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PATTERNS OF HERBACEOUS PLANT SPECIES RICHNESS, COMPOSITION AND SOIL PROPERTIES IN AN ORGANIC CULTIVATION "*LEMON VERBENA*" AND ABANDONED AGROECOSYSTEMS OF GREECE

SUMMARY

Aromatic plants constitute a major segment of the flora, which provides raw materials for use in the pharmaceuticals, cosmetics, and drug industries. *Lemon verbena* is one of more than 30 species of aromatic shrubs in the genus *Aloysia* (family Verbenaceae) with high environmental and economic value. More attention is paid in Greece to the *Lemon verbena* essential oil while their effects on the parameters influencing multiple aspects of ecosystem structure (e.g. biodiversity, soil properties etc) are generally overlooked. Hence, this exploratory study aims to evaluate the effects of *Lemon verbena* and neighboring abandoned (10 years) ecosystems on the herbaceous plant species richness and composition, and soil properties. Also, the multiple regression method was used to investigate the relationship between herbaceous plant species richness and soil properties. The study was conducted in April-May 2016 and 2017 of central Greece. In total, 24 species of herbaceous plants (16 plant species in *Lemon verbena* ecosystem and 12 plant species in abandoned ecosystem) were recorded in the study area. The most frequently occurring plant was *Avena sterilis* (Family: Poaceae) in both types of ecosystems. Moreover, there were significant differences ($p<0.05$) between *Lemon verbena* and neighboring abandoned (10 years) ecosystems for any of the soil properties [soil organic matter, pH, $CaCO_3$, P, K and Mg] measured. Furthermore, multiple regression method showed that soil properties had significant effects on herbaceous plant species richness in which soil organic matter, pH, P and K were the most prominent factors influencing species richness in *Lemon verbena* ecosystem.

Keywords: *Aromatic Plant, Species Richness, Environment, Sustainability, Greece*.

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INTRODUCTION

Greece is considered as one of the most biologically diverse countries of the European continent with high plant diversity and endemism. Greece holds 6% of the Mediterranean area and 26% of the Mediterranean flora. Aromatic and medicinal plants are important factors in sustainable development, environmental protection and public health (Solomou et al., 2016).

One of the most important aromatic plants is *Lemon verbena* (*Aloysia triphylla* [L'Hurit.]) with important health benefits and ecosystem services. More specifically, *Lemon verbena*, is indigenous to South America (Duarte et al., 2007) and brought to Europe by the Spaniards and now is cultivated in many countries in Latin and Central America,in Southern Europe (Greece, France), in Northern Africa (Algeria, Morocco) China, and Iran. It is used as both a cullinary and a medicinal herb. The genus *Alloysia* belongs to the Verbenaceae family which has many genus and species. *Lemon verbenas*' botanical synonyms include *Aloysia citriodora*, *Aloysia sleumeri* Moldenke, *Aloysia triphylla*(L'Hr.) Britton, *Lippia citriodora* (Lam.) Kunth, *Lippia triphylla*(L'Hr.) Kuntze, *Verbena citriodora* Cav., *Verbena triphylla*, and *Zapania citriodora* Lam. (Zamorano-Ponce, 2004). It is a medicinal and aromatic shrub about 0.5–2m in height. It is an evergreen perennial plant, a deciduous sub-shrub, and the genus *Alloysia* comprises about 175 genera and 2,300 species. It likes warm moist conditions with plenty of sunlight. When exposed to frost, it becomes deciduous. *Lemon verbena* prefers light, sandy, medium loamy, well-drained acid, neutral, and basic alkaline (pH of 4.5–7.8.) soils (Marta, 2005; Vogel et al., 2002) and has an annual water requirement of 500 to 1,300 mm.

The lemon-scented essential oil from the *Lemon verbena* have been widely studied for its calming, digestive, abdominal-discomfort, lemony flavor properties (Marta, 2005; Vogel et al., 2002; Argyropouloua et al., 2007).

Lemon verbena traditionally has been utilized as a remedy for gastrointestinal and respiratory disorders. In addition, some species have shown antimalarial, antiviral, anti-spasmodic, antibacterial, antioxidant and cytostatic properties (Ragone et al., 2007; Bilia et al., 2008; Funes et al., 2009; Regnier and Combrinck, 2010). The volatile oil yield oil yield (Martvnez et al., 2007; Ragone et al., 2007). Fresh or dried leaves are used in the same way as lemongrass as an ingredient in stews and soups (van Wyk, 2005). Evidence has shown that essential oil and phenolic compounds such as flavonoids are responsible for the related curative properties of lemon verbena (Rosa and Meireles, 2005). *Lemon verbenas'* essential oil obtained by hydrodistillation of the leaves is 0.22–1.00%. The harvesting season, the time of the day, and the particle size present influence on the volatile (Martvnez et al., 2007).

According to the literature more attention is paid in Greece to the *Lemon verbena* essential oil while their effects on the parameters influencing multiple aspects of ecosystem structure (e.g. biodiversity, soil properties etc) are generally overlooked. Hence, this exploratory study aims to evaluate the effects of *Lemon*

verbena and neighboring abandoned (10 years) ecosystems on the herbaceous plant species richness and composition, and soil properties.

MATERIAL AND METHODS

A number of field experiments were conducted in Thessaly plain (Experimental Farm of the University of Thessaly, Velestino, central Greece, 2014) with an altitude 170 m above the sea level (Fig.1). The soil at the site was a deep, moderately fertile, clay loamy soil that was classified as Calcixerollic Xerochrept (USDA, 1975).
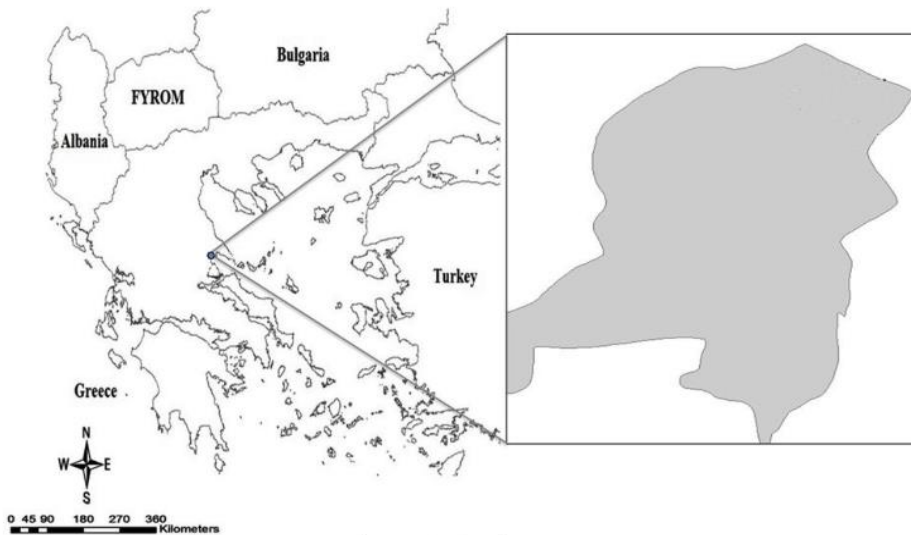

Figure 1. Study area

The climate in Greece is typical Mediterranean climate: mild and rainy winters, relatively warm and dry summers.

Thessaly Prefecture, the largest Greek lowland and the center of the country's agricultural production, is characterized by a more continental climatic character with colder winters and hot summers (Figure 2).

Sampling

The sampling of herbaceous plants was carried out in April-May 2016 and 2017 of central Greece in randomly selected plots of 0.25 m^2, in order to record plant species richness in *Lemon verbena* ecosystem (Cook and Stubbendieck, 1986; Solomou and Sfougaris, 2013). In each plot composite soil samples were taken by the randomized method at a depth of 0–40 cm. Soil organic matter (%) (Nelson and Sommers, 1982), pH (McLean, 1982), CaCO3 (Nelson and Sommers, 1982), texture (clay, silt, sand) (Bouyoukos, 1951), P (Olsen and Sommers, 1982), K and Mg (Thomas, 1982) were measured in each of the soil samples.

Statistical analysis

Relation between plant species richness with soil characteristics was investigated by multivariate analysis. We used the 'multi-regression enter' method that suitable for quantity variables such as species richness (Kalantari, 2002) as a result to create a model. Statistical analyses were performed using the software package IBM SPSS Statistics ver. 19.0 for Windows (SPSS Inc., IBM Company, Chicago, IL, USA 2010).
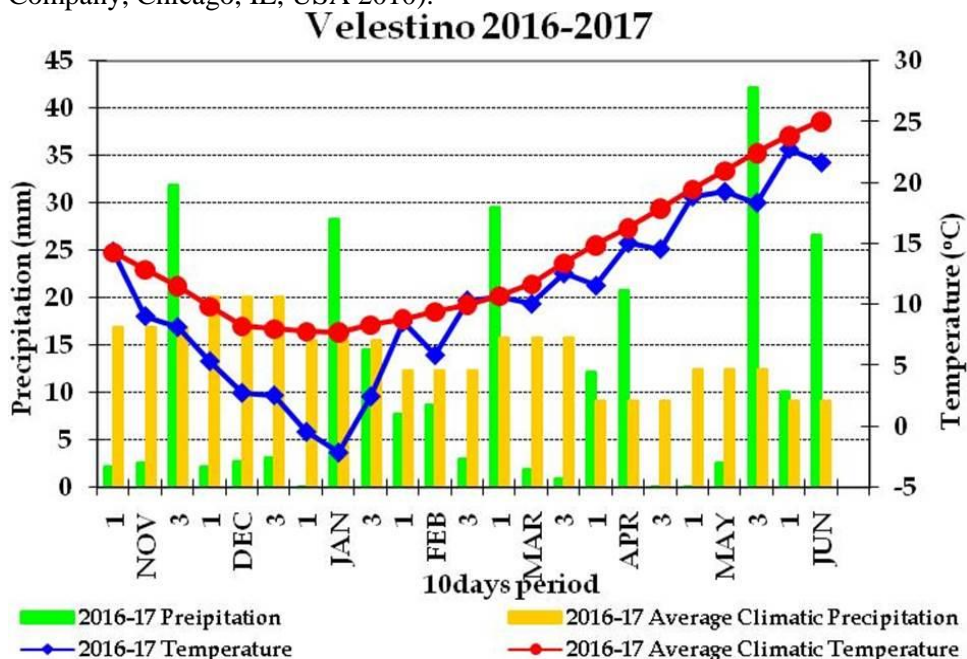

Figure 2. Climate diagram.

RESULTS AND DISCUSSION

Results showed that 24 species of herbaceous plants (16 plant species in Lemon verbena ecosystem and 12 plant species in abandoned ecosystem) were recorded in the study area. The most frequently occurring plant species was *Avena sterilis* (Family: Poaceae) in both types of ecosystems. A possible explanation is that this plant has transferred with seed and dispersal from another areas. *Avena sterilis* is highly invasive in cultivated farms and has probably already invaded many suitable regions of the Greece (Figure 3). According to Cirujeda et al. (2011) management practices, geographical gradients and climatic factors have been found to be the most important factors that explain herbaceous plant species composition and richness.
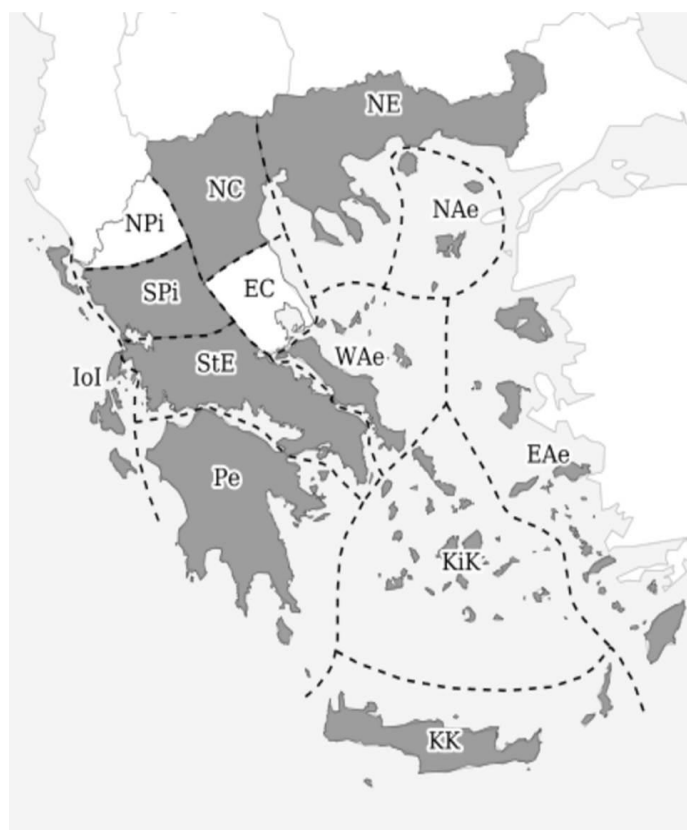
Figure 3. Distribution of *Avena sterilis* [Geography: **IoI** (Ionian Islands)–**NPi** (North Pindos) **SPi** (Souh Pindos) **Pe** (Peloponnisos) **StE** (Sterea Ellas)–**EC** (East Central Greece) **NC** (North Central Greece) **NE** (North-East Greece) **NAe** (North Aegean islands) **WAe** (West Aegean islands) **Kik** (Kiklades) **KK** (Kriti and Karpathos) **EAe** (Kriti and Karpathos). Greece: (East Aegean islands – present; East Central Greece – absent; Ionian Islands – present; Kiklades – present; Kriti and Karpathos – present; North Aegean islands – present; North Central Greece – present; North Pindos – absent; North-EastGreece – present; Peloponnisos – present; SouthPindos – present; Sterea Ellas – present; West Aegean islands – present)].

Generalized Linear Models (GLM) that came up from the processing of plant species richness data, only, in Lemon verbena ecosystem, showed good to excellent ability to "interpret" the dependent variable (herbaceous plant species richness) (based on adj. R^2). The model showed that soil properties had significant effects on herbaceous plant species richness and interprets 78% of the total variation of herbaceous plant species richness. More specifically, soil organic matter, pH, P and K were the most prominent factors influencing species richness in Lemon verbena ecosystem (Table 1).

Table 1. Generalized Linear Model of herbaceous plant species richness.

F	Adj. R	Likelihood Ratio χ^2	AIC	P	Model
11,26	0,78	18,89	40,42	0,00	$1,66+16,46(SOM)^*+0,02(SPH)^{**}$

[*]SOM: Soil organic matter, [**]SPH: Soil pH, [***]P: Phosphorus, [****]K: Potassium.

It is known that ecosystems with different soil nutrients are important for plant growth and community development. Soil parameters like soil organic matter are related to plant species richness. The reason soil organic matter reflects changes in plant species richness is because there is a close relationship between soil organic matter content and plants. Crow (2009) refers that soil organic matter improves the capacity of a soil to hold water and nutrients, and allows their slow release, therefore improving the conditions for plant growth. Also, in sustainable management ecosystems (e.g. natural ecosystem), plant litter and roots are the origin of soil organic matter and higher plant diversity may lead to higher litter diversity, which in turn supports a greater diversity of decomposers and detritivores (Hansen, 2000) that increase soil organic matter content. Our result showed similarity with the study of Grime (1979), where species richness increases linearly with increase in soil pH.

It is noteworthy that soil P and K are very important to plant functions and species richness. The direct effects of P and K on plant species richness probably is due to the application of fertilizers and intensity of land use, as a result in the uptake and storage of (added) nutrients in plants (Grime, 1979; Hautier et al., 2009).

Several studies have found correlations between changes in species richness and a gradient of nutrient availability (e.g. Huston 1980; Tilman 1982). According to a 'humped-back curve' (Grime, 1979; Tilman, 1982) species richness is low at low nutrient levels, increases to a peak at intermediate levels and declines more gradually at high nutrient levels. Similar results have been observed in a several studies (e.g. Tilman, 1982; Vermeer & Berendse, 1983; Janssens et al.,1998; Lichter, 1999).

CONCLUSIONS

Lemon verbena is an ecosystem with very high importance value. A key finding in this study is that *Lemon verbena* ecosystem favors herbaceous plant species richness. Also, soil parameters such as soil organic matter, pH, P and K were the most prominent factors influencing species richness in *Lemon verbena* ecosystem. The higher the species richness of an ecosystem, the higher the probability of maintaining ecosystem functions. Management plans for the biodiversity conservation of aromatic plant ecosystems should therefore focus on the specific site conditions and should take several abiotic and biotic factors into account. Hence, this study will continue into the future.

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