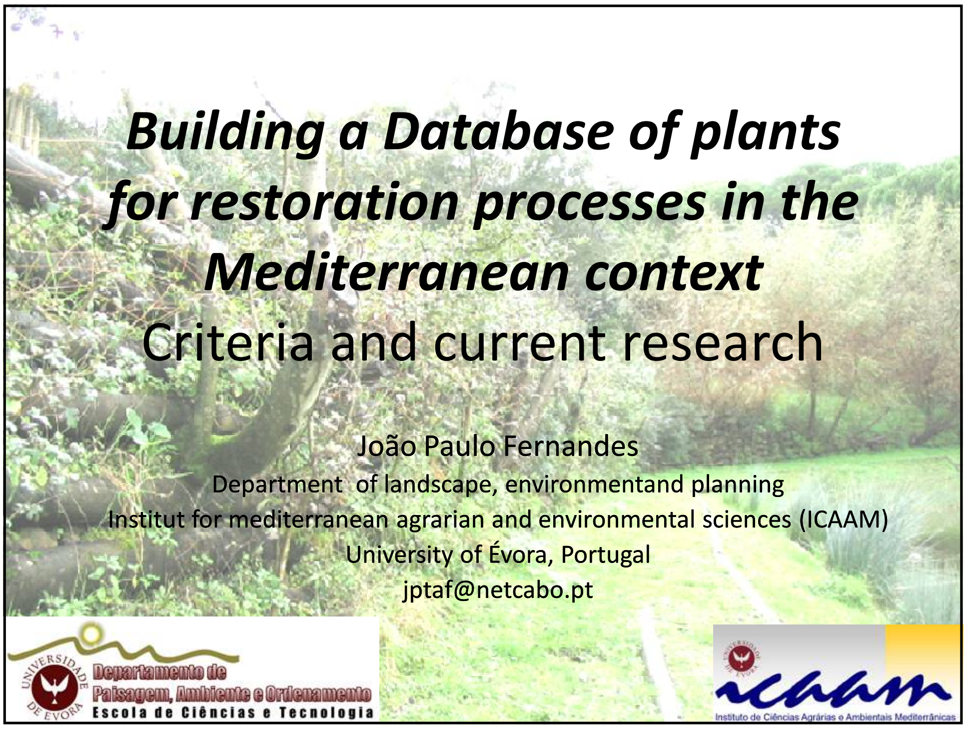


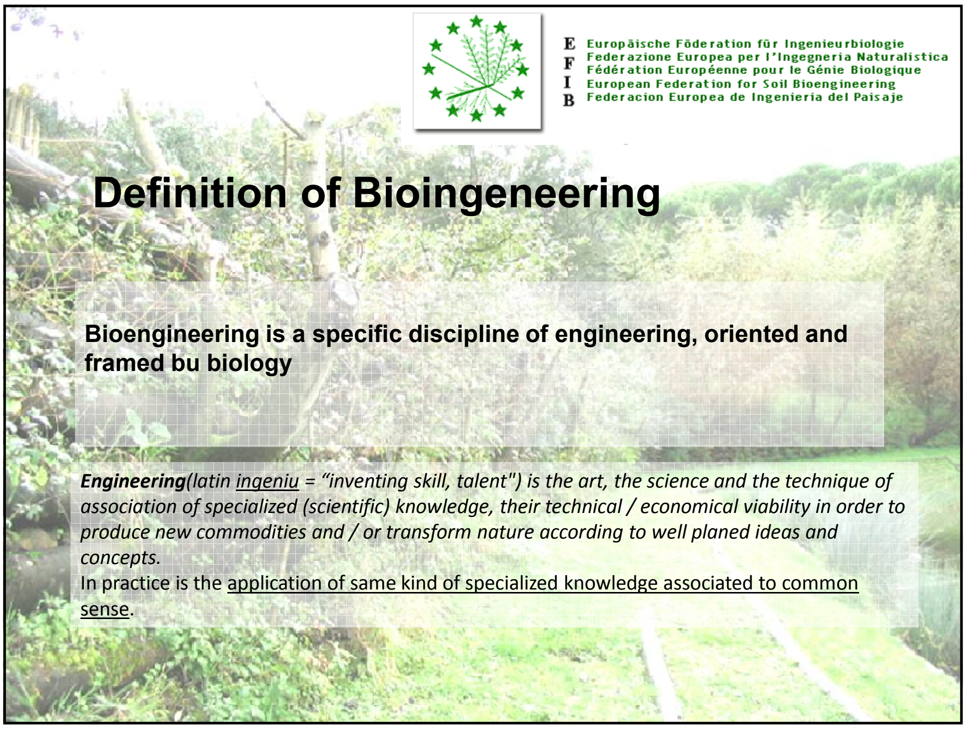
Building a Database of plants for restoration processes in the Mediterranean context

Criteria and current research

João Paulo Fernandes
Department of landscape, environmentand planning
Institut for mediterranean agrarian and environmental sciences (ICAAM)
University of Évora, Portugal
jptaf@netcabo.pt

Departamento de Paisagem, Ambiente e Ordenamento
Escola de Ciências e Tecnologia

icaam
Instituto de Ciências Agrárias e Ambientais Mediterrânicas



E Europäische Föderation für Ingenieurbiologie
F Federazione Europea per l'Ingegneria Naturalistica
I Fédération Européenne pour le Génie Biologique
B European Federation for Soil Bioengineering
Federacion Europea de Ingenieria del Paisaje

Definition of Bioingeneering

Bioengineering is a specific discipline of engineering, oriented and framed bu biology

Engineering*(latin* *<u>ingeniu</u>* *= "inventing skill, talent") is the art, the science and the technique of association of specialized (scientific) knowledge, their technical / economical viability in order to produce new commodities and / or transform nature according to well planed ideas and concepts.*

In practice is the <u>application of same kind of specialized knowledge associated to common sense</u>.

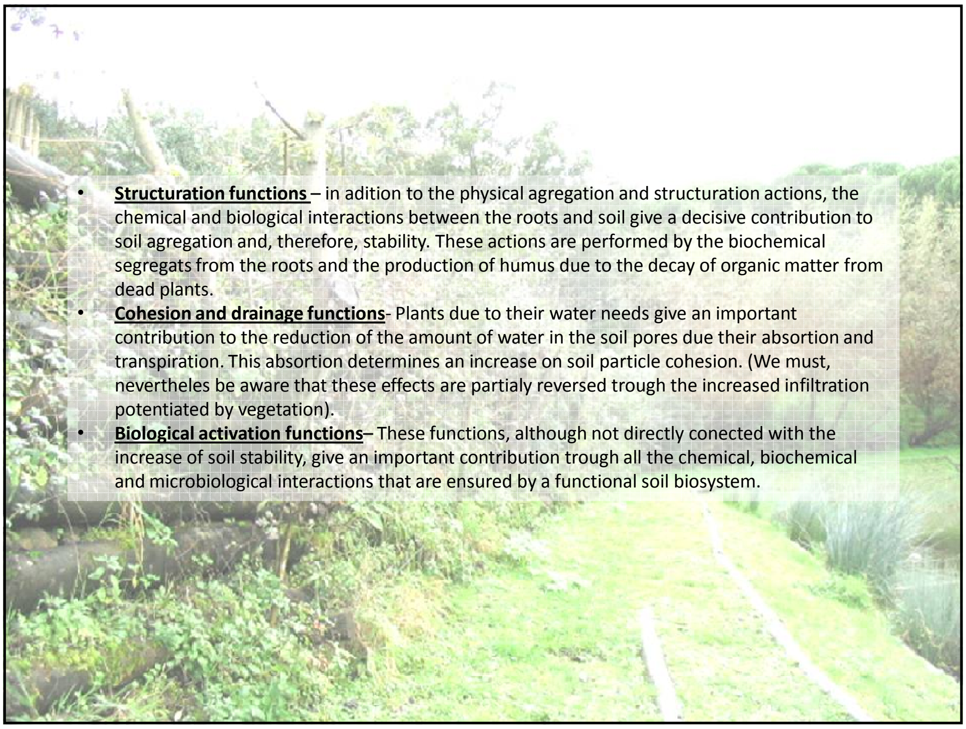
Plants and parts of plants are used as living building materials, in a combination with soil and rock, in such a way as to provide in the course of their development along-term protection against all forms of erosion.

Additionally is the ability to use vegetation and vegetation communities in order to allow their fast recover after disturbances and favor the development of ecosystems better articulated with societal pressures without losses in their value and functionality

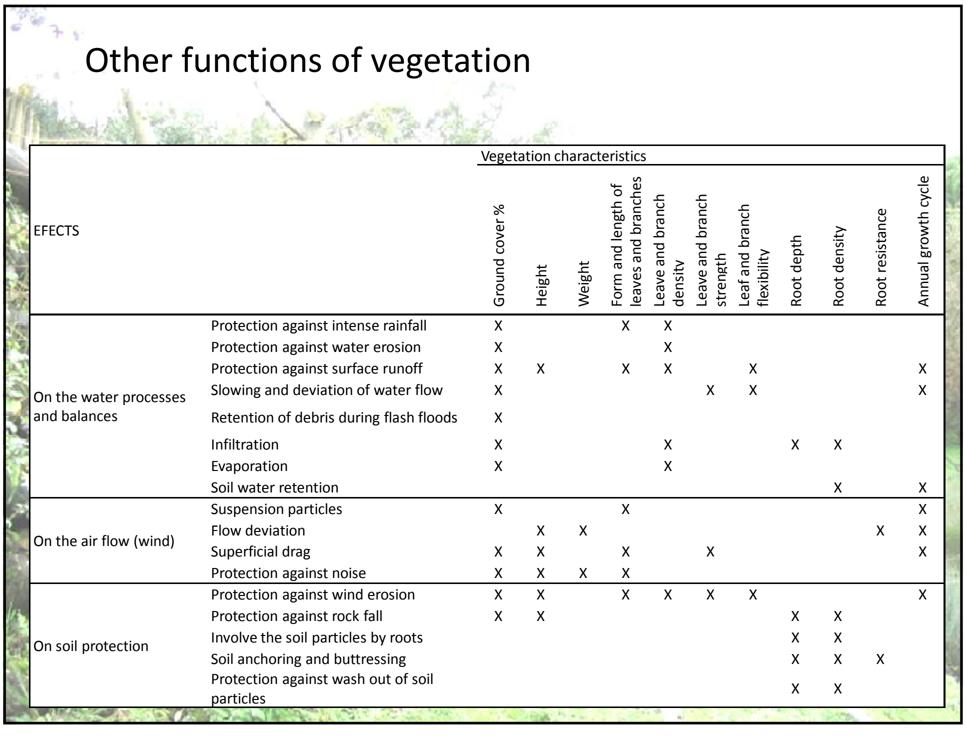
Why are plants so important?

For example: <u>Soil stability and protection</u>

- <u>Cover functions</u>– Through their leaves, branches and trunk plants ensure a more or less dense ground cover. Particularly herbaceous are able to build in a very short term, a very efficient cover that acts as a damping system against the direct impact of rain, wind or even surface runoff. This determines a clear reduction of the erodibility of such environmental factors. These cover ability is also ensured by dense tree or shrub formations together with an intense interception of rainfall that favors the later evaporation of water as well as its slow infiltration and runoff.
- <u>Soil agregation and anchoring functions</u>– Trough their roots vegetation performs a set of physical actions that increase the mechanical stability of soils, its cohesion allowing, therefore slopes steeper than the natural stability angle of their constituent material. These functions are achieved mainly in two ways:
  - Root ramifications penetrate the soil and build a dense network (whose density and depth depends on the plant species) that envelopes and gives structure to the soil particles, increasing their aggregation.
  - Big, deep roots destined to anchor the plant to the soil, ensure, at least up to two meters depth that any shear plan is penetrated and anchored, reducing the risk of land slides along that discontinuity surface.



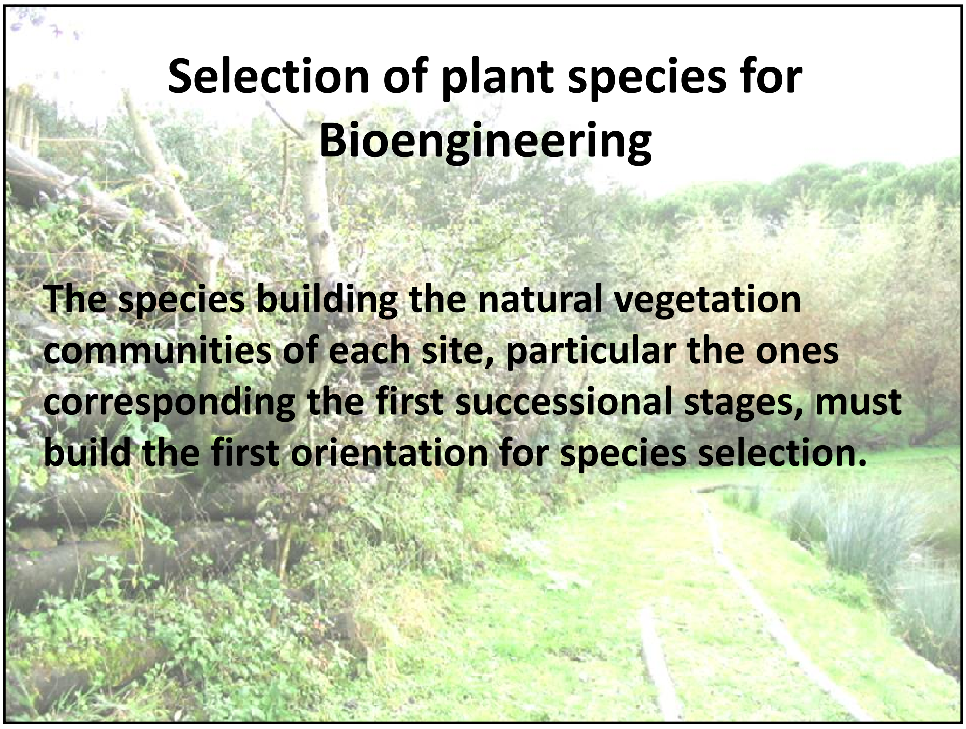
- **Structuration functions** – in adition to the physical agregation and structuration actions, the chemical and biological interactions between the roots and soil give a decisive contribution to soil agregation and, therefore, stability. These actions are performed by the biochemical segregats from the roots and the production of humus due to the decay of organic matter from dead plants.
- **Cohesion and drainage functions**- Plants due to their water needs give an important contribution to the reduction of the amount of water in the soil pores due their absortion and transpiration. This absortion determines an increase on soil particle cohesion. (We must, nevertheles be aware that these effects are partialy reversed trough the increased infiltration potentiated by vegetation).
- **Biological activation functions**– These functions, although not directly conected with the increase of soil stability, give an important contribution trough all the chemical, biochemical and microbiological interactions that are ensured by a functional soil biosystem.



Other functions of vegetation

		Vegetation characteristics										
EFECTS		Ground cover %	Height	Weight	Form and length of leaves and branches	Leave and branch density	Leave and branch strength	Leaf and branch flexibility	Root depth	Root density	Root resistance	Annual growth cycle
On the water processes and balances	Protection against intense rainfall	X			X	X						
	Protection against water erosion	X				X						
	Protection against surface runoff	X	X		X	X		X				X
	Slowing and deviation of water flow	X					X	X				X
	Retention of debris during flash floods	X										
	Infiltration	X				X			X	X		
	Evaporation	X				X						
	Soil water retention									X		X
On the air flow (wind)	Suspension particles	X			X							X
	Flow deviation		X	X							X	X
	Superficial drag	X	X		X		X					X
	Protection against noise	X	X	X	X							
On soil protection	Protection against wind erosion	X	X		X	X	X	X				X
	Protection against rock fall	X	X						X	X		
	Involve the soil particles by roots								X	X		
	Soil anchoring and buttressing								X	X	X	
	Protection against wash out of soil particles								X	X		

EFECTS		Vegetation characteristics										
		Ground cover %	Height	Weight	Form and length of leaves and	Leave and branch density	Leave and branch strength	Leaf and branch flexibility	Root depth	Root density	Root resistance	Annual growth cycle
On soil proprieties	Biochemical aggregation of soil particles								X	X		
	Increase of pore volume								X	X	X	
	Improvement of microorganisms living conditions	X							X	X		
	Humus formation	X				X				X		
On groundwater	Evapotranspiration			X	X					X		X
	Soil water content								X			X
	Internal drainage								X	X		
On the characteristics of the rock	Erosion	X	X		X	X						X
	Transport	X				X						X
	Isolation	X				X						X
	Filter		X			X	X	X				
	Own resistance	X	X			X	X			X	X	X
Mechanical	Surcharge			X								
	Surface mat / net									X	X	X
	Root reinforcement								X	X	X	X
	Anchoring / restraint								X	X	X	
	Buttressing / arching								X		X	
	Root wedging		X			X	X		X	X		
	Expansive action due to root thickness								X	X	X	
	Compression			X						X	X	
On environmental quality	Removal of eutrophic substances									X		X
	Dust filtration and deposition				X	X						X
	Noise absorption	X	X		X	X						X
	Milder microclimate	X	X			X						X



Selection of plant species for Bioengineering

The species building the natural vegetation communities of each site, particular the ones corresponding the first successional stages, must build the first orientation for species selection.

Within this set of species and considering their individual characteristics the selection criteria are very diverse:

- Pioneer character (ecological strategy);
- Adaptation to the site and the projected ecological community (functional, ecological and genetic)
- Adaptation to the local stress factors (soil and climate)
- Resistance / resilience to disturbances
- Resistance to local pathogens
- Guarantee that the selected species combination ensures a balanced succession
- Existence of development and dispersal conditions (mycorrhizae, pollinators, dispersers)
- Typology of vegetative propagation and establishment (seed, vegetative cutting, rooted plant, etc.);
- Availability of establishment material (ease to obtain and to establish on site or nursery);
- Establishment and development speed;
- Technical functionality (cover, typologies of root growing and development, influence on the balance of nutrients, absorption and retention of contaminants, etc.)
- Ease of maintenance.
- Correspondence or adaptation to the site, ensuring that the selected plant material correspond to the ecological conditions of the site and the local vegetation communities and that all plant material is obtained in the vicinity in order to prevent genetic contaminations.

We plead, on the basis of latest results in soil-bioengineering, for the use of plant species that have not been changed by breeding and are of regional origin.

Plants that are of regionally distinctive origins from the wild show the following advantages compared with varieties or alien species and genotypes:

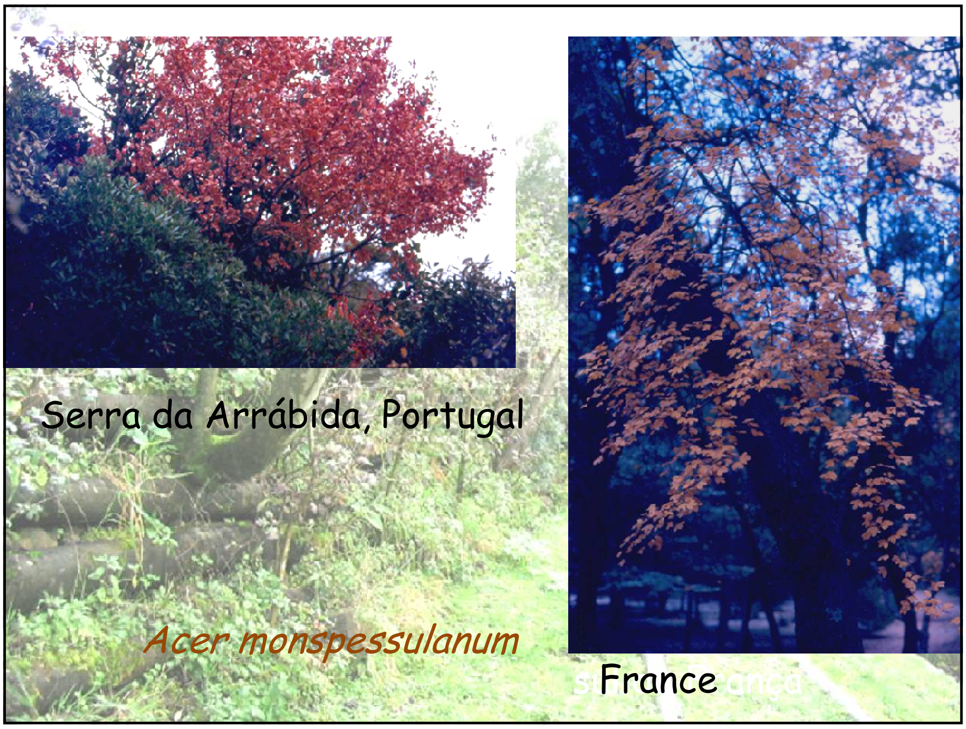
- *successful and enduring effect with an optimal adaptation to the ecosystem*
- *better adaptation to extreme sites and regional climatic and geological distinctions*
- *only possibility to actively develop plant communities typical for the specific landscape*
- *better and sustainable integration into the natural environment and landscape*
- *better cost-benefit ratio and higher economic efficiency*

In addition to these advantages, the use of regionally distinctive plants is compliant with the demands of the Convention on Biological Diversity of Rio de Janeiro 1992 for the conservation of biological diversity.

To make use of these advantages, there has to be laid out the legal basis for trading and introduction of plant- and seed material unchanged by breeders into nature. All constraints for the marketing of "preservation seed" (wild plants) in relation to their propagation, marketing and release, which should be valid after the decision on the draft of the directive on preservation seed mixtures by the EU-Commission (e.g. restriction on volume) are counter-productive for near-natural protection measures and therefore no such restrictions should be introduced. This also affects the decision concerning the obligation to provide evidence about the danger of genetic impoverishment of species, to be allowed to propagate "preservation seed" of those species and to make them available.

Regarding the allocation of contracts in practice a legal basis has to be created, both at an European (EU) as well as at a regional level, so that it is possible to realise and control the targets of the Rio Convention in the sphere of seed- and plant production, and their trade and use.

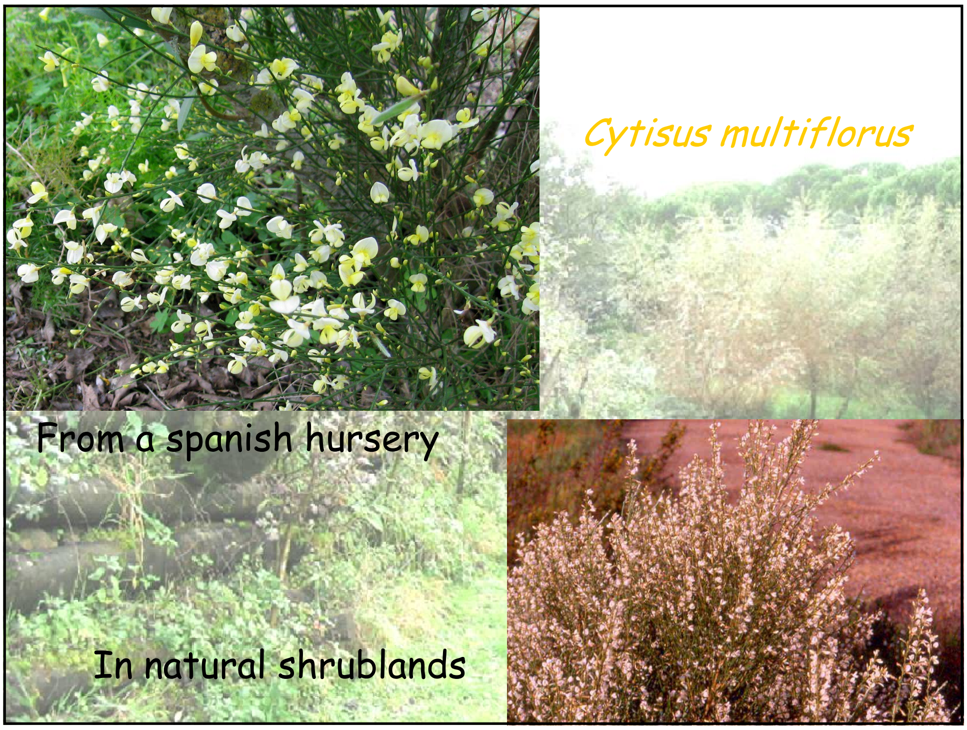
Resolution approved in the "Soil-Bioengineering: Ecological Restoration with Native Plant and Seed Material" Conference, 2006



Serra da Arrábida, Portugal

Acer monspessulanum

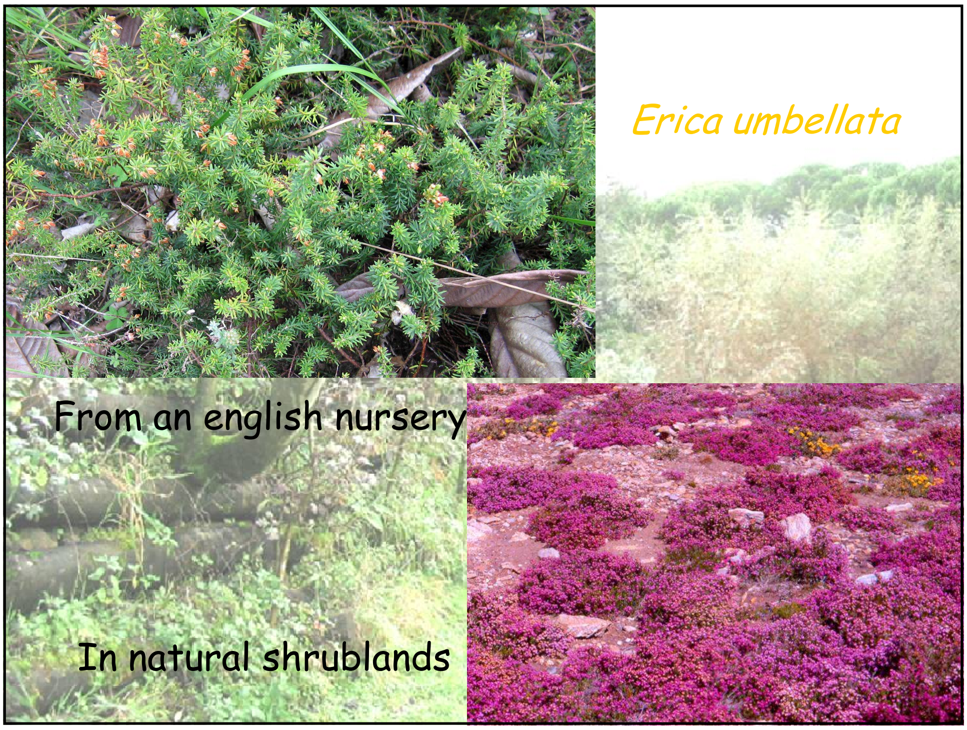
France



Cytisus multiflorus

From a spanish hursery

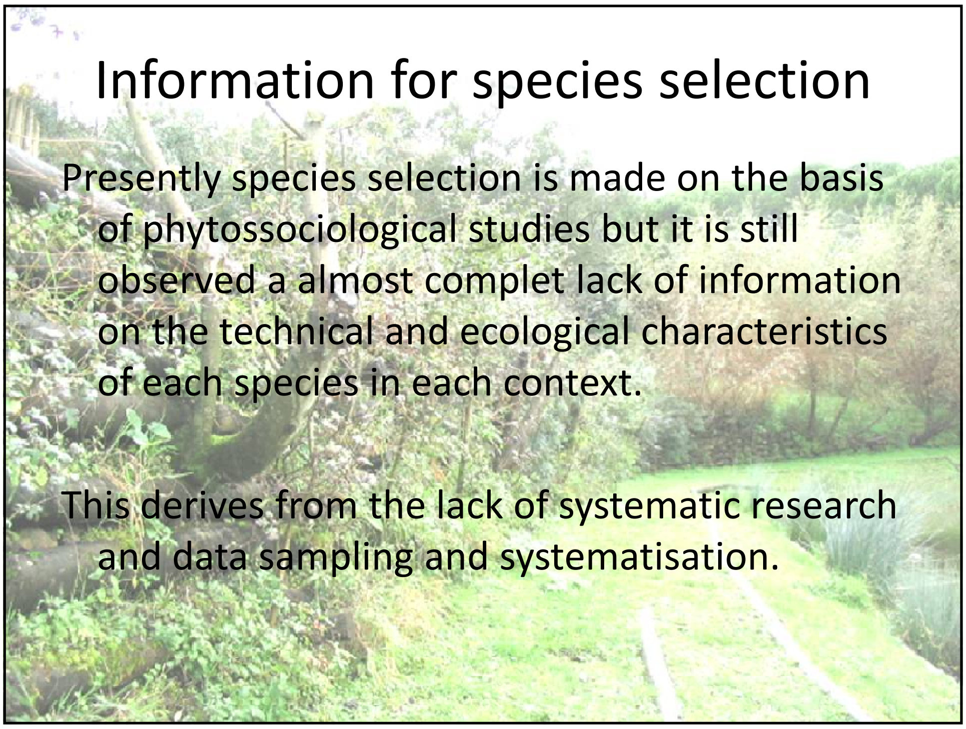
In natural shrublands



Erica umbellata

From an english nursery

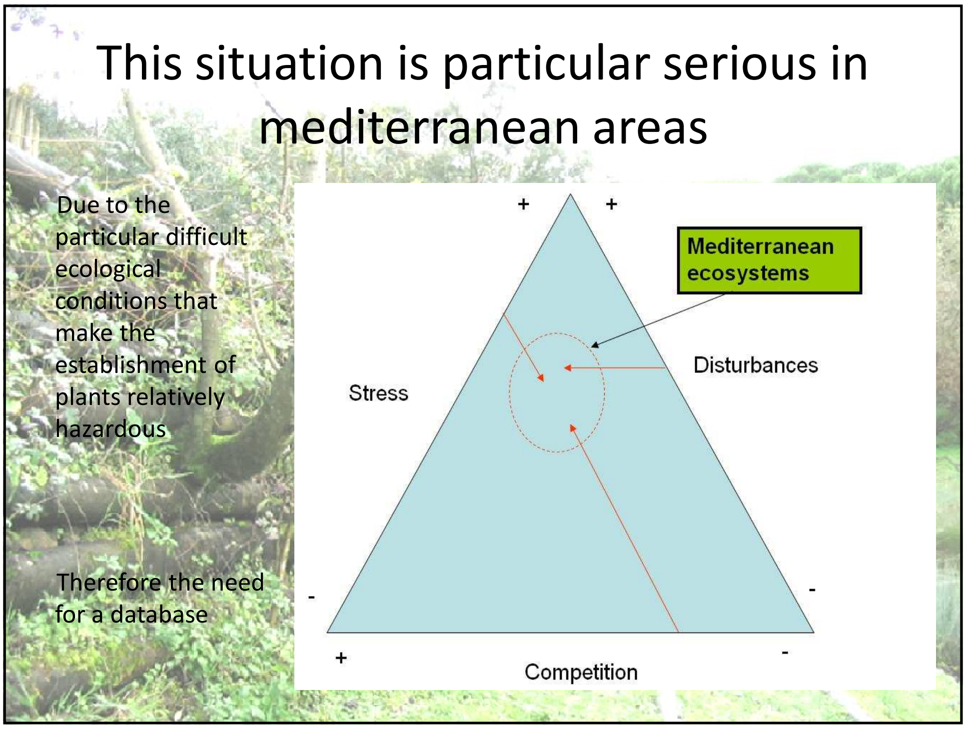
In natural shrublands



Information for species selection

Presently species selection is made on the basis of phytossociological studies but it is still observed a almost complet lack of information on the technical and ecological characteristics of each species in each context.

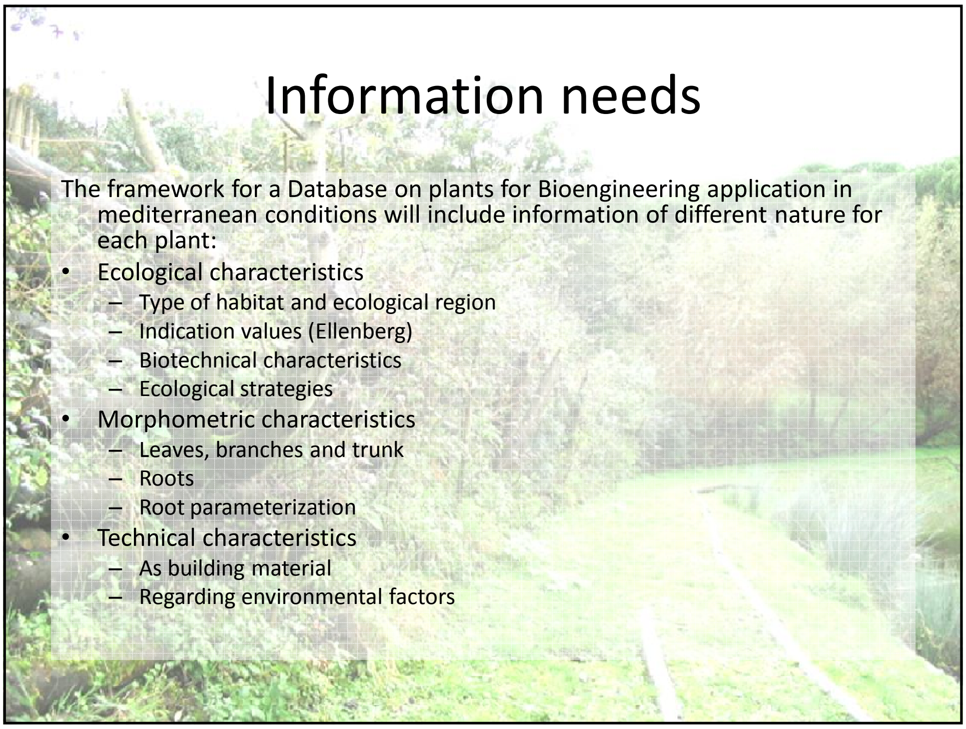
This derives from the lack of systematic research and data sampling and systematisation.



This situation is particular serious in mediterranean areas

Due to the particular difficult ecological conditions that make the establishment of plants relatively hazardous

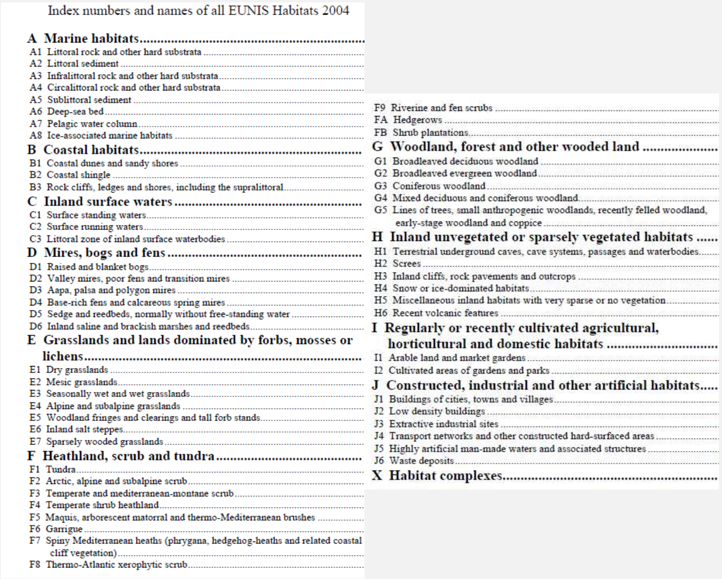
Therefore the need for a database



Information needs

The framework for a Database on plants for Bioengineering application in mediterranean conditions will include information of different nature for each plant:

- Ecological characteristics
  - Type of habitat and ecological region
  - Indication values (Ellenberg)
  - Biotechnical characteristics
  - Ecological strategies
- Morphometric characteristics
  - Leaves, branches and trunk
  - Roots
  - Root parameterization
- Technical characteristics
  - As building material
  - Regarding environmental factors

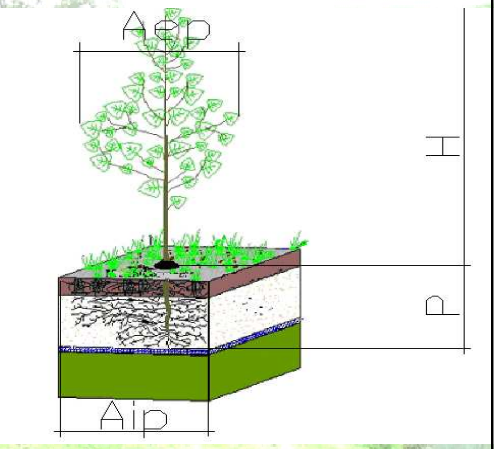
Ecological characteristics	
Habitat types (e.g. EUNIS, 2004)	 Index numbers and names of all EUNIS Habitats 2004 **A Marine habitats** A1 Littoral rock and other hard substrata A2 Littoral sediment A3 Infralittoral rock and other hard substrata A4 Circalittoral rock and other hard substrata A5 Sublittoral sediment A6 Deep-sea bed A7 Pelagic water column A8 Ice-associated marine habitats **B Coastal habitats** B1 Coastal dunes and sandy shores B2 Coastal shingle B3 Rock cliffs, ledges and shores, including the supralittoral **C Inland surface waters** C1 Surface standing waters C2 Surface running waters C3 Littoral zone of inland surface waterbodies **D Mires, bogs and fens** D1 Raised and blanket bogs D2 Valley mires, poor fens and transition mires D3 Aapa, palsa and polygon mires D4 Base-rich fens and calcareous spring mires D5 Sedge and reedbeds, normally without free-standing water D6 Inland saline and brackish marshes and reedbeds **E Grasslands and lands dominated by forbs, mosses or lichens** E1 Dry grasslands E2 Mesic grasslands E3 Seasonally wet and wet grasslands E4 Alpine and subalpine grasslands E5 Woodland fringes and clearings and tall forb stands E6 Inland salt steppes E7 Sparsely wooded grasslands **F Heathland, scrub and tundra** F1 Tundra F2 Arctic, alpine and subalpine scrub F3 Temperate and mediterranean-montane scrub F4 Temperate shrub heathland F5 Maquis, arborescent matorral and thermo-Mediterranean brushes F6 Garrigue F7 Spiny Mediterranean heaths (phrygana, hedgehog-heaths and related coastal cliff vegetation) F8 Thermo-Atlantic xerophytic scrub F9 Riverine and fen scrubs FA Hedgerows FB Shrub plantations **G Woodland, forest and other wooded land** G1 Broadleaved deciduous woodland G2 Broadleaved evergreen woodland G3 Coniferous woodland G4 Mixed deciduous and coniferous woodland G5 Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice **H Inland unvegetated or sparsely vegetated habitats** H1 Terrestrial underground caves, cave systems, passages and waterbodies H2 Screes H3 Inland cliffs, rock pavements and outcrops H4 Snow or ice-dominated habitats H5 Miscellaneous inland habitats with very sparse or no vegetation H6 Recent volcanic features **I Regularly or recently cultivated agricultural, horticultural and domestic habitats** I1 Arable land and market gardens I2 Cultivated areas of gardens and parks **J Constructed, industrial and other artificial habitats** J1 Buildings of cities, towns and villages J2 Low density buildings J3 Extractive industrial sites J4 Transport networks and other constructed hard-surfaced areas J5 Highly artificial man-made waters and associated structures J6 Waste deposits **X Habitat complexes**

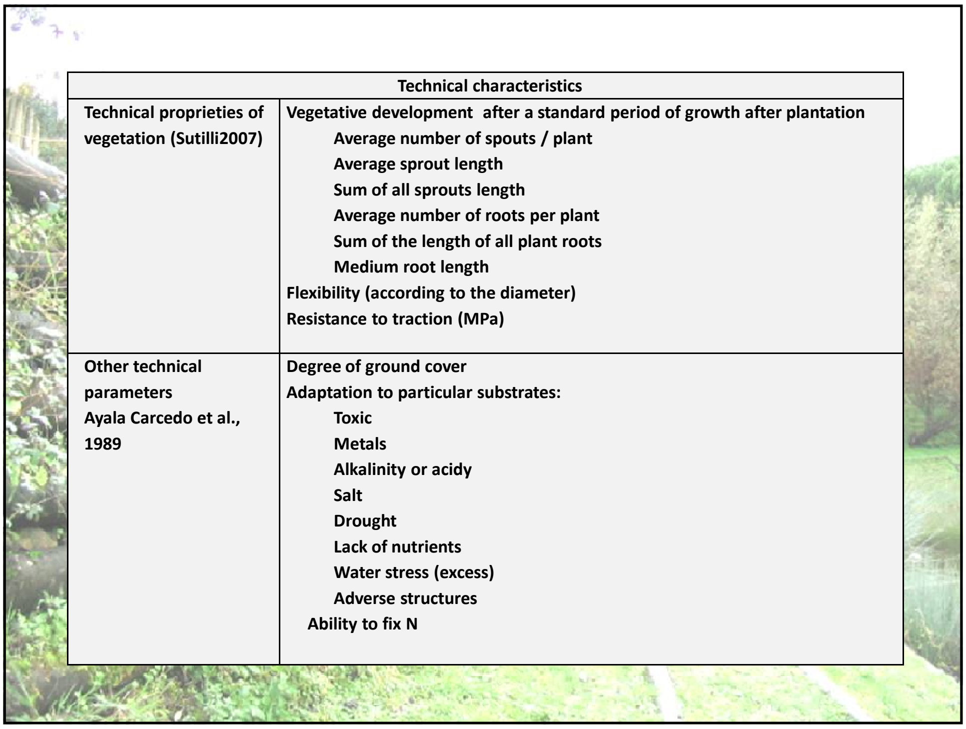
Características ecológicas	
Bioindication values (Ellenberg, 1974, 1979, 1992; Pignatti, S., 2005)	Light (L)
	Temperature (T)
	Continentality (C)
	Moisture or water availability(H)
	Soil reaction(R)
	Nutrients (N)
	Salinity (S)
Biotechnical characteristics (Schiechtl, 1980)	Growth (years)
	Root growth(cm)
	New sprouts(cm)
	Height/diameter
	Size
	Growth rate
	Type of vegetative propagation
	Soil type
	pH
	Salt
	Nutrients
	Moist
	Excess water
	Drought
	Temperature
	Shadow
	Tolerance to altitude
	Fodder value
	Seeds/gr
	Seed rate(Kg/ha)
	Distribution
Ecological strategies in the regenerative stage (Grime, 2002)	CSR classification (C- Competitive, S – Stress tolerant, R - Ruderals)
	Vegetative expansion (V)
	Seasonal regeneration in vegetation gaps (S)
	Regeneration involving a persistent bank of seeds or spores (B_s)
	Regeneration involving numerous wind-dispersed seeds or spores (W)
	Regeneration involving a bank of persistent seedlings (B_{sd})

Características Morfométricas	
Above ground (Cornelini et al., 2008)	Presumable age (years) Height above ground Diameter at 20 cm height (mm) Maximal canopy diameter (cm)
Root system (Cornelini et al., 2008)	Root depth (cm) Root amplitude (diameter of the entire root system) (cm) Length of secondary roots(cm) Thickness of main root(mm) Average root thickness (mm) Secondary root thickness (mm) Dimensions of the rooted space(cm) Type of root: Pivoting Fasciculate Superficial Aerial Volume of rooted soil
Root system Parametrización dos sistemas radiculares para el análisis da estabilidad de encostas con vegetación (Preti, 2008 in Cornelini, 2008)	**Rooted area relation RAR(z)** **RAR(z) =** $\sum_1^m Ar(z)i / Ars(z)$ $Ar(z)_i$= Area of the i-esime seccionated root at depth z Ars(z)= Area of rooted soil at depth z z= depth m= nº of roots at depth z **Root cohesion Cv(z)** **Cv(z) =** $K \sum_1^n Trj \left(Ar(z)j / Ars(z) \right)$ K normaly1,2 Tr_j= traction resistance of the j-esime class of root diameter (MPa) $Ar(z)_j$= sum of all cross areas of roots of the j-esime class of root diameter N= nº of diameter classes at depth z

Syntethic parameters (Cornelini et al., 2008)

Adimensional Index of root architecture	**Index of root semi-sphericity** **A=1/2*(P/Aip)** **(1/2*(root depth / root amplitude)**
Adimentional indexes of stability and solidity	**Index of relative stability** **S=P/H** **(root depth / height above ground**
	Index of potential stability **Sp=L/H** **(length of main root / height above ground)**
	Index of relative solidity **s=Aip/Aep** **(Root amplitude / Plant amplitude above ground)**
Global stability indexes	**Index of root stability** **R=S*s** **(relative stability * relative solidity)**
	Index of global stability **$P=S(s)^2$** **(relative stability *(relative solidity)^2)**





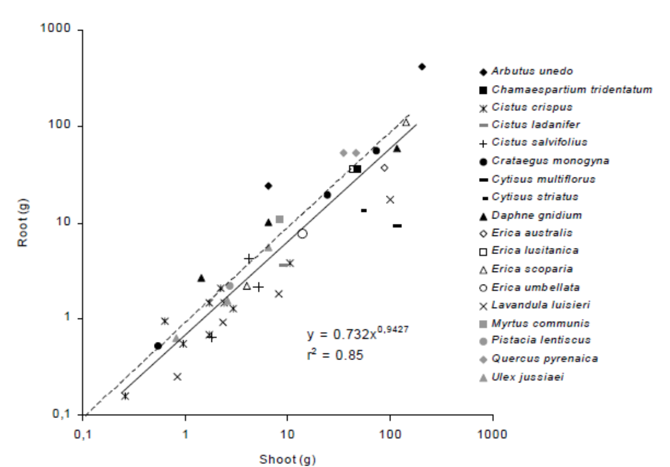
Technical characteristics	
Technical proprieties of vegetation (Sutilli2007)	Vegetative development after a standard period of growth after plantation Average number of spouts / plant Average sprout length Sum of all sprouts length Average number of roots per plant Sum of the length of all plant roots Medium root length Flexibility (according to the diameter) Resistance to traction (MPa)
Other technical parameters Ayala Carcedo et al., 1989	Degree of ground cover Adaptation to particular substrates: Toxic Metals Alkalinity or acidy Salt Drought Lack of nutrients Water stress (excess) Adverse structures Ability to fix N

Examples of research aiming at the identification and characterisation of vegetation for Bioengineering and restoration in the Mediterranean area

Summing up of preliminary results (SICILY)

Species more adequated to stabilisation and consolidation	Species more adequated to anti-erosion interventions
Anagyris foetida	*Artemisia arborescens*
Artemisia variabilis	*Daphne gnidium*
Asparagus acutifolius	*Erica multiflora*
Asparagus albus	*Olea europaea L. var. sylv*
Atriplex haliminus	*Osyris alba*
Calicotome spinosa	*Phlomis fruticosa*
Capparis spinosa	*Pistacia lentiscus*
Cistus monspeliensis	*Prunus spinosa*
Cistus salvifolius	*Prunus webby*
Colutea arborescens	*Pyrus amygdaliformis*
Crataegus monogyna	*Quercus calliprinos*
Ephedra fragilis	*Rhus coriaria*
Euphorbia characias	*Rosa canina*
Euphorbia dendroides	*Rosmarinus officinalis*
Euphorbia rigida	*Sarcopoterium spinosum*
Rosa sempervirens	*Teucrium fruticans*
Salsola verticillata	*Ulmus minor*
Spartium junceum	
Tamarix gallica	
Thymus capitatus	

Root / Shoot relation in mediterranean shrubs in diferent ecological conditions



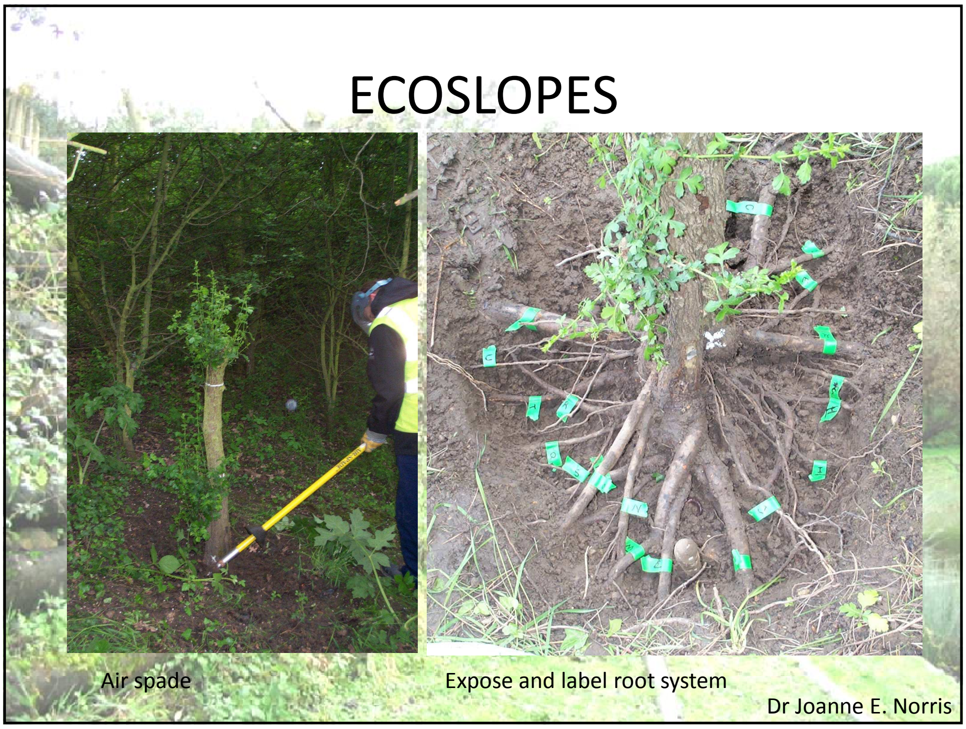
Relaciones entre la biomasa de las raíces y la biomasa de la rama (Silva y Rego 2004)

Fitogeographical zonation of species with ability for bioengineering interventions in Portugal

ESPECIE	NWmN	NWmS	NWoN	NWoS	Nel	Neu	TQ	TF	CWa	CWb	CWca	CWc	Cwo	CN	CSa	CSm	CSp	CEc	CEmN	CEmS	SWm	SWme	SWs	SEm	SEs	Barroc	Barlv	Sotv
Juniperus turbinata										E	E	E	E		E	E	E				E	E	E		E	E	E	E
Salix fragilis L.	SE	SE	SE	SE	SE	SE	SE	SE		SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE
Salix alba L. subsp. alba										E	E	E	E		E	E	E	E	E	E	E	E	E	E	E	E	E	E
Salix vitellina (L.) Arcangeli										SE	SE	SE	SE		SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE
Salix triandra L. subsp. discolor	E	E	E	E	E	E																						
Salix atrocinerea Brot.	E	E	E	E	E	E	E	E		E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Salix salvifolia Brot. subp. Salvifolia	E	E	E	E	E	E	E	E						E	E	E	E	E	E	E								
Salix salvifolia Brot. subp. Australis																						E	E	E	E			
Salix repens L.			E																									
Salix arenaria L.																												
Juglans regia L.	SE	SE	SE	SE	SE	SE	SE	SE																				
Betula celtiberica Rothm. & Vasc.			E	E																								
Alnus glutinosa (L.) Gaertner	E	E	E	E	E	E	E	E																				
Corylus avellana L.	E	E																										
Castanea sativa Miller	SE	SE	SE	SE	SE	SE	SE	SE																				
Quercus coccifera L.																												
Quercus rotundifolia Lam.					E	E	E	E																				
Quercus suber L.	E	E	E	E	E	E	E	E																				
Quercus robur L.	E	E																										
Quercus pyrenaica Willd.	E	E	E	E	E	E		E																				
Quercus faginea Lam.					E	E	E	E																				

Habitats where species with ability for bioengineering interventions can be used in Portugal

	HABITAT																											
ESPECIE	LIT	CON	CUL	HID	HIG	MES	XER	RIP	RUP	OMB	RUD	DUN	SAP	PRA	MTS	MTG	MON	PIN	FLO	SEB	CAS	ARE	CAL	UBS	PAN	HAL	SHA	AGR
Juniperus turbinata	X	X					X					X			X	X						X						
Salix fragilis L.		X		X				X											X									
Salix alba L. subsp. alba		X		X				X											X									
Salix vitellina (L.) Arcangeli		X		X				X											X									
Salix triandra L. subsp. discolor		X		X				X							X	X												
Salix atrocinerea Brot.		X		X				X							X	X												
Salix salvifolia Brot. subp. Salvifolia		X		X				X							X	X												
Salix salvifolia Brot. subp. Australis		X		X				X							X	X												
Salix repens L.		X	X	X				X							X										X			
Salix arenaria L.	X			X				X				X			X							X			X			
Juglans regia L.		X		X		X		X											X									X
Betula celtiberica Rothm. & Vasc.		X	X	X	X	X		X											X									
Alnus glutinosa (L.) Gaertner		X		X				X											X									
Corylus avellana L.		X			X	X									X	X												
Castanea sativa Miller		X			X	X													X									
Quercus coccifera L.	X	X				X	X					X			X	X				X			X					
Quercus rotundifolia Lam.		X				X	X									X	X		X					X				



ECOSLOPES

Air spade

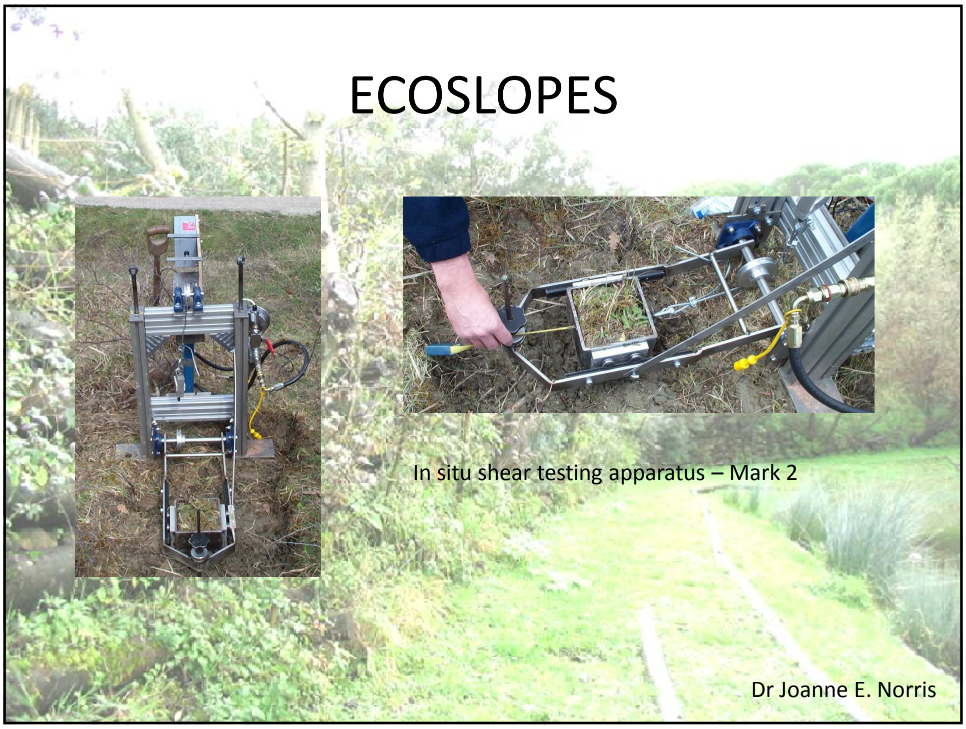
Expose and label root system

Dr Joanne E. Norris

ECOSLOPES

Root pull out apparatus

Dr Joanne E. Norris



ECOSLOPES

In situ shear testing apparatus – Mark 2

Dr Joanne E. Norris

Thank you for your atention!