



## Spatial model of a pyrophyte shrub in Mediterranean terrestrial ecosystems

Josep-Lluís Usó-Doménech, Josué-Antonio Nescolarde-Selva\*, Miguel Lloret-Climent, Lucía González-Franco, Kristian Alonso-Stenberg

Department of Applied Mathematics, University of Alicante, Alicante, Spain

### ARTICLE INFO

#### Keywords:

Gompertz curve  
Growth curves  
K-function  
Point processes  
Spatial pattern  
*Ulex parviflorus Pourret*

### ABSTRACT

The main objective of this work is to study the existence of a possible dependence between different individuals of the same species of Mediterranean shrubs, in particular *Ulex parviflorus Pourret*, located on an area of 100 m<sup>2</sup> in the Desert of Las Palmas (Benicassim, Castellón, Spain). The possible correlation between them is limited to the temporal and spatial dependence, that is to say, to identify if the individuals have statistically significant growth curves, and in the case of being, to see if there is a correlation of the individuals located with proximity in the space. The characteristics (variables) studied are the height and diameter of the *Ulex parviflorus*, and one data per week is available for a period of two years. At the same time, the coordinates ( $x$ ,  $y$ ) within the study region for each individual of the species studied are also available. The conclusion is that the spatial pattern of the *Ulex parviflorus* is not random but is governed by some biological mechanism that provides a structure of inhibition at small distances combining a certain aggregation structure at distances between 3 and 4 m.

### 1. Introduction

Gorse (*Ulex parviflorus Pourret*) is a Fabaceae (family *Fabaceae*). There are about 20 species native to the European Atlantic territory and the western part of the Mediterranean region. The *Ulex parviflorus Pourret* is a pyrophyte species, and is the first colonizer in post-fire stages of ecological regeneration (Fig. 1).

The study of their behavior can provide important conclusions that can have a significant impact on sound management of the territory, both before the fire (prevention) and after it (regeneration). These plants are very important for:

- 1 Holding the soil and preventing erosion.
- 2 They are excellent nitrogen fixers.
- 3 They provide seed banks at very shallow depths.
- 4 The fundamental role of the species *Ulex parviflorus Pourret* is manifested in its close relationship with forest fires, and together with the *Pinus halepensis* is the most important pyrophyte species of the Mediterranean forest (Baeza et al., 2006; De Luis et al., 2004; Dimitrakopoulos and Panov, 2001; Papió and Trabaud, 1990, 1991).

A mathematical population and reproductive model of this species has been developed by Usó-Doménech et al. (2018).

The objective of this work is to study the existence of a possible dependence between different individuals of the same species of

Mediterranean shrubs, in particular, a gorse (*Ulex parviflorus Pourret*) located on a surface of 100 m<sup>2</sup> in the Desert of Las Palmas (Benicassim, Castellón, Spain). The possible correlation between them is limited to temporal and spatial dependence, that is, to identify if individuals have statistically significant growth curves, and if so, to see if there is a correlation of individuals located in space in the near future. The characteristics (variables) studied are the height and diameter of the *Ulex parviflorus*, and a data is available per week for a period of two years, from October to July. In turn, the coordinates ( $x$ ,  $y$ ) are also available within the study region for each individual of the species studied. To study the *Ulex* growth curves as a function of time, parametric modeling is used. To obtain the non-linear regression curves the Statgraphics program is used, and the regression model used is the Gompertz curve.

Recently, Li et al. (2015) studied the ecological restoration and its effects on a regional climate: the source region of the Yellow River, China, they conclude that grassland coverage expansion has improved the regional hydrologic cycle as a consequence of ecological restoration. Banha et al. (2017) published an approach for the management of released pet invaders, namely identifying high invasion risk areas where management efforts should be prioritized. Lister and Leites (2018) propose a modular, hierarchical spatial point process modeling framework for modeling plant communities using this framework in a mid-late successional oak-hickory forest in central Pennsylvania, USA. The main objective of this work is to study the existence of a possible

\* Corresponding author.

E-mail address: [josue.selva@ua.es](mailto:josue.selva@ua.es) (J.-A. Nescolarde-Selva).



Fig. 1. The *Ulex parviflorus* P.

dependence between different individuals of the same species of Mediterranean shrubs, in particular *Ulex parviflorus* Pourret, located on an area of 100 m<sup>2</sup> in the Desert of Las Palmas (Benicassim, Castellón, Spain).

## 2. Characteristics of ULEX PARVIFLORUS POURRET

### 2.1. Ecology and distribution of ULEX PARVIFLORUS POURRET

- 1) **Ecology and distribution:** Its distribution area is the Western Mediterranean. (*Rosmarineta*, *Lavanduletalia stoechadis*). It is a very common and abundant bush in the Valencian Community, provided there is a maritime influence on the environment (*maresía*) as it is very sensitive to the more extreme continental climate. In the Valencian Community: From the port of Morella and Baix Maestrat, to the mountains and the Dianic "Serrànic and Lucèntic Territory" the altitude varies between 0–1250 m. While it is very common in areas near the coast, it gradually dies out as it progresses into the country and stops feeling the influence of wind from the sea. It is indifferent to the nature of the substrate soil, but vegetates best in soils rich in bases and, like most of perennials of the family prefers deep soils.
- 2) **Habitat:** The *Ulex parviflorus* Pourret is a Nanophanerophyte plant. It lives at an altitude of 0–1250 meters.
- 3) **Soil types:** It is a heliophilous plant that lives in open sunny places and it can be found in large deforested areas in the Mediterranean mountains. It lives in coastal regions, in poor, dry and stony soils.
- 4) **Flower characteristic:** The flowers have the following characteristics: a) Solitary or fasciculate on thorns, yellow flowers. b) Size 6–8 mm. c) Zygomorphic flowers, pentamerous with 5 welded sepals and five free and unequal petals. d) The typical papilionacea flower is made up of an upper outer petal generally larger than the other banner petal; on the flanks there are a pair of side petals covered by the banner petal called wings, coated in turn to another couple, the two forward petals that touch at their edges and form the keel. e) In *Ulex*, the banner and keel are similar in length to the calyx, and shorter than the wings. f) Chalice 6–8 (10.5) mm with overlapping hairs or glabrescent. g) Bracteoles 1–1.5 mm wide. h) Thorns 1–2 (3) cm, straight or curved, gray-green and disseminated. i) Androceo consists of 10 stamens (9 soldiers + 1 free). j) Gynoeceum formed by a single carpel, a superior ovary surmounted by a style and stigma within a stamen tube (formed by welded stamens). k) The number of ovules varies from 2 to more numerous and inserts alternating in two rows on a single placenta. It flowers from the months of December to February forming large associations (winter flowering).
- 5) **Characteristics of fruit and seed:** The fruits and seeds have the following characteristics: a) The fruit is a legume, a dry dehiscent fruit, with a sheath that opens in two valves. Size: 7–12 × 3–6 mm. b) The seed contains a large embryo, with or without endosperm. c)

The seeds are ejected violently (with an explosion) to open the leaflets of the legume. This phenomenon is because the shells are dried and tend to be wound helically about themselves along the lines of dehiscence. This opening phenomenon occurs in moments of heat pulses and spreads the seeds around. The fruiting period takes place during the months of December to February (May at the latest).

- 6) **Leaf characteristics:** It is a glabrescent shrub, with leaves reduced to small scales at the base of the spines (less than 1 mm diameter green ash). Simple and small leaves.
- 7) **Most common method of pollination:** The most common method of pollination is insect pollination. The study of pollination of *Ulex parviflorus* corroborates other studies which also states that the optimal pollination period occurs during the day between 08:00 and 18:00. So, the time available for pollination of any flower can be as much as 10 h a day, for up to eight days, but is more effective for 4 days (Richards, 1986). The flowering of this species is early, and there is a very large decrease in competitiveness with other species and consequent effectiveness in seed formation when pollinated by bees.
- 8) **Method seed dispersion:** By studying the dispersion of the seeds of *Ulex parviflorus*, it is found that the structure of the fruit is intimately related to the way it spreads, that is, making an explosive dehiscence (autochory). The seeds of *Ulex parviflorus* are violently expelled from their fruits (explosive dehiscence) then falling to the ground by gravity. The seeds of *Ulex*, benefit then from two processes of dispersion, one primary and another secondary, by the ants. The prominence of the ant and their density in the local ecology may condition the appearance of new plants of *Ulex*.
- 9) **Phytosociological associations:** Gorse lives in thermomediterranean and mesomediterranean floors. Gorse appears in degraded areas of the Garrigue, which leads to the appearance of kermes oak with mastic (*Quercus - Lentiscetum*) and rosemary (*Rosmarino - Ericion*) in which the rosemary (*Rosmarinus officinalis*), heather (*Erica multiflora*), the crown friar (*Globularia alypum*), gorse (*Ulex parviflorus*) and albada (*Anthyllis cytisoides*) are the most common species.

### 2.2. Importance of this species as pyrophyte

*Ulex parviflorus* is considered a very flammable species during the summer, since it conserves its dry elements in branches, stems, etc. The calorific power (energy that can be released in a combustion) of *Ulex parviflorus* would be found in a mid-point along with *Cistus*, *Lavandula*, *Quercus*, *Stipa*, *Thymus*, etc. It is a species that presents a great amount of necromass accumulated at the plant's foot. In advanced stages of maturity, the proportion of necromass may exceed 50% of the total biomass. The distribution of the necromass in height also poses many problems, since in these conditions the height reached by the flames in the fire is much greater. It is a forced germinating species, which is never regenerated by regrowth. Only under mild pruning conditions can the biomass levels be restored. After the passage of fire a high germination rate can be observed that at three months after the fire can be of 60 seedlings per m<sup>2</sup>, decreasing to an average of 7.3 individuals per m<sup>2</sup> 17 years later. A mass of the gorse land is easily installed in the area occupied by other crops abandoned after the fire. In these conditions, the other species have been removed for the installation of the next crop. After the passage of the fire, *Ulex parviflorus* does not find any type of competition and displaces the rest of germinators, except for the arboreal ones like in the case of pines. In mature pine forests, with higher levels of shade, the growth of *Ulex parviflorus* are very poor and with lower seed yields, however after the fire the seeds that germinate produce vigorous individuals that will form a high density of gorse plants. The seed banks studied show that there are no differences in the seed banks of two formations with different stages of development: the number of seeds per square meter is 319 s/m<sup>2</sup> in the 3-year-old brood

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