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Vegetation dynamics within afforested coastal areas: regeneration by native species or invasion by alien species?

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Introduction
During the last century, massive reforestation projects along the dunes of the southern Sicily have been carried out. Such interventions, far from being in line with the current trends of close-to-nature silviculture, are, however, particularly interesting to assess the vegetation dynamics in afforestation areas. Furthermore, these kind of interventions may determine two opposite effects, that is renaturalization by native woody species or invasion by alien species. *Acacia* spp. are among the most widespread and prominent invaders within Mediterranean-climate areas, where they have already shown the capability to deeply change the characters and the functioning of native ecosystems (e.g.: HOLMES & COWLING, 1997). For instance, *Acacia longifolia* (Andrews) Willd. may successfully invade the understory of pine forests, causing the alteration of the water balance and carbon storage of the whole forest ecosystem (RASCHER *et al*., 2011). In Sicily, especially in the last decades, *Acacia saligna* started to abundantly regenerate in many natural and semi-natural areas, with a stark preference for dune and coastal afforested sites (BAZAN & SPECIALE, 2002). The nature reserve "Foce del Fiume Platani" represents an excellent case study in this respect (BADALAMENTI *et al*., 2013).

Aim of the study
The present study aimed at understanding the woody vegetation evolution 16 years after preliminary investigations in the understory of a Mediterranean stone pine (*Pinus pinea* L.) reforestation. Our investigation was particularly focused on regeneration pattern and invasion process of *Acacia saligna* (Labill.) H.L.Wendl..

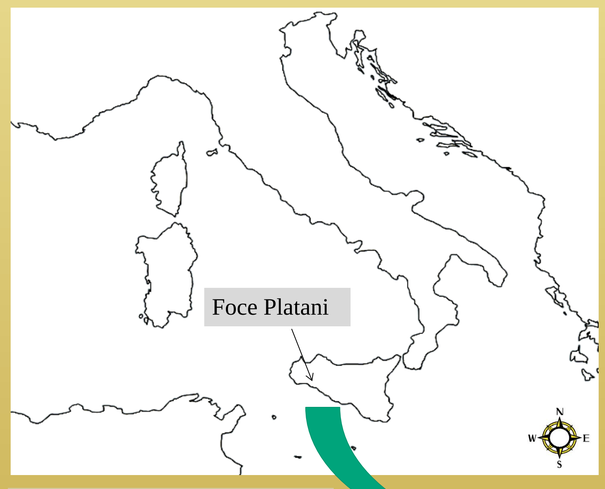
Study Site and Acacia invasion process
The "Foce Platani" nature reserve is located in the Province of Agrigento, along the south-western coast of Sicily, Italy. The study area falls within the Thermomediterranean upper dry bioclimatic belt. The Reserve hosts diverse vegetation types, including Mediterranean maquis, riparian vegetation and, especially, residuals of dune vegetation along the coast. Within the Reserve the invasion process by *A. saligna* has steadily increased in the last 20-30 years. Nowadays, abundant regeneration by *Acacia* may be observed only within a stone pine plantation in the backdune.

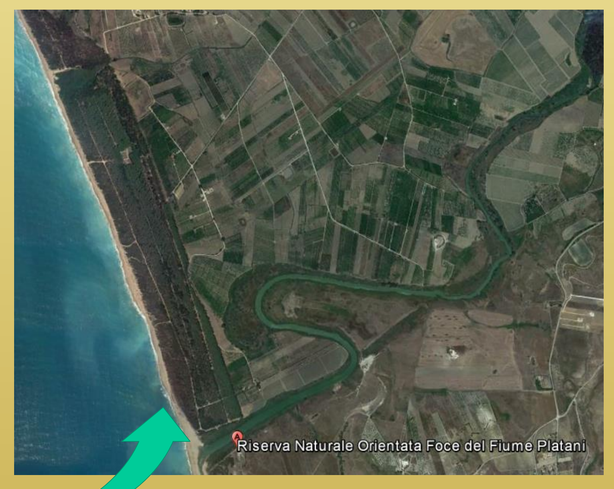
Materials and Methods
The dynamic of woody vegetation within *Pinus pinea* afforested area was evaluated by comparing the results of surveys carried out in 2001 over two 450 m^2 circular plots with new surveys carried out on January 2017 over three 441 m^2 square plots. An additional area was considered in 2017 in order to take into account the particularly abundant natural regeneration. Regeneration by woody species was assessed within four 5x5 m^2 subplots in each plot.
The following parameters were surveyed:
1) dominant canopy traits [Diameter at Breast Height (DBH = $D_{1,30m}$), Tree Height];
2) regeneration abundance (N seedlings or saplings m^{-2});
3) regeneration development (Diameter at root collar, height of the largest saplings).

Results
Acacia density has more than quintupled in just sixteen years, reaching up to 10,800 individuals per hectare. However, native species such as *Pistacia lentiscus* L. and *Olea europea* var. *sylvestris* Mill. also displayed a notable density increase. *Pistacia* density increased up to 9 times, reaching a maximum density of 9,300 individuals per hectare, whereas *Olea* density increased as much as 800 times, with a maximum density of 120,000 individuals per hectare. Preliminary investigations showed that only about 15% of light was available in the understory of the pine plantation.

Table 1 – Dendrometric data of *Pinus pinea* cover (Mean ± standard deviation; 2001 vs. 2017). For basal area the total amount was considered.

Plots		Tree density (N ha^{-1})		DBH (cm)		Height (m)		Basal Area (m^2 ha^{-1})	
2001	**2017**	**2001**	**2017**	**2001**	**2017**	**2001**	**2017**	**2001**	**2017**
1	**1**	573	570	21.10	23.3 ± 3.7	8.79	10.3 ± 0.5	19.95	29.7
2	**2**	774	499	20.20	24.2 ± 1.9	7.83	9.1 ± 0.6	24.76	23.0
2	**3**	774	771	20.20	23.4 ± 4.0	7.83	9.2 ± 0.3	24.76	34.1

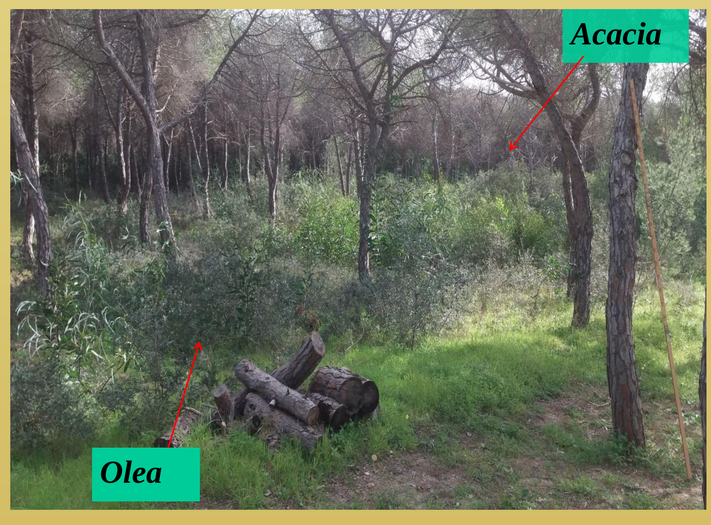




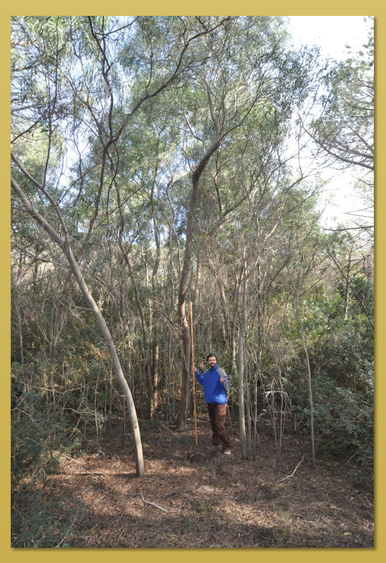
Study site – The "Foce Platani" Nature Reserve, is located along the south-western coast of Sicily.

Invasion process – Massive natural regeneration by *A. saligna* in the understory of *Pinus* plantations has been observed in the Foce Platani reserve in the last 20-30 years.

Regeneration by native species – Massive regeneration by *Olea europea* var. *sylvestris* and *Pistacia lentiscus* was observed especially where thinning was not performed and canopy cover was higher.



Management is the key – In such extremely dynamic situations, light availability has a prominent role in driving regeneration pattern. Forest management plays a key role. Localized interventions only where native species occur may favor the renaturalization process. By contrast, thinning seems to foster *Acacia* invasion and its rapid spread where this species is present.



Invasive pattern – Some *Acacia* individuals reached the upper layer of the forest canopy thus representing nowadays the dominant tree species in some areas.

Thinning effects – The clearing of Pine cover seems to accelerate the development and spread of *Acacia* saplings.

Table 2 – Dendrometric data of the regeneration layer (Mean ± standard deviation; 2001 vs. 2017).

Years		Species	Density (N ha^{-1})		Δ	Diameter at root collar (cm)		Height (m)	
2001	**2017**		**2001**	**2017**		**2001**	**2017**	**2001**	**2017**
1	**1**	***Pistacia lentiscus***	1,017	9,300	+9.1	1.29	0.7 ± 0.01	1.20	0.90 ± 0.07
		Olea europaea* var. *sylvestris	73	58,900	**+806.8**	0.30	0.3 ± 0.01	0.12	0.40 ± 0.01
		Acacia saligna	2,035	10,800	+5.3	3.81	1.9 ± 0.12	1.20	1.00 ± 0.06
2	**2**	***Pistacia lentiscus***	2,717	9,700	+3.6	1.51	3.5 ± 0.18	0.83	3.10 ± 0.10
		Olea europaea* var. *sylvestris	543	60,500	**+111.4**	0.16	1.7 ± 0.01	0.19	2.30 ± 0.01
2	**3**	***Pistacia lentiscus***	2,717	3,800	+1.4	1.51	0.6 ± 0.01	0.83	1.50 ± 0.02
		Olea europaea* var. *sylvestris	543	125,200	**+230.6**	0.16	0.5 ± 0.01	0.19	0.60 ± 0.01

Conclusions and Management Options
On the one hand, the understory of *Pinus pinea* seems to offer suitable microclimatic conditions to facilitate *A. saligna* regeneration and seedlings establishment, protecting them from marine aerosols and frequent winds. No renegeneration sign has been observed in the dunes next to the sea. On the other hand, light availability appears to be a key factor to trigger natural regeneration by *Acacia* in mass and rapid growth. A similar ecological strategy has been found in *A. longifolia* (RASCHER *et al*., 2011). However, further investigations are needed in order to define the ecophysiological bases of its invasive potential. Canopy cover was one of the main factors explaining the observed pattern. This study case may be emblematic for the management of afforested areas in the Mediterranean where thinning aimed at favoring the renaturalization by native woody species could trigger the possible spread of invasive alien species that may counterbalance the positive effects of the necessary interventions. However, in absence of any active management, an increase of the invasion process by *A. saligna* within Foce Platani is also expected because this alien species appears to be increasingly competitive against native species. Thus, the invasion process must be constantly monitored in order to avoid an uncontrolled spread of this alien species and only moderate thinnings have to be performed at least in short-medium term perspective.

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