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Strategies for the re-naturalization of reforestation: the case study of the Sicilian clay hills

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Introduction and aim of the study

Over the last decades many areas have been reforested along Europe, with a great proportion been made with exotic species. Very often these reforestations do not evolve in more diverse forest stands, and some kind of management is necessary to try to promote this evolution.

The holes are a silvicultural technique consisting in open small gaps to create favourable conditions for the establishment of other species changing the former structure, microclimate and competitive conditions, mirroring the natural process that occurs in structured and mature forests.

The best size of the hole seems to be around 500 m², as smaller holes may not change significantly the conditions and larger holes seems to favour degradation processes like soil erosion and loss of organic layers.

The afforestaion of the Santa Ninfa Natural Reserve (Trapani Province, W-Sicily) were made using essentially *Pinus* spp. and *Eucalyptus camaldulensis*. Particularly, this last species occur in a high density, forming a monospecific forest stand covering 19 ha (8% of the reserve), where practically no kind of management has been made until now and very few natural regeneration is observed.

The aim of the study was to verify the effectiveness of the restoration actions combining the holes technique and planting native species with different management levels.

Study Site

The study was performed in the "Grotta di Santa Ninfa" natural reserve (longitude between 12°53'45'' and 12°55'45''E, latitude between 37°46'50'' and 37°47'50''N), in the Trapani province of southwestern Sicily (Fig. 1). The elevation ranges is between 400 and 625 m a.s.l. The study area has a typical Mediterranean climate, with mean annual rainfall and temperature of 860 mm and 17 °C, respectively. The geology is characterized by gypsum rocks; as a consequence of the high solubility of gypsum, carsic phenomena are widespread in the area. The soil are clay.

The vegetation co-occuring with the *Pinus* and *Eucalyptus* reforestations is represented mainly by nitrophilous plants from the class *Stellarietea mediae* and from sub-nitrofilous and heliophilous plants from the class *Artemisietea vulgaris*, with very few differences in overall community composition compared to the adjacent vegetation, and no evident sign of evolution towards more complex and natural formations.

Materials and Methods

1) We surveyed the 19 ha *Eucalyptus* reforestation and selected 10 areas where the reforestation was less developed, with smaller individuals and smaller gaps, to open the holes. Before the removal of the *Eucalyptus*, the number of individuals and dendrometric parameters were measured (Table 1). Also we characterized the woody natural regeneration registering all individuals divided in 3 height categories: smaller than 1.5 m, from 1.6 to 4 m and taller than 4 m (Table 2). After the removal of all *Eucalyptus* woody material, each hole was measured and georeferenced with GPS.

2) From the climatic, edaphic and potential vegetation analysis we selected 18 species to be planted: *Celtis australis*, *Ceratonia siliqua*, *Olea europea* var. *silvestris*, *Quercus amplifolia*, *Quercus virgiliana*, *Quercus ilex*, *Pistacia terebinthus*, *Pistacia lentiscus*, *Phillyrea angustifolia*, *Phillyrea latifolia*, *Rhamnus alaternus*, *Crataegus monogyna*, *Myrtus communis*, *Spartium junceum*, *Pyrus pyraster*, *Laurus nobilis*, *Ulmus minor* and *Tamarix africana*. The last 2 species were used only on the hole 4, that was close to a water stream. *Celtis australis*, *Pyrus pyraster* and *Pistacia terebinthus* were planted but excluded from the analysis due to their low number (N < 15). All seedlings were classified according to their general integrity before planting.

3) The seedlings were manually planted at 40x40x40 cm holes on December 2014. Around each seedling a basin (1x1 m) to help water accumulation was realised.

In all seedlings, with the exception of those on hole 2, natural fiber discs were add to simulate mulching.

Just one irrigation was made on the summer of 2015 and manual soil management were made on May and November 2015 to prevent competition with herbs. No kind of intervention was made after that.

Results

In total 904 seedlings from 18 species were planted, with an average of 90 seedlings per each hole.

The first control was made after 5 months, and an average mortality of 6%was registered , with species-specific mortality ranging from 0% up to 33.3%. One year later the average mortality reached 52.6%, ranging from 11.1% up to 90%. On the last survey, the cumulative mortality reached 55.64%, ranging from 27.3 up to 70.7%.

Spartium junceum and *Ulmus minor* showed the lowest mortality while *Arbutus unedo* and *Quercus pubescens* s.l. showed the highest, with more than 90% of mortality.

The negative initial conditions of the seedlings were positively correlated with post plantation mortality, demonstrating that for some species there is low probability of correcting initial problems like inappropriate size, age or deformations of the root system.

Most *Eucalyptus* resprouted and were managed to avoid competition with the seedlings.

Conclusions and Management options

The density of individuals originated from natural regeneration was very low, demonstrating that at some areas active interventions are needed to enhance the naturalization speed of artificially reforested areas.

Regardless of soil, climate and topography, the *Eucalyptus* reforestations in Sicily often show low floristic abundance and diversity, mainly a result of the high densities and competitive superiority of this exotic species; so interventions are needed.

The eucalypt individuals felled were measured to evaluate the cubic meters of obtainable wood (Table 1). In fact, in perspective the biomass obtainable by renaturalization processes is expected to produce energy in small cogeneration implants.

References

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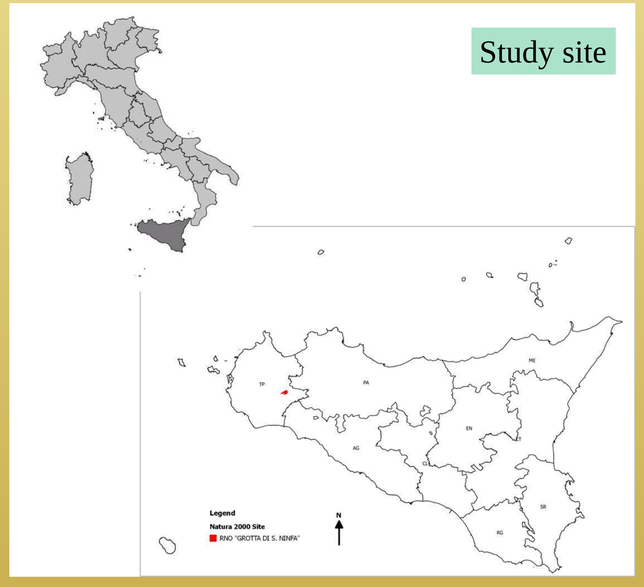
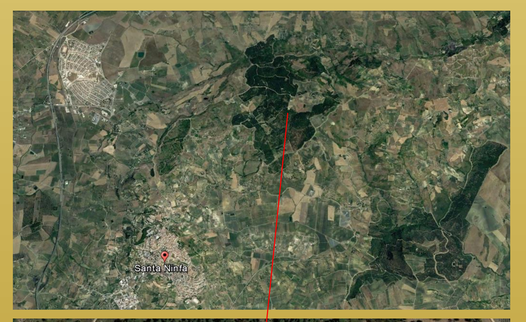




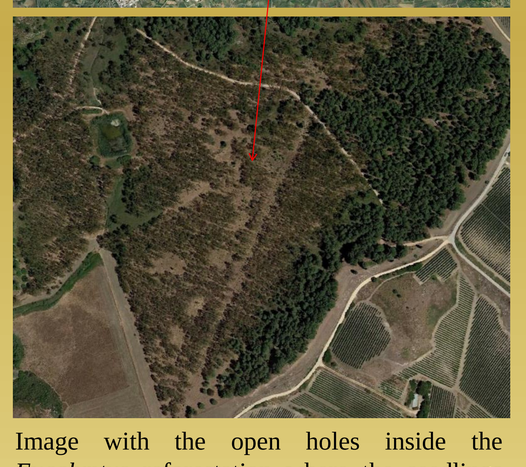


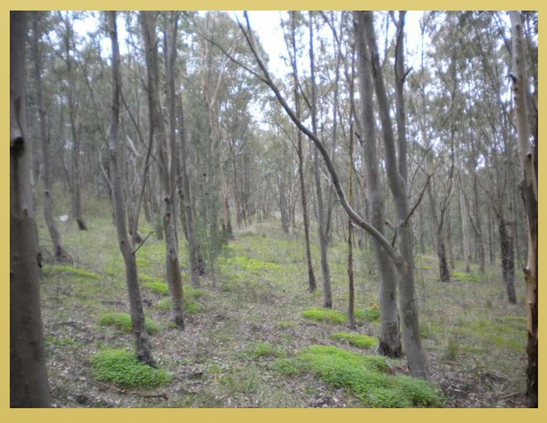
Image with the open holes inside the *Eucalyptus* reforestation where the seedlings were planted.

Table 1 – Characteristics of the holes and main structural parameters of the *Eucalyptus* reforestation.

Hole	N plants	Area (m²)	Density (N/ha)	Volume (m³)
1	37	639	579	5
2	31	1116	278	8
3	47	781	602	9
4	31	1271	244	9
5	46	771	597	10
6	26	567	459	6
7	28	733	382	4
8	31	1078	288	5
9	32	612	523	11
10	40	593	675	6

Table 2 – Natural regeneration registered on each hole before the interventions**.**

Species/Hole	1	2	3	4	5	6	7	8	9	10
Olea europaea var *sylvestris*		14	17	2	30	11	2		3	
Crataegus monogyna		4	4		7					
Pinus halepensis <1,5m	11	1	10		10	8		6	4	
P. h >1,5m-<4m	5	2	13	5		3	6	10		
P. h >4m	4		21		9	2		3	2	
Laurus nobilis		1	1							
Quercus pubescens s.l.					1					



Eucalyptus before the intervention.

Hole after the intervention.

Table 3 – Number of seedlings planted, mortality and overall conditions before planting of each specie.

Specie	N planted	% mortality	Overall condition[1]
Spartium junceum	54	11.1	2
Ulmus minor	36	13.9	3*
Myrtus communis	25	28.0	3
Fraxinus ornus	60	30.0	3
Phillyrea angustifolia	148	31.1	3
Pistacia lentiscus	42	50.0	2
Crataegus monogyna	25	56.0	3
Quercus ilex	79	59.5	3
Tamarix africana	62	64.5	2
Laurus nobilis	63	65.1	3
Olea europea var. silvestris	45	71.1	3
Rhamnus alaternus	51	76.5	3
Ceratonia siliqua	20	80.0	2**
Quercus sp.	156	87.8	1**
Arbutus unedo	21	90.5	1**
Total planted/average mortality	**904**	**55.6**	

1: old plants (>1 year) with overdeveloped rooting system; 2: Young plants (<1 year) with good rooting system; 3: Ideal age (1 year) . * Nude root; ** Damaged leaves.

A plant of *Spartium junceum* with the disc (on the left). On the right the disc is partially covered by soil.