyparrhenia hirta (L.) Stapf, Euphorbia dendroides L, Lomelosia cretica (L.) Greuter)*. Intervention aimed at speeding up the process of greening by implementing the number of herbaceous species that germinate quickly at the first rains of the autumn season.

Fig.4 Infructescens and seeds of *Ruta chalepensis* collected on site

- Planting of infructescences: Spreading of seeds and infructescences following harvesting from local native species (*Artemisia arborescens, Ruta chalepensis L., Hyparrhenia hirta (L.) Stapf, Euphorbia dendroides L, Lomelosia cretica (L.) Greuter.*
- Sea mulch Hydroseeding: hydroseeding with structuring agents also having the beached posidonia FOS for the mulch. The purpose of this intervention was to ensure rapid plant cover, essential for the fight against erosion. Species used: *Festuca arundinacea, Loietto perenne, Festuca rubra, Loietto italico, Bromo eretto, Cynodon dactylon, Festuca ovina, Poa pratensis, Trifoglio ibrido, Ginestrino tenue,* as well as the infructescences of the species referred to in the prior technique.
- Sea Hydromulching: The FOS of Posidonia has been used experimentally as an organic mulch in hydromulching operations (hydroseeding made using a mixture composed primarily of water and mulch). The mulch is a layer of material, usually organic, that is applied on the soil surface to maintain high soil moisture, improve the bio-chemical characteristics of the soil and hinder the rooting of invasive wild species.The FOS of posidonia used was locally stored minimum from 14 months to 24 months, characterized by a low salt content due to the rainwater that diluted it


Fig.5 Sea Hydromulching with Posidonia FOS

- Slope Fascine & Biorollers: The biorollers, a technique invented for the occasion, are to be considered an evolution of the fascine; they are made by wrapping themselves in a cloth

made of natural fibers, vines or olive pruning in fascine with soil. To promote greening, the biorollers have been pre-seeded and seedlings are planted, as for the fascine. In this case, as a substitute for the plant material and the soil, the technosoil (composted green soil improver) was also produced, starting from the reuse of FOS (Organic Stabilized Fraction) of posidonia and from urban green pruning waste (citrus and mixed species) was also used). For best results, the biorollers were used in combination with the jute biomat spread capable of further limiting surface erosion. Native species have also been used in this case, such as *Artemisia arborescens, Ruta chalepensis L., Hyparrhenia hirta (L.) Stapf, Euphorbia dendroides L, Lomelosia cretica (L.) Greuter.*

Fig. 6 Realization of bio-rollers with technosoils and vines pruning

- Branch Layering of Gullies: Some fascine have been placed in correspondence of the erosion gullies, because these are the points of greatest criticality in the areas subject to desertification. The monitoring of the gullies correspondence has detected that the water runoff has determined that the solid transport part of the surface of the soil blanket was easily trapped by the fascine. This process has not only prevented the loss of land from the area, but has encouraged the continuous accumulation of material in the bundles and therefore the partial closure of the gullies in favor of the subsequent revegetation.
- Pit Planting: Native shrubs and sods with high propagation capacity have been planted (about 3400 plants + 2000 sods) to encourage the consolidation of the slopes with "Forced deep rooting" techniques that significantly improve, up to 80% the probability of survival of plants in hard environments. The method includes placing in depth (L= 1,5 m, hole from 32-40 mm to be performed with drill) of peat additivated with slow release granular fertilizer, containing Magnesium and Iron, and water retentive in quantity and quality depending on the soil characteristics and soil depth. Species used: *Pistacia lentiscus* L., *Artemisia arborescens* L., *Ruta chalepensis* L., *Fraxinus ornus* L., *Chamaeropsis humilis* L., *Ceratonia siliqua, Myrtus communis* L.

Fig.7 Planting with "Forced deep rooting"

- Slope Protection Biomat & Organic Pillows: The organic pillows with biomat in jute were made with vegetation waste coming from the cutting of prunings, earth, stakes and boulders placed in the concavities of the slopes. The upper biomat is designed to retain soil particles. The works are aimed at increasing the water absorption capacity of the soil.

Fig.8 Slope Protection Biomat & Organic Pillows (Before in 2014 and after in 2017)

- Vegetasted stone walls and Cyclophoidal walls: Cyclopean walls were a circular economy intervention because they used only stone material taken locally. The decrease in gradients has allowed to significantly reduce the water runoff speed and therefore the associated erosion capacity. Also, the processes of infiltration of water into the ground have been encouraged, a phenomenon that, in addition to helping to mitigate the erosion exerted by the water, allows increasing the soil moisture, favoring the rooting of the vegetation.

Fig.9 Vegetasted stone walls and Cyclophoidal walls (Before in 2014 and after in 2017)

4. Phases and during of multidisciplinary monitoring

Multidisciplinary monitoring has been drawn up by a team of different professionals (geologists, engineers, naturalists, agronomists) and concerned soil bioengineering, ecology and botany, pedology, hydraulics and erosion risk. It has been divided into three phases, which lasted four years, from 2014, the year of construction of the works, until 2017. It

started in the period between April and October 2014, at a time during which the work was still under way, while from the 5th monitoring with the completed works. A further conclusive technical inspection was carried out in September 2018.

Date Monitoraggi per Scheda						
	PERIODO DI MONITORAGGI	ANNO	INGEGNERIA NATURALISTICA	ECOLOGIA+BOTANICA	PEDOLOGIA	IDRAULICO+EROSIONE
I°	1^	2014	28-apr	28-apr	11-giu	28-apr
II°			10-lug	10-lug	29-lug	10-lug
III°			26-set	26-set	31-ott	25-set
IV°				19-nov		
V°			20-dic	20-dic	16-dic	20-dic
VI°		2015	06-mar	14-mar	20-feb	06-mar
VII°			26-giu	25-Mag	24-Mag	23-giu
VIII°			Risultati finali settembre '15		3- set	
IX	2^	2016	29 dic	30 dic		29 dic
X	3^	2017	19 dic	30 dic	8 nov	19 dic

Fig.10 Phases of the monitoring 2014-2017

	X Monitoraggio		
	INGEGNERIA NATURALISTICA	ECOLOGIA+BOTANICA	IDRAULICO+EROSIONE
M	Muretti a secco	Muretti a secco	Muretti a secco
F	Semina di Fiorume	Semina di Fiorume	Semina di Fiorume
P	Arbusti e cespi	Arbusti e cespi	Arbusti e cespi
B		Biorulli	
S	Biostuoia e Biorullo		Biostuoia e biorullo
C	Cuscini organici	Cuscini organici	Cuscini organici
I	Idrosemina	Idrosemine	Idrosemina

Fig. 11 Types of monitoring

5. Risults

The results obtained in the Portella del Cerriolo Park indicate a complete revegetation of the area and a containment of the desertification risk. The works are totally green and now, because the new vegetation, is difficult to locate. The images show a comparison of the area before the interventions in 2014 and the situation in 2017. Soil loss, assessed using the *Universal Soil Loss Equation* (USLE) model, has been reduced to the point where the area falls into the lowest risk class. The effectiveness of the greening interventions has also generated benefits from an ecological point of view; the use of strictly native species has allowed the emergence of phenomena of vegetation evolution towards spontaneous communities. Hydroseeding and Sea hydromulching played a key role in increasing soil fertility, which promoted the propagation of both species originally present in the area and invasive species. From a global point of view, the works of soil bioengineering have had a great success especially for the reduction of slopes with cyclophoidal walls and for a floristic re-activation mainly from bio-rollers and by the diffusion of germplasm collected through sowing.

Bio-rollers have proven to be very effective interventions for the containment of soil surface erosion; not only allowed the terracing of the area but, intercepting the solid particles transported by rainwater, they prevented the removal from the site. The results obtained from the coupling of the biomats with the bio-rollers are also positive. These have in fact helped to retain the soil, preventing it from being washed away and have also protected young plants formed by the erosive action of the water, encouraging its growth. All the works also, being made of biodegradable material and over time are replaced by the vegetation, ensuring total ecological restoration of the area. The use of *Posidonia oceanica* residues was decisive to increase the amount of organic substance, the porosity and the water retention capacity of the mixture used in the soil. In the realized soil, the quarry rocks represente the skeleton while the stabilized organic substance represente the useful fraction for the vegetation. In the case of *Posidonia oceanica* it is necessary that its content by weight does not exceed 1/5 of the total mass of the technosoil (Italian D.lgs 75/2010).

Fig.12 State of the area in 2014 and March 2017 (Portella del Cerriolo Park, Custonaci, Trapani).

6. Next Step

These extraordinary results, obtained in contained times, have given rise to new experiments in the field of the creation of artificial soils: the technosols. In line with the principles of environmental sustainability and circular economy, waste materials can be used (vine or olive pruning, vegetable waste of urban pruning, beached biomass, local stone and quarry waste etc.), giving them a new destination and thus reducing disposal costs. In addition to waste materials it is also possible to use quality components, such as for example the vermicompost deriving from the process of digestion of equine manure by worms (*Eisenia foetida e Eisenia andrei*), an excellent soil improver, but further improved by the action of worms. Also, now there is a research for the thickening, and therefore the possible use, of liquid digestate, a byproduct of the anaerobic digestion of manure, for the production of biogas, with high quantities of carbon, nitrogen and other elements useful for the vegetation. And it is still possible to use mycorrhizae (*Rhizoglomus* sp.) to improve the technosoils qualitatively and in particular favor the root development of the species used. In order to meet the specific local needs, the technosoil must be composed of more or less variable components, which characterize the same and finalize it appropriately to the application

area. For the type of land degradation, caused by the extraction of marble, more ecological restoration techniques will be tested, aimed more at reclaiming the quarries and then the objectives of the DLDD (*Desertification Land Degradation & Drought*) of the UN and landscape restoration.

Fig.13 Vermicompost at the establishment of Giarre (Catania)

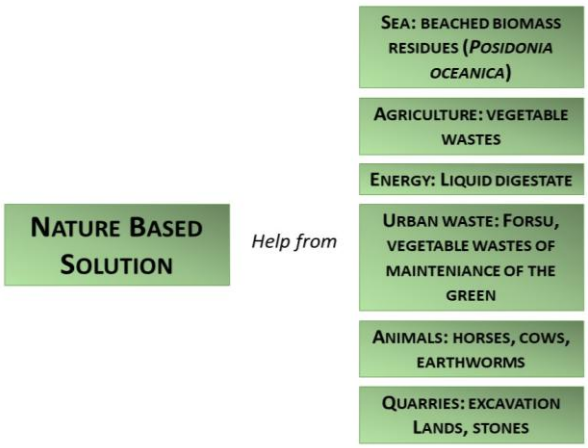

Fig.14 Nature Based Solution

Another field of application that will involve the municipality of Custonaci is that related to the project LIFE The Green Link "Restore desertified areas with an innovative tree growing method across the Mediterranean border to increase resilience" which aims to contribute to the development of effective strategies to promote resilience in the Mediterranean, through the experimentation of an innovative method for the restoration of desertified areas. The "Coocon" (a material with high water efficiency, low-cost and 100% biodegradable, alternative to traditional irrigation techniques) will be tested in 6 different areas of Italy, Spain and Canary Islands exposed to desertification, including Custonaci.

In addition to testing the application of the Coocon, the Municipality of Custonaci will be able to initiate parallel experiments by making any changes:

- Adding to the FOS mycorrhizal pastil, stabilized for about 18 months, from beached posidonia (*help from the sea*)
- By replacing the mycorrhizal pastil with Vermicompost certified by equine manure (*help from the horses*) possibly already mycorrhized.
- Replacing the mycorrhizal pastil with bovine manure digestate (*help from the cows*).

Fig.14- Coocon. (http://thegreenlink.eu/en/home/).

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