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Garden plants dynamics at urban/fallow land interfaces: influence of local versus landscape factors

Audrey Marco¹, Sébastien Oliveau², Nicolas Pech³,
Thierry Dutoit⁴ & Valérie Bertaudiere-Montes⁵

Abstract

Rural areas have been subjected to a strong pressure of urbanization which reorganizes landscape mosaics in creating new ecological interfaces: garden/fallow land. These latter are the place of specific floristic dynamics through the movement of cultivated plants from garden to a neighbouring habitat. In order to understand these ecological processes, the pool of cultivated plants were firstly characterised in Mediterranean gardens. Then, the escaped garden plants and the factors explaining their presence in post-cultural fallow lands were identified with a spatial analysis on two hierarchical levels: the local structure of fallow land and its surrounding landscape. The high number of escaped garden plants in fallow lands is related to a well adapted pool of cultivated plants to the Mediterranean climatic and edaphic constrains. The species richness of escaped garden plants in fallow lands was also mainly associated with four landscape variables (41%) corresponding to the proximity and the density of gardens and the openness of landscape around the fallow lands. The dispersal process occurs mainly over short distance. Three local factors related to vegetation structure and topo-edaphism conditions explain 4.8% of total variation. The set of these results highlight that in urbanized landscapes garden plants dynamics are more determined by the composition of landscape through the organization of introduction sites than ecological conditions within establishment sites.

Keywords

Cultivated species, dispersal, landscape mosaic, urbanization, Mediterranean area

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Introduction

European rural areas have been subjected to a rapid change in land-use and land-cover over the last years. Urbanization, spreading rapidly in many areas of the world, shows in Europe a recent but explosive growth occurring in a scattered way throughout the countryside (ANTROP, 2004; EEA Report, 2006). Essentially isolated residential houses and highly crowded housing estates are spreading rapidly in many rural areas. At the same time, the abandonment of agricultural lands in front of the industrial competition since 1950 induces an increase in the number of fallow lands in rural landscape (réf). The strong juxtaposition between houses and fallow lands creates new ecological interfaces which can be the place of new ecological plants dynamics. Effectively, gardens of residential houses, representing areas of voluntary introduction of native and alien cultivated plants, are in contact with a diversity of habitats which might be colonized by introduced species. Horticultural species, which are well-adapted to environmental constraints, are able to escape, reproduce, and establish outside gardens (SUKOPP, 2004).

An important objective of landscape ecology is to determine the influences of landscape structure on ecological processes, including the movement of organisms (BUREL & BAUDRY, 1999). The dispersal of perennial garden plants is undoubtedly an important movement of organisms to take into account at urban/fallow lands interfaces. More and more studies underline the importance of these species in changes of natural flora composition. In Britain, SMITH et al., (2006) demonstrate that the composition of garden flora by growth form is strongly dominated by biennial or perennial and could support the view that the disproportionate number of certain life-forms (shrubs and geophytes) in the naturalised alien flora of Britain is due to their over-representation in the garden flora. Moreover, researchers are now turning their interest towards long-lived species (PETIT et al., 2004), particularly woody species in alien plant establishments and invasions (Richardson et al., 1994; RICHARDSON & HIGGINS, 1998; SIMBERLOFF et al., 2002). Owing to WEBER (2003), 71% of invasive plants species in the world are perennial plants (24.4% shrubs, 19.2% trees, 16.7% perennial herbs and 10.7% perennial grasses).

Although there is an important literature on alien plants establishments, it is difficult today to identify precisely which factors drive specifically alien species patterns and also which spatial-scale influences mainly these processes. There has been considerable debate over whether the number of species found in a patch is more strongly controlled by forces acting at the landscape or local level (WRIGHT et al., 2003). In a patchy landscape, the number of plant species found in any particular patch is the result of the interaction between dispersal and persistence. For a species to be present in a patch, it must first disperse from the regional species pool including cultivated and native species into the focal patch, then establish and persist. The species richness of a patch will be the sum of those species present in the regional species pool that successfully disperse into and persist in the patch (VAN DER VALK 1981). Viewing ecological mechanisms at different spatial scales is therefore very important to discern the drivers of alien patterns and to understand mechanistic interpretation of ecological processes. However, often controls on alien establishment have been often examined at one scale and few studies use a dual scale approach. There is therefore a need to lead studies at both small-scale and large-scale to understand the dynamics of garden plants in these new contexts.

Among the most important factors that drive alien species establishment, studies have highlighted the proximity to large sources of potential invaders or "propagule pressure", extent of openness, and frequency of disturbance (MORAN, 1984; TIMMINS & WILLIAMS, 1991). Nevertheless, the majority of these factors have been identified at urban/forest interfaces (MORAN, 1984; TIMMINS & WILLIAMS, 1991; ROSE & FAIRWEATHER, 1997; ANDERSON, 1999; SULLIVAN et al., 2005) and along roadsides (TYSER et al., 1992) whereas human disturbances especially human uses are different at urban/fallow land interfaces. Inside forest fragments, vegetation is disturbed by human activities such as tracks and trampling of understorey vegetation off tracks, which facilitate weed establishment whereas although fallow lands in rural areas were subject to a strong pressure of agricultural activities in the past, there are now poorly visited. The study of these interfaces should provide useful information on the influence of human disturbances in the urbanizing rural areas.

Several characteristics of human habitations are also important factors in alien plants establishment and invasion, particularly the distance from human habitations (SULLIVAN et al., 2001, 2005). For example, in studying movement of exotic plants into coastal native forests from gardens in northern New Zealand, SULLIVAN et al., (2001, 2005) highlight that the particular exotic plant species found in a forest sample were significantly more likely to be found in the neighbouring settlement than in other more distant settlements. Moreover, TIMMINS and WILLIAMS (1991) have also demonstrated that natural vegetation close to settlements in New Zealand tends to contain many more exotic plant species than natural vegetation far from settlements. Also, the adjacent dumping of garden waste was a major source of weed introductions to foredunes of coastal SE Queensland (BATIANOFF & FRANKS; 1998). The number of exotic species in disturbed habitats on Tiwi Islands, Australia, increased with age of neighbouring (FENSHAM & COWIE; 1998). SULLIVAN et al., (2005) have demonstrated also that the number of houses within 250 m of a forest area, alone, explained 66.8% of the variation in the number of exotic plant species in coastal forests in eastern Northland, New Zealand. These studies reflect how important this group of factors (distance from human habitations, age of neighbouring settlements and build-up density) is in terms of alien establishment processes.

The Mediterranean area is an excellent study area to study garden plant dynamics in patchy landscapes. Particularly, the western coast (in Spain, in Portugal, in France...) is one of the most hot spots of urban sprawl (EEA Report, 2006). It is characterised by an urban spreading out. The overpopulation of cities in coastal areas has led to an urban spread in the hinterland (OGER, 2005; JULIEN, 1999; BONIN & LOISEL, 1997). Isolated residential houses and highly crowded housing are being established in the surrounding countryside and the development of gardens in this area becomes a possible danger for natural vegetation, which is exposed to reservoirs of potentially invasive plants and genetically transformed species. In addition, the agricultural abandonment in the Mediterranean region provides simultaneously a large number of suitable sites as fallow lands for alien species establishment and plant invasions.

In French Mediterranean region, strongly affected by urbanization, 90% of the most notorious invaders are perennial ornamental plants (e.g. *Cortaderia selloana* (Schult.), *Acacia dealbata* (Link), *Buddleja davidii* (Franchet), *Ailanthus altissima* (Miller), *Robinia pseudoacacia* (L.)...) which cause several damages in a multitude of ways: environmental, economic, social and sometimes health problems (JEANMONOD, 1998; AME & CBNMP 2003). In addition to the risk of invasion, these new escapees may also reproduce with spontaneous species leading to a loss of genetic variability of native flora (LOCKWOOD & MCKINNEY, 2001; OLDEN et al., 2004; WHELAN et al., 2006). The common practice of creating hybrids in the horticulture and plant breeding industries poses additional risks to native plants, since these artificial hybrids may form a bridge for gene transfer between two formerly intersterile species (LOCKWOOD & MCKINNEY, 2001). It becomes problematic for the Mediterranean area which is considered among the 34 hotspots of biodiversity in the world thanks to its exceptional amount of endemic plants (MÉDAIL & QUEZEL, 1997; MYERS et al., 2000; MITTERMEIER, 2004).

The aim of this work is therefore to focus on dynamics of garden plants at urban/fallow land interfaces at both small-scale and large scale. The urbanizing rural landscape in south-eastern French Mediterranean region is a good opportunity to identify the pool of cultivated plants in private gardens and also the species which escape from their introduction sites to fallow lands. It allows us to determine the most important spatial-scale that drive escaped garden plants establishment in this context. This work would be useful to understand the role of landscape in alien establishment processes, and more generally, should provide information to the ecological dynamics in urbanizing rural landscape.

Methods

Study site

The study was carried out in a south-eastern French rural area, in the Mediterranean Basin region (43°44'N, 5°18'E) (Fig. 1).

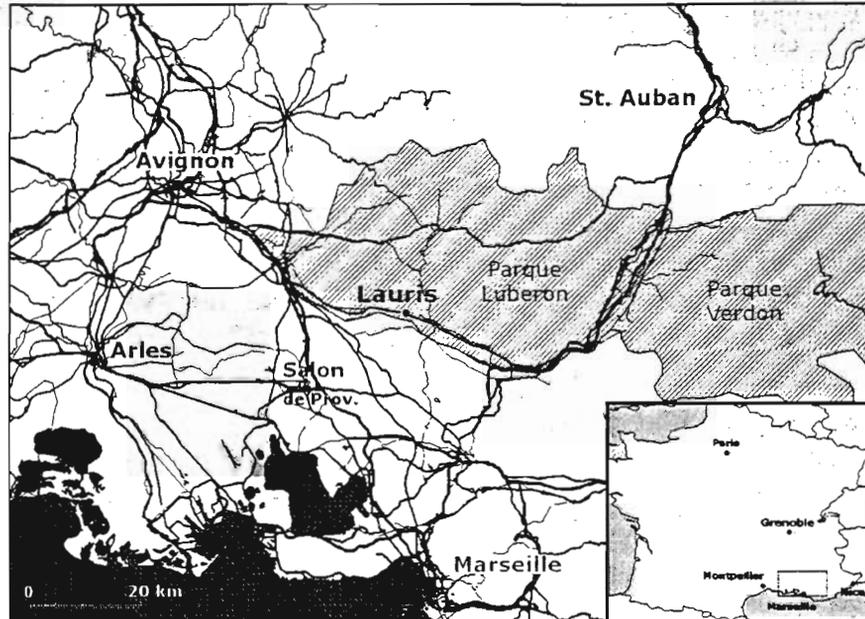


Figure 1: The study area showing the village of Lauris located in the Natural Regional Park of Luberon in the French Mediterranean area

The village of Lauris is located in the Natural Regional Park of Luberon, (Vaucluse department) bordered in the north by the watershed of the Petit Luberon and in the south by the Durance river. It consists of 53% of wooded areas, 27% of agricultural areas and 10% of urban areas and is within meso-mediterranean bioclimate.

From the end of the nineteenth century to the beginning of the twentieth century, there was a strong development of polycultivation. On the calcareous plateau, vineyards, cherry trees, almond trees and olives were cultivated whereas the Durance's plain near the river, which is rich, fertile and irrigated, was essentially specialized in market gardening. At the middle of the twentieth century, in front of the industrial competition, the agriculture which made live 90 % of the population becomes marginal. Today, it collects less than 2 % of the working population and 10 % of the municipal territory are uncultivated. Only the vine growing remains the main agricultural activity of the territory thanks to the development of the Label guaranteeing the origin Coasts of Luberon. Add to this agricultural abandonment, there are over the last thirty years a strong development of isolated residential houses and highly crowded housing estates. Given the influence of two big towns Aix-en-Provence and to a lesser extent of Marseille, the population of Lauris has doubled, rising from 1620 inhabitants in 1975 to 3 143 inhabitants in 2005.

Vegetation sampling

In order to identify the pool of cultivated flora, 120 gardens were selected through a process of door knocking and requesting permission to undertaken surveys on the resident's property. In order to reduce refusals or absences of homeowners, a publicity campaign was carried out using local papers or municipality announcements, prior to visits and each area was systematically visited between April and July 2005 during the week and the week-end in order to sample the gardens of people working and of people who have a second home. In total, fewer than 10% of homeowners refused the floristic sample of their garden and they didn't concern one social class.

In each garden, native and alien cultivated plants (excluding the constituent species (grasses) in lawns) were recorded during an exhaustive survey of the garden. The inventory was drawn up distinguishing thirteen landcovers of the garden: lawn, gravelled path, flower bed, pot and tub, hedge, wall, borders of swimming pool, playing field, pine forest, oak grove, orchard, vegetable garden, and olive grove. Taxonomic identification was carried out on the basis of the 'Universal Encyclopedia of 15,000 plants and flowers of garden' owing to BRICKELL & MIOULANE (2004). Plants which could not be identified were labelled as "unknown" or "Genus sp." when the genus could be identified or "Genus « group »" when the group of cultivar could be identified. The intergeneric hybrids were recorded as "x Genus species", interspecific hybrids "Genus x species". Some horticultural plants involve species that are difficult to distinguish from varieties, such as taxa of Arum, Aubrieta, Chrysanthemum, Dahlia, Dianthus, Iris, Gazania, Gladiolus, Heuchera, Lilium, Mandevilla, Narcissus, Osteospermum, Paeonia, Petunia, Pyracantha, Tulipa, Rhododendron and Rosa; these were identified only to genus level.

In order to study the escaped garden plants in fallow lands, 460 plots were locally identifying with Map info GIS (Map info release 7.8 software). During June and July 2006, 180 plots were visited because some plots were mowed before the vegetation sampling, others had a too strong shrubby stratum making difficulties the vegetation sampling and some couldn't be analysed due to the lack of information of their landscape variables. In each plot, we sampled all the perennial escaped plants from gardens. Using a reasonably consistent search effort of 30–90 minutes per site depending on site terrain, accessibility, and areas, we walked all over the plots. We noted on a scale plan of plot abundances of escaped garden plants which were then reported to Map info GIS.

Predictor variables for General Linear Model

Some local fallow land characteristics have been collected at the same time as vegetation sampling: Soil fertility, State in which the plot was abandoned, % Herbaceous stratum, % Ligneous stratum $0 < H < 0.50\text{m}$, % Ligneous stratum $0.50 < H < 2\text{m}$, % Ligneous stratum $H > 2\text{m}$ and Present human activities. By questioning local farmers and by studying aerial photographs of different periods (1973, 1989, 1996, 2001, 2006), other local variables such as Type of last cultivation, Year of abandonment have been collected. Fallow land size (total area of fallow land in m^2) was calculated with Map info GIS.

The landscape variables have been also collected with Map info GIS coupling the digital land registry and the aerial photographs of Lauris. We chose to analyse the influence of landscape variables in a close surrounding landscape around fallow lands because the earlier studies seem to show the importance of short distance from human habitations in alien species establishment and the effective distance of seed dispersal by Mediterranean bird was found to be ca. 100m (NE'EMAN & IZHAKI, 1996; DEBUSSCHE & ISENMANN, 1994). The landscape variables belonged to two predictor groups. We considered the first to be landscape variables related to introduction site of garden plants such as Distance from garden (distance (m) from the nearest garden; 0 m = parcel adjacent to a garden), Number of houses within a radius of 50 m, 100 m, 150 m and 200 m around the plots, Area of gardens within a radius of 50 m, 100 m, 150 m, and 200 m around the plots, Number of escaped garden plants in houses (the number of escaped garden plants present in the visible portion of the gardens of houses within a radius of 50 m around the plots was noted for each fallow land at the same time of the vegetation sampling), Age of houses (age of the oldest house within a radius of 50m around the plots), Interface garden/fallow lands (the presence or not of a hedge was noted at the same time of the vegetation sampling). The second group of landscape variables are related to rural matrix such as Area of landcover types (areas of forests, crops, vineyards, fruit trees cultivations, fallow lands, road or railway) were measured within a radius of 50m and 200m.

Data analysis

In order to assess the ability of the cultivated plants to survive under Mediterranean environmental constraints, information on the origin of the species, the resistance to the frost (level of hardiness) and the dryness of cultivated plants were taken from BRICKELL and MILOLANE (2004). The origin of the plants bulked according to 12 origins: Europe, America, Asia, Africa, Oceania, Mediterranean Basin, Tropical, Eurasia, Eurafica, Northern Hemisphere, Mixed (species coming from more than three different continents) and Horticultural (species resulting from artificial hybrid selection). The resistance to the frost bulked according 4 levels: killed by the frost ($T^{\circ} > + 5^{\circ}\text{C}$), semi-hardy ($T^{\circ} > 0^{\circ}\text{C}$), hardy ($T^{\circ} > -5^{\circ}\text{C}$) and very hardy ($T^{\circ} > -15^{\circ}\text{C}$). The resistance to the dryness was given owing 5 levels: very low, low, medium, strong and very strong. The proportion of growth forms (annual, biennial, perennial) and Raunkiaer's form was also given (RAUNKIAER, 1934). We clarified then in which landcovers the most frequent species are present.

Before analysing the landscape and local data by a general linear modelling, the variables were transformed to a more normal distribution and to achieve a linear relationship between the response variable and the recorded variables. The square root transformation ($X+0.5$) was applied to the response variable (escaped garden plants richness) and to variables concerning Number of escaped garden plants in houses, Number of houses. The variables Fallow land size, Distance from garden, % Herbaceous stratum, % Ligneous stratum $0 < H < 0.50\text{m}$, % Ligneous stratum $0.50 < H < 2\text{m}$, % Ligneous stratum $H > 2\text{m}$ and the different Areas of each landcover types were log transformed ($X+1$).

Pearson's product moment correlation coefficient was used to test the strength of linear relationships between continuous variables. One way ANOVA was used to determine relationships between class and continuous variables. A level of $p < 0.05$ was taken to denote a significant relationship.

As an exploratory process, the continuous variables that had significant correlations and the class variables that showed a significant relationship with the response variable were used in a stepwise regression in Minitab (Minitab r.14 software) in order to identify a useful subset of the predictors. Multiple linear regressions were conducted to identify independent variables making the strongest statistical contributions to variation in species richness selection procedures. Significance of each variable retained in the adequate model was tested using the α - statistic ($p < 0.05$ to enter and remove).

Then, they were used in a "best subsets" analysis in Minitab. A "best subsets" analysis gives the two regression models with the highest level of explanation for each number of independent variables. The indicated models were tested using the general linear modelling procedure in Minitab which uses a regression approach by creating a "full rank" design matrix from the factors and covariates. Each response variable is regressed on the columns of the design matrix. Continuous variables were used as covariates in the models, which used adjusted (Type III) sums of squares. A model with the highest adjusted R^2 was accepted if all components of the model were significant, and the residuals distributed, at least approximately, normally, as shown in a histogram. If this was not the case, the models with lesser levels of adjusted R^2 in the best subsets analysis were examined until one or none satisfied these requirements. Given the great range of variables, a model was established for each predictor groups and then a global model was established only with the variables previously selected by the two first models.

To understand the relationship between the response variable and the recorded variables selected by the global model, a principal correspondence analysis (PCA) was also performed in Minitab.

To detect any significant differences in the proportion of dispersal mode of escaped garden plants among fallow lands, Chi-square tests were performed using Minitab.

The significant terms of the explanatory variables selected in the regression analysis were analysed further to determine the comparative influence of local (l) and landscape (L) variables in escaped garden plants richness variation. The total variation within the number of species was decomposed among the two types of explanatory variable (i.e. l and L) and the percentage of explained deviance calculated for four different components: (a) pure effect of local variation alone, (b) combined

variation due to the joint effect of local and landscape components, (c) pure effect of landscape alone and (d) variation not explained by the independent variables included in the analysis. The decomposition of the variation in the species richness into the two sets of explanatory variables was carried out by means of a partial regression analysis. As explanatory variables were not mutually independent, this approach can help determine the amount of variation overlap and clarify the influence of the variables considered. In the process of variation decomposition the species richness (y) was regressed with the two types of variables together, which represent the total explained variation in the dataset ($a + b + c$). Regressing y with each one of the explanatory variables yields the variation attributable separately to l ($a + b$) and L ($b + c$). Fractions a , b , and c were estimated according to the sets of equations, where:

$$\begin{aligned} a + b &= l & b + c &= L & a + b + c &= lL \\ \text{and } a &= l - b & b &= L + l - lL & c &= L - b \end{aligned}$$

Results

573 horticultural plants were collected in the investigated area of 215, 000 m². With regard to the growth pattern of species, 92% were perennials, 7% annuals and 1% biannuals. Taxa were overwhelmingly trees and shrubs: 55.1% of taxa were phanerophytes and 21.4% chamaephytes. 12.4% of taxa were geophytes (bulbs and rhizomes), 6.3% of taxa were hemicryptophytes and 4.8% therophytes. The most abundant species were *Cupressocyparis leylandii* ($n = 1\,548$), *Cupressus arizonica* ($n = 1\,243$), *Pyracantha* sp. ($n = 1\,104$), *Prunus laurocerasus* ($n = 1\,011$), which are all planted in hedges, and *Rosa* sp. ($n = 1\,034$).

Taxon origin was varied and 85% were not Mediterranean. Taxa came mainly from Asia (22.5%), America (18.9%) and Europe (11.3%). Concerning the species introduced from America, 62% are originated from North America among which more than half from Mexico. 7% of the taxa were African among which 79% came from South Africa. Mediterranean Basin taxa and taxa which came from climatic regions under Mediterranean influence represented 24.4%.

With regards to the resistance to the frost of the species (Fig. 2a), 56% were very hardy species (T°), 18% hardy species, 9% semi-hardy species and 19% can be killed by the frost. Concerning the resistance to the dryness (Fig. 2b), 17% are very resistant species, 33% are resistant species, 23% are medium resistant species, 20% and 7% are respectively low and very low resistant species.

Overall 27 escaped perennial plants from garden were found in the 180 fallow lands sampled (101 ha) with highly variable abundances going from one to more than a thousand individuals (Tab. 1).

The most abundant escaped garden plant was *Pyracantha* sp. with 1653 individuals. We decided to determine only at genus level because field observations seems to show several horticultural hybrids and not only *Pyracantha coccinea* naturalized in Mediterranean area (Fournier, 2000). The most important dispersal mode of escaped garden plants was ornitochory with 45%, 33% of escaped garden plants had a vegetative dispersal mode, and 22% are wind dispersal. The wind dispersal species are more important in fallow lands of alluvial plain ($\chi^2 = 14.45$, $ddl = 1$, $p < 0.001$).

The best final model which was conserved explained nearly 74% (73.6%) of the variation in number of escaped garden plants and seven explanatory variables were significant: three local variables and four landscape variables which were previously selected (Table 2).

The ordination of the first two axes of the principal correspondence analysis (PCA) showed the relationships between all components of this model (Fig. 2).

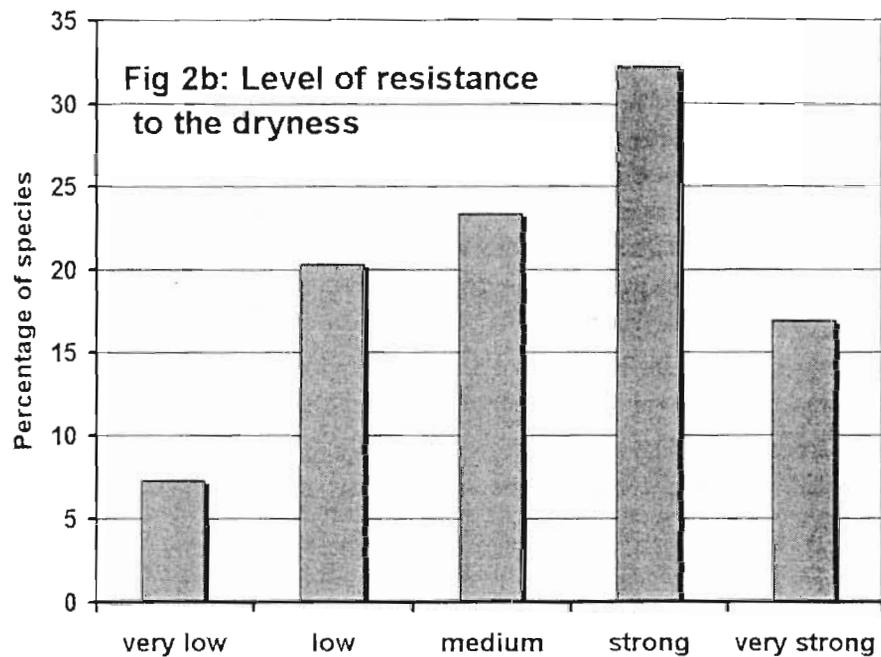
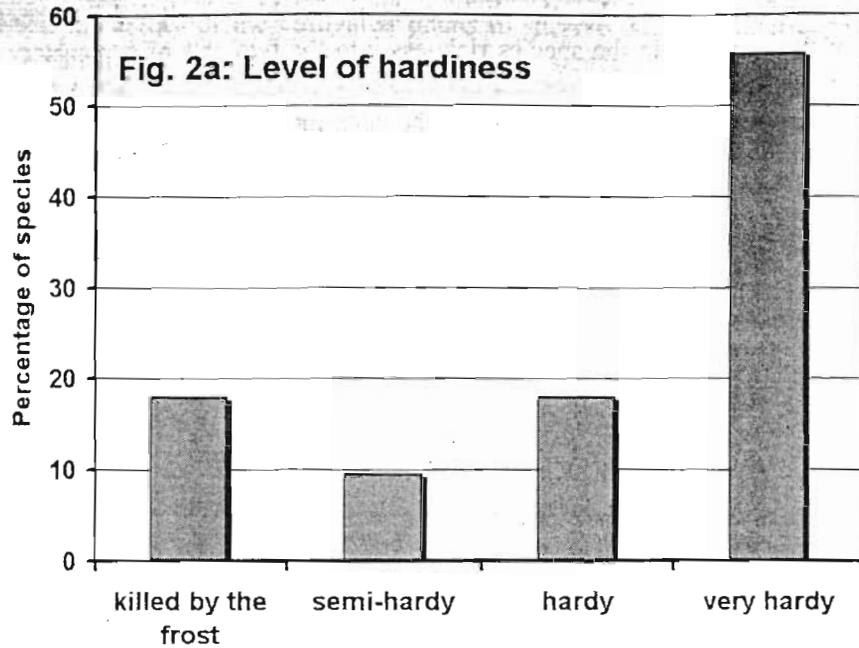


Figure 2: Frequency distribution of levels of resistance to the frost (2a) and to the dryness (2b) of cultivated species in 120 gardens sampled in 2005 in the urbanizing rural area of Lauris, southern France

The first two axes represent about 53% of the variance. On the first axis, we can see the response variable strongly correlated with the “Number of escaped garden plants in houses within a radius of 50m” ($r = 0.785$, $p < 0.001$). The response variable had also a significant correlation with vegetation structure, and in a lesser extends with the Number of houses and garden areas within a radius of 50m. The second axis separated fallow lands of the topo-edaphism conditions and proportion of cereal fields within a radius of 200m. The fallow lands of alluvial plain were richer ($F = 1.52$; $p < 0.001$) in escaped garden plants (mean richness = $1.94 (\pm 1.60)$) than those of calcareous plateau (mean richness = $1.05 (\pm 1.18)$) and they were also more surrounded by cereal fields.

Escaped garden plants	Abundance in fallow lands
<i>Pyracantha</i> sp.	1653
<i>Iris</i> sp.	200
<i>Acer negundo</i>	168
<i>Juglans regia</i>	93
<i>Cupressus sempervirens</i>	49
<i>Buddleia davidii</i>	49
<i>Ailanthus altissima</i>	33
<i>Broussonetia papyrifera</i>	29
<i>Pinus nigra</i>	26
<i>Syringa vulgaris</i>	21
<i>Olea europea</i>	19
<i>Quercus pyrenaica</i>	19
<i>Robinia pseudoacacia</i>	17
<i>Phyllostachys aurea</i>	16
<i>Ligustrum ovalifolium</i>	12
<i>Quercus pedunculata</i>	12
<i>Cotoneaster lacteus</i>	10
<i>Cotoneaster selkirkii</i>	7
<i>Rosmarinus officinalis</i>	6
<i>Thuja orientalis</i>	3
<i>Cedrus atlantica</i>	3
<i>Parthenocissus quinquefolia</i>	2
<i>Barberis thunbergii</i>	1
<i>Cotoneaster horizontalis</i>	1
<i>Laurus Nobilis</i>	1
<i>Opuntia</i> sp.	1
<i>Eleagnus xebbingei</i>	1

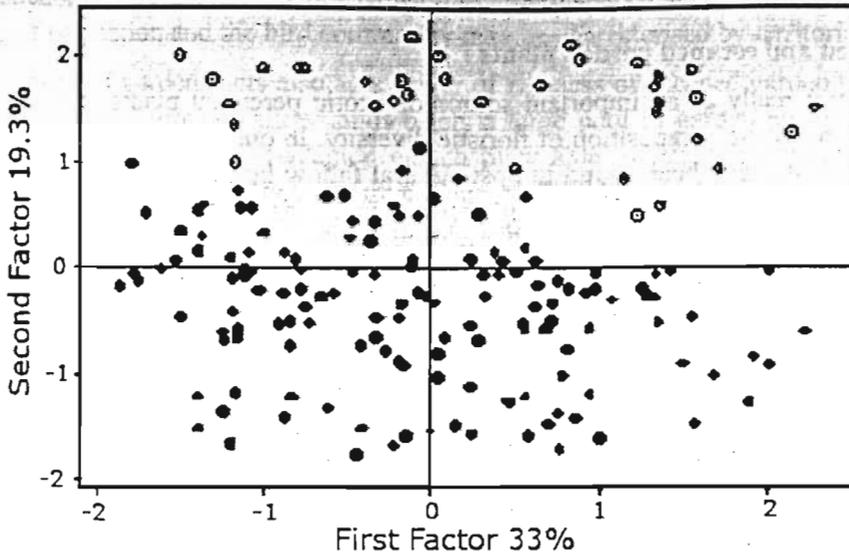
Table 1: List of escaped garden plants, with their abundance, sampled in 180 fallow lands of Lauris.

Pyracantha sp groups together several hybrids

The total variation within the number of species was decomposed among the two types of explanatory variables (Table 2). The decomposition of the variation shows that the largest fraction of the variability (41.4%) in the number of species is accounted for by the pure effect of landscape variables, while the pure effect of local variables explains only 4.8% of total variation in species richness. The joint influence of local plus landscape is also important (27.4%). Variation partitioning shows us that local variables exerted a weaker influence on total escaped garden plants richness compared to landscape variables.

Source	Variable	DL	SC seq	SC ajust	CM ajust	F	P	Pure effect	Joint effect
Topo- edaphism conditions	I	1	2.4820	0.3363	0.3363	5.37	*		
% ligneous stratum 0<H<0.50 m	I	1	7.1395	0.2798	0.2798	4.47	*	4.8%	
% ligneous stratum 0.5 m<H<2 m	I	1	3.5346	0.6491	0.6491	10.37	**		
Species richness in escaped garden plants in houses of 50 m	L	1	15.4889	13.5998	13.5998	217.27	***		27.4%
% Garden area within a radius of 50 m	L	1	0.3163	0.5190	0.5190	8.29	**	41.4%	
No houses within a radius of 200 m	L	1	0.4259	0.6019	0.6019	9.62	**		
% Cereal field area within a radius of 200 m	L	1	0.6712	0.6712	0.6712	10.72	***		
Error		172	10.7661	10.7661	0.0626				
Total		179	40.8245					73.6%	

Table 2: The analysis of the variance of the best final model with seven variables retained after stepwise multiple regressions and the variation partitioning in the number of escaped garden plants from gardens in post-cultural fallow lands of Lauris between the two explanatory variables. The decomposition of the variation has been carried out by partial regression analysis using generalized linear models and the percentage of total explained deviance as the measure of explained variation. P-values are indicated as follows: * P < 0.05, ** P < 0.01, *** P < 0.001; I (local) and L (landscape)



- Fallow land plots on calcareous plateau
- Fallow land plots on alluvial plain

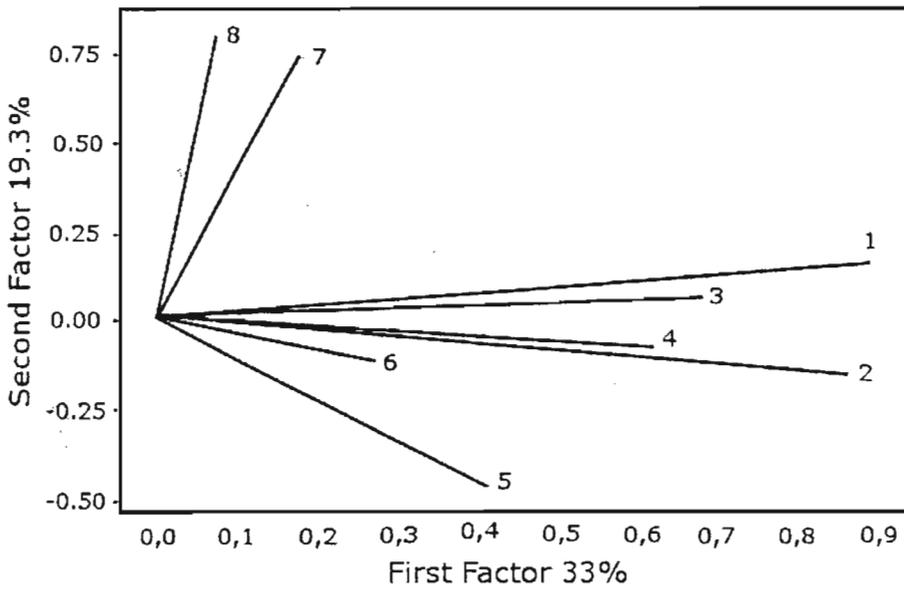


Figure 3: PCA ordination of the fallow land plots with the independent model; 1: Species richness of escaped garden plants in fallow lands; 2: Species richness in escaped garden plants in houses within a radius of 50 m; 3: % Ligneous stratum 0.50<H<2 m; 4: % Ligneous stratum 0<H<0.5 m; 5: % Garden area within a radius of 50 m; 6: No houses within a radius of 200 m; 7: Topo-edaphism conditions; 8: % Cereal field area within a radius of 200m

Discussion

Pool of cultivated and escaped garden plants

Private gardens act really as an important source of exotic perennial plants that spread into native vegetation and modify the composition of floristic diversity. In our study, a high number of perennial escaped garden plants have been found in post-cultural fallow lands and could be related to the fact that the pool of horticultural plants in the study area is well adapted to the Mediterranean climate. The major constraints for naturalization in Mediterranean area are the summer dryness and the winter frost which play key roles through limiting factors. In private gardens, a quarter of horticultural taxa came from climatic regions under Mediterranean influence and the majority of garden plants are resistant to the summer dryness and characterised by a high level of hardiness. Thus garden owners, planting species adapted to Mediterranean climate, reinforce the risk of alien species invading the Mediterranean countryside in helping them to surmount environmental "barriers". In order to affirm or not this hypothesis, gardening practices are now investigated by a social inquiry in order to understand the role of this factor in garden plants dynamics.

Urban/fallow lands interfaces constitute an important place for plant dynamics in urbanizing rural areas. But we sampled in fallow lands about 5% of the exotic perennial garden plants brought in Lauris gardens. If we refer to the "10 Rule" proposed by WILLIAMSON and FITTER (1996) to quantify the risk of alien spread, approximately 10% of the exotic plants that are brought to a new region will actually escape into the wild. Of these escaped plants, only 10% will become naturalized, and 10% of the naturalized plants will become invasive. According to that, our results indicate it is likely that the post-cultural fallow lands may not be the only one establishment site for escaped garden plants and other habitats such as roadsides, abandoned sections etc. should be inventoried. If the urbanization of rural areas continues to increase as rapidly as these last years, post-cultural fallow lands will become a transient habitat and the other habitats of landscape mosaic could be predominant on the biological processes of alien dispersal in years to come.

Influence of landscape on garden plants dynamics

Landscape composition plays a key role in garden plant dynamics because landscape factors explained more than 40% of the total variation of the richness of escaped garden plants in fallow lands. It determines the dispersal process of escaped garden plants from garden to fallow lands which is prior to species establishment. Particularly, characteristics of human habitations in a closed surrounding of post-cultural fallow lands look very important. The closest juxtaposition between gardens and fallow lands increases the risks of alien species establishment because it offers the opportunity of escaped garden plants to find immediately a suitable site to establish outside gardens. It helps them to surmount rapidly "dispersal barriers". Also like at urban/forest interfaces (SULLIVAN et al., 2005), the specific escaped garden plants found in a fallow land plot were likely to be found in the neighbouring houses.

The proximity of sources of propagules seems to be a significant driver of richness of escaped garden plant species in Mediterranean post-cultural fallow lands because the escaped garden plants found in fallow lands had a strong probability to be introduced in a closed surrounding. This suggests us that the distance of dispersion of escaped garden plants in adjacent areas looks to be relatively closed to alien introduction sites. In the fields, we have also observed that the presence of hedge at garden/fallow land interface often facilitates entry of hedge escaped garden plants in fallow land due to their proximity to establishment sites. Despite these observations, the presence of hedge at garden/fallow was not significantly correlated with the number of escaped garden plants. It was not included in the final model certainly for the lack of its representativeness in our data set. The landscape composition in these territories seems to induce short dispersal process although the majority of escaped garden plants are characterised by long-dispersal mode such as wind or bird

dispersal. In such landscape, the efficiency of wind as long dispersal vector may be reduced due to the heterogeneity of vegetation and the bird community may be characterised by territorial birds.

The highest density of gardens acts also as a driver of richness of escaped garden plant species. The great number of gardens around fallow lands offers a large pool of garden plants and enhances the probability to have a potential well-adapted garden plant able to establish outside gardens. Houses spread by low housing density types in urbanizing rural areas constitute consequently a suitable context for escaped garden plants establishment. Characterised by isolated residential houses dispersed in rural landscape, it constitutes a real threat for post-cultural fallow lands firstly by enhancing the juxtaposition between alien source areas and establishment sites.

Add to human habitations, the openness of landscape around fallow lands increases the number of escaped garden plants in these habitats. Effectively, the fallow lands surrounded by a large proportion of cereal fields were significantly richer in escaped garden plants than the others. They had precisely richer in wind dispersal species. This could support the view of OZINGA et al., (2004) who have demonstrated that the proportion of species with a high potential for dispersal by wind increases with increasing openness of the landscape. The efficiency of wind as a dispersal vector is indeed constrained by the height and density of the surrounding vegetation.

Influence of local scale

Ecological conditions of plots appear determining plant establishment processes but also in plant dispersal process. Particularly, vegetation structure which is a good predictor to species richness of escaped garden plants. Facilitation is one of the mechanism affecting plant colonization of abandoned agricultural land (VERDU & GARCIA-FAYOS, 1996). The presence of fallow lands characterised by a shrubby stratum constitute suitable sites for birds by offering perching places and facilitate therefore alien species bird dispersal. Garden shrubs (*Pyracantha* sp., *Cotoneaster* sp....) which are frequently planted in hedges in the study area, are particularly attractive for frugivorous birds. For example, *Pyracantha* is the most frequent in gardens and offers a great density of fruits (several millions per ha) at a period where fruits from spontaneous plants are scarce (DEBUSSCHE & ISENMANN, 1990). In the Mediterranean region, the seeds of numerous plant species are dispersed by vertebrates, especially birds which occur in very high numbers during migration and in winter (DEBUSSCHE & ISENMANN, 1990). In our study, 45% of escaped garden plants had a bird dispersal mode. Thus, garden owners, planting bird dispersal species in gardens and particularly in hedges, facilitate their dispersal. They reinforce therefore the risk of alien species spreading in the Mediterranean countryside in helping them to surmount "dispersal barriers".

The topo-edaphism conditions were significantly correlated with the number of escaped garden plants and particularly the good fertility and moisture of soils. Timmins and Williams (1991) in New Zealand showed also that soil fertility was significantly correlated with the number of weeds and particularly in reserves of high soil fertility. Moreover, OHLEMÜLLER et al. (2006) had a significant correlation between fertility and alien species richness. WISER et al. (1998) and HOWARD et al. (2004) reported also high fertility sites being more prone to invasion by exotic plants species in forests of New Zealand and the eastern US respectively. However, although the topo-edaphism conditions were significantly correlated with the number of alien species, they were, contrary to our study, not used in the final model in the majority of the studies (TIMMINS & WILLIAMS, 1991; OHLEMÜLLER et al., 2006). This result shows the importance of edaphic constraints of calcareous soil as a limiting factor for numerous species (acid soil species, deep soil species, wet soil species...) in Mediterranean region. Thus, fallow lands near the Durance River characterised by very fertile and irrigated soils provide an opportunity to escaped garden plants to establish outside gardens in offering less restricting soil conditions.

Different types of disturbance affect alien plant establishments and invasions in different ways (ALSTON & RICHARDSON, 2006). In our study, present human activities (walking, mowing,

clearing...) within fallow lands were not at all associated with the number of escaped garden plants, although human impact and use within establishment sites are among the most important factor determining alien species establishment (TIMMINS & WILLIAMS, 1991). This result is explained by the fact that types of human disturbances observed within fallow lands of our study area didn't favour alien species establishment. Effectively, fallow lands in rural areas are not visited contrary to forest fragments and forest reserves which are more popular recreational areas. In these habitats, the visitors create disturbance and facilitate dispersal of alien plant species. Moreover, we didn't observed freshly dumped garden wastes at garden/fallow lands interfaces which are among one of the most important human weed-dispersal mechanisms (SULLIVAN et al., 2005). Add to that, some fallow lands plots are regularly mowed each year, reducing consequently the development of woody stratum in plots, very useful for bird dispersal in Mediterranean region.

Conclusion

This study shows that there is an important pool of escaped perennial garden plants in the Mediterranean post-cultural fallow lands whereas the strong climatic and edaphic constraints constitute limiting factors to the naturalization of alien plants in this area. This result is linked to the pool of cultivated garden plants which is well-adapted to the Mediterranean context. Gardening practices but also life-history traits should be more investigated in order to understand the role of these factors in alien plant establishment.

Multiple factors are responsible for structuring the richness of escaped garden plant species in the area. The proximity of sources of propagules, the closest juxtaposition between gardens and fallow lands, and the great number of gardens around fallow lands increase the risks of alien species establishment in these habitats. Dispersal process of escaped garden plants occurs mainly over short distance. These results show also how urbanization context in rural areas, particularly house spread by low housing density, enhances alien plant establishment. The openness of landscape observed around fallow lands seems to favour alien species wind dispersal, whereas the shrubby stratum in old fallow lands constitute suitable sites for birds by offering perching places and facilitate therefore alien species bird dispersal. The topo-edaphism conditions play also a key role in escaped garden plants establishment, particularly alluvial soil which offer less restricting soil conditions for alien species establishment.

The study demonstrates also that it is very important of analyzing ecological mechanisms at multiple spatial scales because both small-scale and large-scale have help us to discern the drivers of escaped garden plant dynamics in post-cultural fallow lands. But landscape scale appears really here as one of the most important spatial scales structuring dispersal process of escaped garden plant species. The set of these results show how post-cultural fallow lands are under considerable threat from alien plant invasion. It underlines also the importance of leading further research on intrinsic characteristics of garden plants, such as life-history traits and seed biology, and on planting practices in order to provide a clearer understanding of the new floristic dynamics in changing territories.

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