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# Exploring agroecosystem floristic and vegetation diversity in a Mediterranean landscape

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**Abstract**

A floristic and vegetation study of the agroecosystems of east Attiki prefecture (Greece) was performed and constitutes the first investigation into this type of ecosystems for this area. A data set of permanent plots encompassing vegetation in agroecosystems and fields of the area was established. This data set was classified using cluster analysis to identify vegetation differences between the different cultivation types. The ecological interpretation of the sites covered by agroecosystems was based on classic analysis of the chorological and life-form spectra of the plant taxa recorded from these sites, Böhling's ecological indicator values of certain plant species and plant – substrate relation. The diversity indices of these agroecosystems were also measured and compared with the ones of the natural vegetation of the surrounding area. Temporal changes of the agroecosystems' plant species were also studied. Our results revealed five different types of cultivation vegetation with different substrate preferences and different plant diversity values. The contribution of agroecosystems to the areas' plant diversity proved to be significant. Open dry fields were found to be the richest and most temporally heterogeneous agroecosystems. Conclusively, the maintenance and conservation of the agroecosystems of the study area is strongly suggested since they prove to be a significant diversification agent who helps to avoid the loss of the high Mediterranean biological diversity. Additionally, under certain conditions, indicator plant species found in agroecosystems may be used to monitor environmental changes on the area.

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## Introduction

Athens is probably the most widely-known city of Greece and is inhabited since prehistoric times. Our study area, Messogeia, belongs to east Attiki prefecture and is in great proximity to Athens, Greece's capital. It has been cultivated for thousands of years providing food for the people of Athens, but also for other parts of Greece cities. Agroecosystems have co-existed and co-evolved along with the natural vegetation as cultivation has been of non-intensive type for most of the area. Vineyards and olive groves have been, and still are, the main types of cultivation since antiquity and constitute an important and characteristic feature of the Mediterranean landscape. Furthermore, they support an interesting variety of living organisms, increasing area's biodiversity, a fact that makes the study and conservation of these ecosystems essential. The aim of this work is to study in depth the floristic and vegetation diversity of this area.

Man's activities through the ages have increased landscape diversity and therefore biodiversity. In the Mediterranean region the relevance of historical events to present processes in the landscape increases with proximity to our own times (Grove 1996). Several studies indicate that grass and shrublands are among the most biologically diverse ecosystems of Europe, particularly those of the Mediterranean Basin (Lumaret and Kirk, 1991; Verdú *et al.,* 2000; Allen 2003; Jorge *et al*., 2007). In the area of Attiki (Greece) the human influence to the natural environment dates back to prehistoric times.

Although very few arable farms are designated for nature conservation, agroecosystems cover large areas of land in Europe and are important for a wide range of plants and animals, many of which are in steep decline. Therefore, the need for efficient and effective measuring of biodiversity and monitoring of these agroecosystems is just as great as for semi-natural habitats protected in nature reserves. (Hurford, 2006).

The Mediterranean basin is one of the 25 hotspots of biodiversity in the world. It hosts 25.000 species, of which 13.000 are endemic, this latter group represents 4.3% of the worldwide flora (Myers *et al.*, 2000). It is the largest biodiversity hotspot on earth (over 2000000 km$^2$) and it includes several separate refuge areas (Médail *et al.*, 1999). Traditional agroecosystems are still found all over the Mediterranean region in several different biotopes (ie. mountains, plains etc.). Several of these ecosystems may be of particular importance for preserving crop biodiversity. Indeed, many plant species were originally domesticated close to the Eastern shores of the Mediterranean, where our study area is located. Hence, we might encounter contrasted patterns of genetic diversity within crops (ie. of *Olea europaea*) throughout the Mediterranean area, with more crop diversity available in the Eastern Mediterranean (Achtak *et al.*, 2010).

In addition to producing valuable plants and animals, biodiversity performs many ecological services. In agricultural systems, biodiversity performs ecosystem services beyond production of food, fibre, fuel, and income, examples include recycling of nutrients, control of local microclimate, regulation of local hydrological processes, regulation of the abundance of undesirable organisms, and detoxification of noxious chemicals. These renewal processes and ecosystem services are largely biological therefore their persistence depends upon maintenance of biological diversity (Altieri, 1994). However, modern agriculture implies the simplification of the structure of the environment over vast areas, replacing nature's diversity with a small number of cultivated plants and domesticated animals (Altieri, 1999). After thousands of years of struggling to eradicate weeds from their arable fields, major advances in technology during the 20th century gave farmers the ability to produce 'clean' crops, having a detrimental effect on the fields' floristic and vegetation diversity. Wilson and King (2004) suggest that the most significant developments (efficient seed-cleaning techniques, widespread application of herbicides, development of highly nitrogen-responsive crops, increase in nitrogen applications, near-complete mechanization of farming, changes in crop rotations, hedgerow removal and efficient field drainage) leading to the declining conservation value, hence biodiversity, of arable land in the UK. have had a profound effect on both the arable weed flora and on the birds and invertebrates associated with it. Arable weeds now represent c. 20% of the most rapidly declining species of higher plant in the UK (Preston *et al.*, 2002). In our study area some of these 'weeds' are Greek endemics, valued very high in terms of conservation importance, which exist on the area for a very long time and therefore need to be preserved along with their respective habitat (agroecosystems).

*Area description*

The study area is located in East Attiki, Greece. It borders to the east with South Evoikos Gulf, the streams of Rafina and Erasinos in the north, the foothills of Immitos Mountain in the west and Vari Bay in the south. It is part of the wider basin of Messogeia and it occupies 274.18 km². Morphologically, it can be separated into two sections, namely hilly and flat. The hills of Merenda – Perati – Etos – Barako etc., with an altitude ranging from 198 to 614 m, are situated in the perimeter of the study area, whereas in the central part there is the Messogeia Plain with an altitude from 80 to 100 m. The site of the new Athens International airport is located right in the centre of the study area and also of Messogeia plain (Fig. 1).

The land here is cultivated since 6000 BC and this makes agroecosystems the oldest land-use and ecosystem type of the area. They occupy 134.84 km², which is more than half of the total study area. Farmers of the Messogeia have changed agricultural practices throughout historical times, to improve mainly crop and livestock production. During the last two to three decades there has been a trend towards a rapid decrease of the agricultural land and intensification of cultivation practices in the remaining one; this has come as a consequence of the increasing population of the capital (Athens), which is in great proximity with the study area, and the subsequent urban expansion. Furthermore, the construction of a new international airport right in the middle of cultivated land, the expansion of the road and railway network and industrial plants on the area, have definitely proved to have had a negative impact on the flora and fauna that have adapted to prevailing conditions in this area during millennia.

*Climate*

The climate of the study area belongs to the intense thermo-Mediterranean type, where long hot and dry and short cool and wet periods prevail during the year. Precipitation is limited, with small duration and snowfall is rather rare. The drought period usually begins in April and lasts until October. Data from 7 meteorological stations covering the period of 1974 to 2010 showed that the mean annual temperature is 17.2 °C, while mean annual precipitation is up to 352.6 mm. For the period 1947–60, the mean annual temperature was almost the same (17.9 °C), however the mean annual precipitation was notably higher (537 mm). This manifests a significant decrease of 34.4%.

*Geology*

Geologically, the study area is part of the Attico–Cycladic Massif. Two main units dominate in the geological structure of Attiki: (a) the crystalline basement (Palaeozoic–Upper Cretaceous), and (b) the Neogene–Quaternary clastic deposits. The basement consists of schists and carbonate rocks. The Neogene and Quaternary deposits fill up both the degradations and tectonic grabens of the East Attiki basin and consist of marly limestones, marls, clays, sandstones, conglomerates and other coarse, unconsolidated sediments (Jacobshagen 1986; Katsikatsos 1992).

*Plants as ecological indicators*

In this study, we use an actual set of plots of rural vegetation in East Attiki. The scope of the study is to describe and measure the diversity of vegetation of the agroecosystems of the area and compare it with that of adjacent natural vegetation. Plants provide valuable information on ecological, biogeographical and historical features of the ecosystems. Among these, bioclimatic and biogeographic aspects are perhaps providing global information easily comparable to those obtained from other biological components of the ecosystem (Verdú *et al.*, 2000). Indicator plant species may be used to monitor and evaluate environmental change and may provide us with early warning signals when these changes are about to occur. It is very important in developing and using ecoindicators to select the most effective ones in characterizing the systems of interest (Dale and Beyeler, 2001) in our case agroecosystems. Biological monitors or biomonitors i.e., organisms (plants, animals, fungi, bacteria, etc.) which show an integrated response to air pollution and other environmental factors, can be used as a complementary system to monitor the effects of pollutants and other human impact and to provide reliable indications on the quality and the characteristics of the environment (Hinds, 1984; Bargagli, 1989; Beeby, 2001; Conti and Ceccheti, 2001; Batzias *et al.*, 2006).

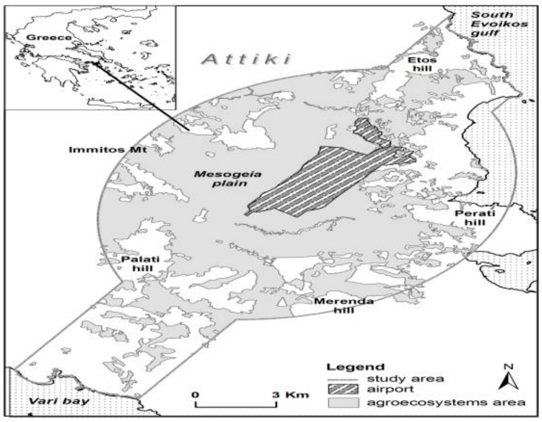



**Fig. 1.** Map of the study area.

Ellenberg was the first to use plant species as ecological indicators in Central Europe (Ellenberg 1979, 1988; Ellenberg *et al.* 1991). Hill *et al.* (1999, 2000) modified and evolved Ellenberg's indicators in order for them to be applied in Great Britain. The same was done by Böhling *et al.* for Naxos Island (2002) and Böhling for South Aegean (2004) Greece, based also on Ellenberg's principals. In the present study we use Böhling's (2004) ecological indicator values system.

There is a great gap considering studies on the floristic and vegetation diversity of man-induced ecosystems, as agroecosystems, in Greece. Untill now agroecosystems have been studied from an economic point of view and also for several factors that may affect their performance (i.e. pesticides, fertilizers etc.) or their fauna (i.e. birds, insects etc.). Studies of the flora of these ecosystems have been conducted (i.e. Turland *et al.,* 2004; Siebert, 2005 for Crete island), but not in relation to abiotic factors (i.e. geology etc.) or measuring biodiversity per se (i.e. via diversity indices). This paper comes to fill part of this gap and prove that agroecosystems, especially when cultivated traditionally and not intensively, are contributing greatly to an area's biodiversity.

## Materials and methods

*Plant collection and identification*

The study of the rural flora of Messogeia is based on collections made by the authors from November 2005 until June 2010. During fieldwork, not only the rural but all the flora and vegetation of the study area has been recorded and identified. Plant samples were collected and their exact position was recorded by GPS (Global Positioning System). Herbarium specimens are deposited at the Botanical Museum of Patras University (UPA). Species identification and nomenclature follow Flora Europaea (Tutin *et al.*, 1968, 1972, 1976, 1980 & 1993), Flora d' Italia (Pignatti, 1982), Flora Hellenica (Strid & Tan, 1997, 2002) and Med-Checklist (Greuter & al., 1984, 1986, 1989). The life-form categories follow Raunkiaer's system (1934), while Pignatti's (1982) classification was used for the chorological analysis of plant taxa, with extra information on oriental taxa provided by Davis (1965-1988).

*Vegetation sampling and analysis of data*

More than 80 permanent plots were practiced on the agroecosystems of the study area. We have visited and sampled these plots on regular intervals throughout a calendar year in order to record their floristic seasonal changes. The plots' dimension was 50×50m and the Braun-Blanquet method was used. However, only 41 of these plots were used to the final vegetation analysis. These were the plots that proved to have maintained their land-use as agroecosystems throughout our sampling period (2005-2010). Plots on which their land-use has changed through the years (i.e. due to land reclamation for housing and consequent construction activities) were not included in our final results. We have measured the floristic diversity on these 41 plots by using Shannon's (H') and Simpson's (D) indices, evenness in distribution of species within the sampling area was also measured, by using Equitability index (J). The Shannon index stresses the species richness component, whilst the Simpson index emphasizes dominance as opposed to the richness (Nagendra, 2002; Magurran, 2004). We then compared agroecosystems' plant diversity with that of natural habitats by using the Mann-Whitney U test included in SPSS (version19.0, IBM Corp., Chicago, USA).

The 41 vegetation plots on rural fields were elaborated by the means of Turboveg database management system (version1.99t, IBN-DLO, Wageningen, NL & University of Lancaster, U.K) and TWINSPAN (Two-way Indicator Species Analysis) included in PC-ORD (version 6.0, MjM Software, Gleneden Beach, Oregon, U.S.A.) in order to determine whether there are any significant differences in vegetation composition among the different cultivation types (olive groves, vineyards etc.). Analysis revealed differences in the vegetation accompanying the various cultivation types.

*Land-use mapping*

Information on land-use/cover in the form of maps and statistical data is very vital for spatial planning, management and utilization of land for agriculture, forestry, pasture, urban, industrial, environmental protection, economic production, etc. Based on extensive field survey we have mapped land-use changes for the time period of 1991-2011 with the combination of field observations, high-resolution panchromatic aerial photographs (of 1991, 1997 and 2010), a time-series of satellite imageries, Remote Sensing (RS) techniques and Geographic Information Systems (GIS) by using ArcGIS ver.9.3. Further information on mapping of the area may be obtained from Spanou (2010).

*Böhling's classification system*

Moreover, ecological indicator values were assigned to certain rural plant species according to Böhling's classification system (Böhling *et al.*, 2002, 2004). Böhling's classification system is based on Ellenberg's system, but is preferred and used at the present study as it is described exclusively for plant species occurring in Greece. The Böhling (and Ellenberg) indicator values are species-specific scores ranging from 1 to 9 (except for Moisture where they range from 1 to 12) and estimate the optimum ecological occurrence of species along environmental gradients (Ellenberg *et al.*, 1991). Evidence for the accuracy of these indicator values was provided by several studies reporting a close correlation between the indicator values and corresponding measurements of environmental variables on large gradients (Schaffers and Sýkora, 2000; Diekmann, 2003). As suggested by Wamelink *et al.* (2002), we used Böhling indicator values for comparisons within the same vegetation type, in our case agroecosystems.

*Geology-Plants interactions*

Substrate and plant species correlation was studied by using detailed GIS geology maps of the study area in combination with sampling positions (measured with GPS) in agroecosystems. In this way the exact substrate that every taxon and agroecosystem type exists was recorded. A database of the substrate of the study area was created with the use of GIS. The database categorizes the area's substrate into eight types and characterises each of these types with a representative substrate profile. The substrate-physical and substrate-chemical parameters as well as the water and nutrient balance characteristics of the profiles were measured in situ and were included in the GIS-database. This database was used in the study.

## Results

*Flora and vegetation*

From the collection, identification and recording of the rural flora of the study area it is concluded that it consists of 207 taxa belonging to 46 families and 157 genera. Of these 207 rural plant species 56 (27.05%) are considered new floristic reports for the area and four taxa are Greek endemics: *Anchusella variegata* (L.) Bigazzi, Nardi & Selvi, *Chondrilla ramosissima* Sibth & Sm., *Erysimum graecum* Boiss. & Heldr. and *Nigella arvensis* L. subp. *aristata* (Sm.) Nyman. As expected, the *Compositae, Leguminosae* and *Gramineae* families account for more than half (52.17%) of the total rural flora, while the families of *Cruciferae* and *Umbelliferae* are also well represented.

**Table 1.** Life-form units of agroecosystems' plant species.

| Life-form unit | Number of taxa | Percentage (%) |
|---|---|---|
| Chamaephytes | 6 | 2.90 |
| Geophytes | 17 | 8,21 |
| Hemicryptophytes | 52 | 25.12 |
| Hydrophytes | 2 | 0.97 |
| Phanerophytes | 13 | 6.28 |
| Therophytes | 117 | 56.52 |
| Total | 207 | 100 |

In the life-form spectrum of the area's flora (Table 1), therophytes (T) have the highest percentage (56.52%), followed by hemicryptophytes (H) (25.12%). The percentage of geophytes (G) is considerably high (8.21%), while other life-forms occur in smaller percentages. The strong domination of therophytes was expected and reflects the thermo-Mediterranean climate type of the area.

The chorological spectrum of the area's flora (Table 2) shows that the Mediterranean elements (Euri-, East-, Steno- and Widespread Mediterranean) prevail with 62% while other chorological types (Cosmopolitan and Sub-Cosmopolitan, Temperate etc.) follow with significantly smaller percentages. The prevailing of Mediterranean elements was mostly expected taking under consideration the geographic location of the study area and its climatic conditions.

Analysis and elaboration of the 41 vegetation plots practiced on the agroecosystems of the study area by Turboveg, TWINSPAN and finally DCA (Detrended Correspondence Analysis) resulted in the determination of five main groups of cultivation vegetation. It has also revealed some differences between the flora which characterizes and accompanies the different types of cultivation (olive groves, vineyards, pistachio orchards, wet fields and dry fields). DCA ordination performed on our relevés has plotted quite clearly similar samples close together (Fig. 2). Cluster 1 contains samples taken from olive groves, cluster 2 from vineyards, cluster 3 from wet meadows, cluster 4 from dry meadows and cluster 5 from pistachio orchards.

Vegetation of wet meadows and pistachio orchards, as shown in Figure 2, appears to be significantly different from that of olive groves and dry meadows, whereas dry meadows and vineyards are grouped close together. This is due to the fact that they have some species in common.

*Diversity indices*

Species richness is a fundamental measurement of community and regional diversity that underlies many ecological models and conservation strategies (Whittaker, 1972; Gotelli and Colwell, 2001). To measure the plant diversity of the area's agroecosystems we have applied Shannon's diversity index (H'), which is one of the most widely used (Kent & Coker 1992): $H' = -\sum_{i=1}^{s} p_i \ln p_i$ and Simpson's diversity index (D): $D = \sum_{i=1}^{S} p_i^2$. The Equitability (evenness) index (J): $J = \frac{H'}{\ln S}$ was also measured.

These indices and the average species number (S) were measured for the whole of the rural area as well as for every type of cultivation separately (Table 3).

As shown from table 3 (in bold letters) dry fields are the most diverse in plant species and also species rich agroecosystems (Poschlod *et al.*, 2011). According to this author, dry calcareous grasslands are considered among the most species-rich and endangered ecosystems in the Central-European landscape. They are usually of anthropogenic origin and mainly a result of grazing by domestic animals. This seems to apply for our study area also, which is located in South East Europe, as it is cultivated since the ancient times and has sustained grazing, mainly by sheep, and human presence for a very long time.

**Table 2.** Chorological units of agroecosystem plant species.

| Chorological unit | Number of taxa | Percentage (%) |
|---|---|---|
| Endemics | 4 | 2 |
| Euri-Meditteranean | 63 | 30 |
| East-Mediterranean | 13 | 6 |
| Steno- Mediterranean | 45 | 20 |
| Widespread Mediterranean | 13 | 6 |
| Temperate | 13 | 6 |
| Eurasiatic | 9 | 8 |
| Boreal | 3 | 1 |
| Tropical-Subtropical | 4 | 2 |
| Cosmopolitan and Sub- Cosmopolitan | 35 | 17 |
| Cultivated | 3 | 1 |
| Northamerican | 2 | 1 |
| Total | 207 | 100 |

Agroecosystem type (i.e. vineyards, olive groves etc.) had a major effect on the species richness of plants. Our results show that although dry-grasslands, in general, was the most species rich agroecosystem type, only preserving dry-grasslands will not be enough to sustain species richness in the agricultural landscape. Both vineyards and olive groves are common Greek agricultural landscapes and also very rich in species and along with dry-grasslands need to be conserved.

In order to compare the diversity of agroecosystems with that of the neighbouring natural habitats types (Spanou *et al.*, 2007) we have estimated the median value of diversity and evenness of each natural vegetation type occurring on the area (Table 4). The description of the habitat types follows Natura 2000 nomenclature. Significant differences between agroecosystems and natural vegetation were found (Mann-Whitney U test), mainly for the diversity and evenness indices between agroecosystems and East Mediterranean garrigues, diversity indices between agroecosystems and common reed-beds (72A0) as well as abandoned fields (1070) and eveness index between agroecosystems and Vegetated sea cliffs of the Mediterranean coasts with endemic *Limonium* spp. (1240). From table 4 we may conclude that for our study area 'East Mediterranean garrigues' appears to be the most diverse in plant species habitat, however agroecosystems, although a man-made type of ecosystem, have a quite high biodiversity index (H'= 2.07), higher than that of other natural habitat types of the area, ie. '*Olea* and *Ceratonia* forests', 'East Mediterranean tamarisk thickets', 'Mediterranean and thermo-Atlantic halophilous scrubs' etc. This is partly explained by the intense presence of man in these ecosystems' history.

**Table 3.** Average Species number (S), Shannon's diversity index (H'), Simpson's diversity index (D) and Equitability index (J) and respective standard deviation of different agroecosystem types.

| Cultivation type | S | H' | D | J |
|---|---|---|---|---|
| Olive groves | 16.36±8.7 | 1.862±0.748 | 0.76±0.1477 | **0.78**±0.1173 |
| Vineyards | 20.07±6.41 | 2.083±0.507 | 0.756±0.1533 | 0.717±0.1164 |
| Pistachio orchards | 12.25±5.32 | 1,511±0.606 | 0,599±0.1851 | 0.603±0.1399 |
| Wet (fallow) fields | 10.6±6.31 | 1.696±0.536 | 0.731±0.0952 | 0.774±0.0351 |
| Dry (fallow) fields | 20.71±3.11 | **2.322**±0.575 | **0.79**±0.1412 | 0.765±0.1690 |
| **Total rural area** | 17.3±4.53 | 2.07±0.0747 | 0.77±0.0741 | 0.72±0.319 |

**Table 4.** Median values of diversity (H' & D) and evenness indices (J) calculated for cultivations (Natura2000 code:1020) and all natural habitat types that occur on the study area. Asterisks indicate statistically significant difference in diversity or evenness between cultivations and all other vegetation units according to the Mann-Whitney U test. Vegetation units' Natura2000 codes: 1240, Vegetated sea cliffs of the Mediterranean coasts with endemic *Limonium* spp.; 1310, *Salicornia* and other annuals colonizing mud and sand; 1410, Mediterranean salt meadows (*Juncetalia maritimi*); 1420, Mediterranean and thermo-Atlantic halophilous scrubs (*Arthrocnemetalia fruticosi*); 2110, Embryonic shifting dunes; 2250, Coastal dunes with *Juniperus* spp. (conservation priority habitat); 2260, *Cisto-Lavenduletalia* dune sclerophyllous scrubs; 5212, *Juniperus phoenicea* arborescent matorral; 5340, East Mediterranean garrigues; 9320, *Olea* and *Ceratonia* forests; 9540, Greek Aleppo pine forests.

| Veg. Unit | 1020 | 9540 | 5340 | 9320 | 5420 | 5212 | 8216 | 72A0 | 2110 | 1410 | 92D0 | 92C0 | 1070 | 1240 | 1020 vs 9540 | 1020 vs 5340 | 1020 vs 9320 | 1020 vs 5420 | 1020 vs 5212 | 1020 vs 8216 | 1020 vs 72A0 | 1020 vs 2110 | 1020 vs 1410 | 1020 vs 92D0 | 1020 vs 92C0 | 1020 vs 1070 | 1020 vs 1240 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H' (Median) | 2,07 | 1,96 | 2,85 | 1,88 | 2,15 | 2,2 | 2,08 | 1,17 | 1,99 | 2,03 | 1,76 | 2,56 | 3,13 | 1,93 | | * | | | | | * | | | | | * | |
| D (Median) | 0,77 | 0,76 | 0,91 | 0,71 | 0,81 | 0,80 | 0,82 | 0,62 | 0,69 | 0,82 | 0,76 | 0,89 | 0,93 | 0,85 | | * | | | | | * | | | | | * | |
| J (Median) | 0,72 | 0,72 | 0,87 | 0,68 | 0,74 | 0,76 | 0,84 | 0,76 | 0,72 | 0,86 | 0,74 | 0,87 | 0,92 | 0,99 | | * | | | | | | | | | | | * |

*Plants as ecological indicators*

From the 207 rural plant species of the study area 148 are, according to Böhling's classification system, indexes for more than one ecological factor. These factors are: Light, Temperature, Continentality, Humidity, Soil reaction, Soil nutrients and Salinity. 148 species account for more than half (71.50%) of the total rural plant species of the study area; therefore they may be safely used to describe the ecological conditions which prevail. Plant indicator values (Fig. 3 Table) show that the agroecosystems of the study area host mainly thermophilous and photophilous plant species of semi-arid environments, which grow on alkaline soils of low salinity, very rich in nutrients (in our case most probably due to fertilizers used in cultivations). Most agroecosystems species are on the sub-Continental side of the chorological spectrum. Our measurements, by using indicator plans, describe in great detail the current ecological situation of the study area.

**Table 5.** Rural plots and geological substrate.

| Substrate group & description | Plots (number/percentage) | Number of species | Geological substrate code and description |
|---|---|---|---|
| 1 alluvial deposits | 16 (39.02%) | 122 | Pt: Brown-coloured, terrestrial and fluvial-terrestrial deposits |
| | 2 (4.88%) | 20 | Hfl: Deposits on torrent beds |
| 2 marls, loams etc. | 12 (29.27%) | 104 | $M_s$.m,st,c: Marls, loams, sandstones, conglomerates |
| | 1 (2.44%) | 20 | k,sch: Limestones |
| 3 limestone | 2 (4.88%) | 33 | $M_s$.tv,k: Terra rossa and travertinoid limestone |
| | 3 (7.32%) | 38 | J.$mr_1$: Lower marble |
| | 1 (2.44%) | 18 | $K_1$.k: Intensely recrystallized limestones |
| 4 limestone-schists | 4 (9.75%) | 33 | $T_{i-s}$.sch: Multicoloured limestones-schists |
| Total plots | *41* | | |

*Seasonal changes in agroecosystems' vegetation*

Seasonal variation is another factor affecting plant diversity in agroecosystems. Our floristic collections throughout all seasons of a year have indicated that the agroecosystems of the study area present an ever changing, dynamic plant species composition pattern, mainly due to the following two reasons:

- Different cultivation practices are applied at each field. Intensively cultivated land, by heavy ploughing, application of fertilizers and pesticides etc. presents less diverse floristic succession than the one cultivated more traditionally. For example, the most vineyards of the area are intensively cultivated and have wild plant species and weeds eradicated every year. On the other hand, many olive groves undergo only a few agricultural interventions; this results in higher plant species richness – and even biodiversity - with some of these species (mainly shrubs) being perennial.

**Table 6.** Changes in land-use.

| | Area 1991 ($m^2$) | Area 2010 ($m^2$) | Change in area ($m^2$) | Change in area |
|---|---|---|---|---|
| Agroecosystems | 146.056.745,53 | 135.042.439,98 | - 11.014.305,6 | - 8% |
| Natural vegetation | 73.744.916,25 | 71.847.966,63 | - 1.896.949,62 | - 3% |
| Built areas | 54.379.014,54 | 67.290.269,59 | + 12.911.255,05 | + 20% |

Agroecosystems are characterised by rapid succession and changes of their accompanying flora. Therefore, seasonal changes are very characteristic and intense. This fact is based in the dominance of annual species following different growth, flowering and fruiting patterns.

A real-life example showing the temporal succession of the plant species of a dry field from the study area is displayed in the following diagram.

**Late Winter – Early Spring**
*Anemone coronaria, A. pavonina, Sinapis alba, Calendula arvensis, Euphorbia helioscopia*

⇩

**Middle & late Spring**
*Hypochoeris achyrophorus, Malva sylvestris, Vicia villosa, Chrysanthemum coronarium*

⇩

**Summer**
*Scolymus hispanicus, Echinops graecus, Carlina corymbosa, Pallenis spinosa, Piptatherum miliaceum*

*Plant species and geological substrate*

By the means of GIS we have related our plots in agroecosystems to their respective geological substrate. Results are presented in table 5. Plots were located mainly on three different substrates: alluvial deposits (1), marls, loams etc. (2) & limestone (3). Detailed mapping of all agroecosystems of the study area in relation with its geological map confirm our results that cultivated land on the area occurs mainly on alluvial deposits, marls and loams. Those substrates have rendered Messogeia plain, which is a significant part of our study area, suitable for cultivation since the ancient times.

Despite the intense human presence and impacts Messogeia has partly succeeded to maintain its agricultural character, although the area covered by agricultural land/cultivations has been significantly reduced (approximately by 7 $Km^2$ for the time period 1991-2011). The change in land-use from 1991 until 2011 is depicted in the maps of the two time periods (Fig. 4a & b) and is presented in table 6. We have grouped the main land uses in four categories: agroecosystems, built areas (which include settlements, airport site, industrial sites, sporting facilities etc.), natural vegetation.

**Discussion**

The floristic findings of the studied agroecosystems were mostly expected for this type of land use, however the four Greek endemics that were found in such a disturbed by man habitat type are rendered as significant and come to underline the conservation value of land that has been cultivated since ancient times. Life-form spectra of the plants of the area were created as the spectra are regarded as an indicator of prevailing environment. Occurrence of similar biological spectrum in different regions indicates similar climatic conditions (Khan *et al.*, 2011). However, due to disturbance (i.e. human impact) the proportion of life-forms may be altered. The strong domination of therophytes was also expected and reflects the thermo-Mediterranean climate type of the area. The prevailing of Mediterranean elements complies with the geographic location of the study area and its climatic conditions.

Analysis of vegetation plots showed that vegetation of the various cultivation types is distinctively clustered in five groups. This means that the plant species which accompany the five types of cultivation vegetation of the area are clearly different, reflect their abiotic preferences and characterize each cultivation type. Therefore, the occurrence of various cultivation types, in contrast to monoculture, increases the areas' floristic diversity.

Species richness is a fundamental measurement of community and regional diversity that underlies many ecological models and conservation strategies (Whittaker, 1972; Gotelli and Colwell, 2001).

Applying various diversity and evenness indexes in our area indicated that agroecosystem plant diversity and evenness in distribution of species for Mediterranean agroecosystems is very close with the one measured in the area's natural habitat types. This is due to the fact that agriculture is a land-use that is practiced in our study area since the ancient times. Plants here have co-existed and co-evolved with the cultivars, which have not changed much through the ages and have sustained mild human presence. This confirms the hypothesis that disturbance with frequent or intermediate frequency increases diversity, as it eliminates sensitive species, whereas very infrequent disturbance allows time for superior competitors to eliminate species that cannot compete (McGinley, 2010).

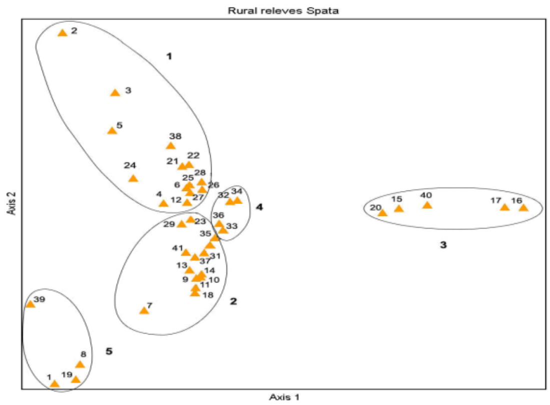



**Fig. 2.** Detrended Correspondence Analysis (DCA) of the 41 rural plots. Interpretation of groupings partially derived form TWINSPAN analysis on these plots (cluster 1: olive groves, cluster 2: vineyards, cluster 3: wet meadows, cluster 4: dry meadows and cluster 5: pistachio orchards).

As agroecosystems were created by man, their existence has been conditioned by traditional management and their diversity mirrors not only edaphic and climatic conditions (Critchley *et al.* 2002; Kalusová *et al.*, 2009), but also historical and present management (Schaffers, 2002; Gustavsson *et al.*, 2007; Klimek *et al.* 2007; Chýlová and Münzbergová, 2008; Başnou *et al.*, 2009; Karlík and Poschold, 2009). This, as stated by Rozbrojová *et al.*, applies for Central Europe and, as our results concerning indicator plant species point out, seems to apply for Mediterranean agroecosystems too.

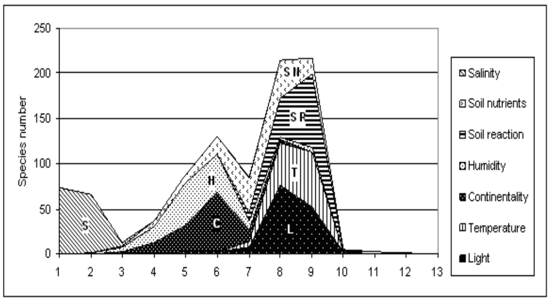
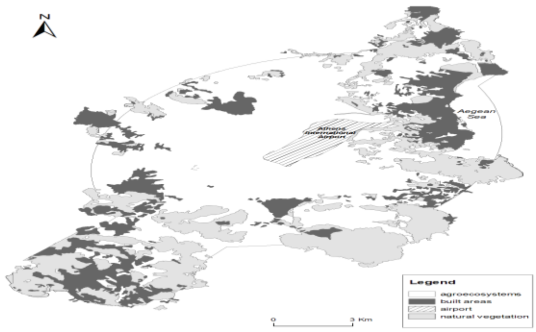


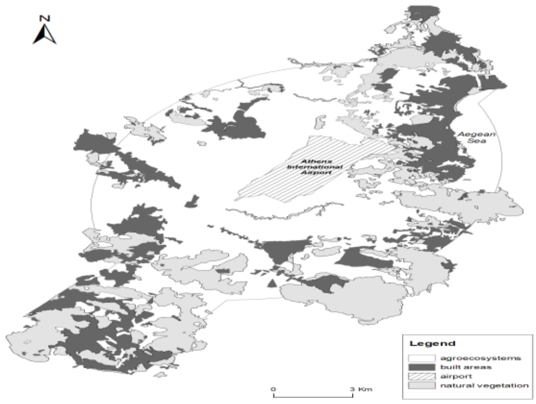

**Fig. 3.** Diagram showing the distribution of rural plants species to the various ecological factors (S: Salinity, SN: Soil Nutrients, SR: Soil Reaction, H: Humidity, C: Continentality, T: Temperature, L: Light).

Detailed mapping of agro-ecosystems sites in relation to their geological substrate showed that the cultivations are still practiced where they were traditionally used to, mainly rich in nutrients alluvial deposits. However, these substrates do not appear to be as rich as they used to and so farmers tend to over-use fertilisers which eventually end in the streams and ponds of the area, leading them to eutrophication.

Documentation of the land-use/cover change provides information for the better understanding of historical land-use practices, current land-use patterns and future land-use trajectory (Fisseha *et al.*, 2011). The subsequent conversion of land cover types may alter ecosystems' dynamics and functionality so greatly and shift them to a different stable state (Zziwa *et al.*, 2012) Land-uses comparative mapping revealed that built areas have increased significantly, mainly taking the place of natural vegetation and less of cultivated land. This has as a result for our study area to maintain until today its agricultural character. However, yet shrinkage of traditionally cultivated land and natural vegetation areas due to increasing needs for housing will definitely lead to subsequent reduction of the area's biodiversity.




A. Study area 1991 situation.




B. Study area 2011 situation.

**Fig. 4.** Study area.

Over the years agriculture as a land-use has been fully integrated into the area's landscape history and therefore has developed a unique pattern of plant diversity, different to the one of natural vegetation, but also as important from a conservation point of view.

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