Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Horticulture

Open Access

Effect of Land-Use Intensification on Soil Properties and Plant Species Diversity in the Mediterranean Agroecosystem

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RESEARCH ARTICLE

Abstract
In recent decades, agriculture in Greece has undergone significant changes due to the intensification of land use. This intensification, contrary to the sustainable land management, has an impact on the healthiness of the environmental agroecosystem. This study aimed to investigate if these cultivation systems influence some of the main edaphic properties and plant species diversity and which are the main anthropogenic interventions which may have a decisive role in the changes of soil physicochemical properties and the reduction of plant species. To assess the environmental implications among different types of land-use, the most sensitive and reliable edaphic indicators were measured and plant species diversity was recorded. Three land-use types such as maize crops, alfalafa and abandoned land were selected and ten fields with an area of approximately 1 ha in each land use type were taken. The results indicate that among the edaphic parameters pH, sand, electrical conductivity (EC), soil organic matter (SOM), NO_3^- as well as Ca^{+2} and Cu^{+2} soil concentration presented statistically significant differences among thirty cultivated fields. Among three different land uses, the edaphic variables EC, SOM, BD, Cal & Na concentrations presented significant differences. A higher soil organic matter content was observed in abandoned land while bulk density and electric conductivity value as well as Na^+ concentrations were lower compared to other land uses. In total 122 taxa belonging to 30 families were recorded, while the families with the greatest species diversity were Poaceae, Asteraceae and Fabaceae in all land uses. Therophytes was the dominant life-form, followed by the Hemicryptophytes and Geophytes. The findings of the present study imply that different agronomic practices influence soil quality parameters, which are likely to affect species diversity and the environmental implications among different land uses.

Keywords: richness of plant species; agricultural soil use management; *Medicago sativa* L.; *Zea mays* L; soil quality.

Received: 04 November 2022
Accepted: 17 March 2022
Published: 15 May 2023

DOI:
10.15835/buasvmcn-hort:2022.0041

INTRODUCTION
Plants and soil conditions are in a constant interaction, while changes in land-use affect input and output fluxes of nutrients and carbon in agro-soils (Dupouey et al. 2002), leading to land quality and soil fertility changes which in turn affect crop productivity, plant species diversity and the decisions for management practices (Bakhshandeh et al. 2019; Ahmad et al. 2016; Benton et al. 2003). Kosmas et al. (2000) report that the increase of organic matter in topsoils of abandoned land is the most significant soil improvement factor, positively affecting soil proprerties and plant species diversity. A crucial point is whether anthropogenic interventions have led to the extinction of native species in cultivated land. Only a few studies focus on the effect of land-use on the edaphic properties and plant

species diversity, under particular soil and climatic conditions at a field level, which must always be taken into consideration for sustainable land management (Buhk et al. 2017; Knudsen et al. 2017; Honnay et al. 2003). According to Balzan et al. (2020), a reduction of plant species and functional diversity due to the agricultural intensification was recorded in the Mediterranean arable land, while Plieninger et al. (2014) in a meta-analysis of the Mediterranean basin data, including Greece (Papanastasis 2007), mention that the responses of vascular plant richness were heterogeneous in different land-use types. Alfalfa (*Medicago sativa* L.) and maize (*Zea mays* L.) are crops which could be included in an integrated crop rotation system even with the participation of a winter wheat, providing higher crop yields over time. Forage legumes as Alfalfa (*Medicago sativa* L.) have been introduced into these rotation systems because of their positive impacts on nitrogen fixation abilities, and ability to increase soil fertility by maintaining soil organic matter and improving soil physical conditions (Denton et al. 2011; Porqueddu and González, 2011). These pasture crop rotations have been shown to be highly effective, and the inclusion of the legume component results in various benefits, which often leads to an improved overall farm productivity (Edwards et al. 2019; Martin et al. 2020). Despite the fact that the usual rotation strategy followed is the one or two year maize cultivation followed by a 4-year cultivation of alfalfa, in many cases maize is cultivated as monoculture for several years. To assess the environmental implications of these cultivation systems, the most sensitive and reliable edaphic indicators were measured, the plant species diversity was recorded and all of them were compared with data coming from measurements in the abandoned lands. Thus, the aim of this study was to investigate if these cultivation systems influence some of the main edaphic properties and plant species diversity and which are the main anthropogenic interventions which may have a decisive role in the changes of soil physicochemical properties and the reduction of plant species.

MATERIALS AND METHODS

The study area is located in the municipality of Agrinio in the prefecture of Aitoloakarnania in Western Greece (38°37'N, 21°22'E). It occupies an area of 5448 km^2, representing the 4% of the total area in Greece. The mean annual temperature is 17.5 °C and the mean annual rainfall ranges from 800 to 1000 mm, having seasonal variation. Three land-use types such as maize crops, alfalfa and abandoned land were selected as they consist some of the most important cultivated land in the municipality of Agrinio, and ten (10) fields with an area of approximately 1 ha in each land use type were taken. These fields are all in lowland areas with an altitude not exceeding the 300 m above the sea level. The usually management practices taken place in each land use are shown in Table 1.

Table 1. Land use types and usually management practices of the study area*

	Abandoned land	**Alfalfa**	**Maize crops**
Description	Abandoned farmland used for grazing. Previously, cultivated with tobacco (1883–2005).	*Medicago sativa* L., mean alfaalfa yield: 20-25 tonnes ha^{-1}.	*Zea mays* L., mean maize yield: 10-12 tonnes ha^{-1}.
Fertilization	No inorganic fertilizers Only sheep manure	Before sowing: 400 Kg ha^{-1} phosphorus fertilizer (0:20:0); after the second cutting: 400 Kg ha^{-1} phosphorus fertilizer (0:20:0)	Before sowing, early to mid-April: 700 Kg/ha/NPK mineral fertilizers (20:10:10); June-July: 400 Kg/ha/simple-nitrogen (34.5:0:0).
Plant protection	No pesticides	Herb: (a) Before sowing: mechanical manipulation of soil. (b) After sowing: Insecticide Coragen 20 SC with a.i: chlorantraniliprole 20% at dose approximately 50 g a.i. ha^{-1}	Herb: (a) Before sowing: mechanical manipulation of soil. (b) After sowing: One herbicide spray per year was applied with mixed or simple a.i: nicosulfuron, rimsulfuron, dicamba at dose 50-60 g a.i. ha^{-1}, 10 -15 g a.i. ha^{-1} and 240-280 g a.i. ha^{-1} respectively, took place approximately 30-35 days after sowing (DAS).
Tillage	No tillage	Mouldboard ploughing at a depth of 20-25 cm on March, followed by one rotary hoeing. Sowing dates were from early March to mid-April in an amount of approximate 35-45 kg of seeds ha^{-1}.	Mouldboard ploughing at a depth of 20-25 cm on March, followed by one rotary hoeing before early to mid-April. Sowing dates were from early to mid-April for each year. Maize was planted at an approximate density of 80-88 thousand plants ha^{-1}.
Irrigation	No irrigation	Gun sprinklers: Two (2) irrigations of 800-1000 m^3/ha between two cuttings.	Gun sprinklers from early-June until early September, 6-8 times. Irrigation dose: 900 to 1200 m^3/ha/year.

*Data is coming from the processing of questionnaires which completed by producers and agronomists of the study area

The soil unit type in all fields is Calcaric Fluvisol (Yassoglou, 2004), while the land slope ranges from 0 to 3%. Soil sampling took place in the winter season for three years (2017-2019), when soils are inherently variable in their distribution of plant nutrients. Each soil sample which was received in maize and alfalfa fields as well as in abandoned lands, consisted of 10 cores, well mixed on site, and was collected from different points in the field with a zigzag soil sampling method (Sabbe et al. 1987). Sampling was conducted by using a Dutch auger to a depth of 0–30 cm for all soil samples. Undisturbed soil cores for each field were received from 0-30 cm depth using 100 cm3 -cylinders (5 cm height and 5.04 cm diameter) for the assessment of soil bulk density (BD) according to Lutz (1947). In this study eighteen (18) soil physicochemical properties (pH, EC, SOM, total $CaCO_3$, Bulk Density - BD, NO_3^-, P_{Olsen}, Ca, Na, K_{avail}., Mg_{avail}, Fe_{DTPA}, Zn_{DTPA}, Cu_{DTPA}, Mn_{DTPA} and the texture indicators sand/silt/clay) were analyzed, as described by Kosma et al. (2022) and were used in order to estimate the effect of land-use types on edaphic properties and plant species diversity in cultivated land.

Native plant species that occurred in the selected fields of the three different land-use types were collected during the three-year experiment and data concerning the plant species presence/absence were recorded in a total of 30 fields. Plant specimens were identified mainly according to Tutin et al. (1968–80, 1993). Plant nomenclature follows Dimopoulos et al. (2013); (2016).

Principal component analysis (PCA) was used to assess how many and which of the above (18) mentioned parameters can be considered as representative edaphic indicators correlated both to native plant species presence/absence in abandoned land and the environmental changes arising from the chosen land management practices. CANOCO software version 4.5 (ter Braak and Šmilauer, 1998) among the plant species and selected environmental variables was used, in order to assess the effect of multivariate edaphic factors on plant species distribution pattern as well as on that of sampling fields where was recorded the presence/absence of them.

RESULTS AND DISCUSSIONS

Soil analysis was initially performed in the total study area (*Stotal*) in a large (18) set of soil properties data. The soil reaction in *Stotal* showed that soil pH values ranged from 6.3 to 8.3 with a mean value of 7.16 (near neutral), while the EC values ranged from 0.35 to 1.88 with a mean value of 0.82 dS m^{-1}. Moreover, the mean content of soil organic matter was1.6 % and ranged from 1.0 to 2.7 % as it is shown in Table 2. Among the three different land uses (maize, alfalfa & abandoned land), the edaphic variables EC, SOM, BD, Ca & Na concentrations presented significant differences (Table 2).

Table 2. Soil fertility status of three different land uses (maize, alfalfa & abandoned land), comparison of the mean ± standard deviation values of the examined edaphic properties after long term cultivation in Western Greece

Edaphic variables	**Land use (LU)**			
	Maize crops (n=10)	**Alfalafa fields (n=10)**	**Abandoned land (n=10)**	**Total land (n=30)**
pH	7.09±0.27	7.04±0.30	7.36±0.50	7.16±0.08
EC dSm^{-1}	0.80±0.26*	1.08±0.41*	0.58±0.12*	0.82±0.35
SOM (%)	1.32±0.38*	1.40±0.21*	1.94±0.21*	1.55±0.43
BD (g cm^{-3})	1.43±0.07*	1.43±0.07*	1.30±0.09*	1.39±0.10
Total $CaCO_3$	5.32±4.36	2.07±1.77	3.46±2.65	3.62±3.30
Sand (%)	39.7±8.49	36.9±0.89	35.9±1.83	35.9±1.83
Silt (%)	31.7±6.13	39.8±5.92	37.1±11.9	36.2±8.86
Clay (%)	28.7±6.60	34.4±6.32	29.0±8.89	30.7±7.59
Ca (mg Kg^{-1})	3210±562*	3115±329*	2422±545*	2916±601
Na (mg Kg^{-1})	86±31*	106±79*	43±18*	78±55
Mg_{avail} (mg Kg^{-1})	151±68	160±75	204±154	172±105
K_{avail} (mg Kg^{-1})	502±389	427±77	633±263	520±279
NO_3-N (mg Kg^{-1})	10.6±2.27	13.1±4.48	11.7±2.70	11.8±3.35
P_{Olsen} *(mg Kg^{-1})*	16.4±5.91	15.8±3.74	18.4±6.15	16.9±5.31
Cu_{DTPA} *(mg Kg^{-1})*	1.29±0.49	2.31±1.59	2.58±1.92	2.06±1.52
Zn_{DTPA} *(mg Kg^{-1})*	0.80±0.60	1.06±1.39	1.36±0.95	1.08±1.02
Mn_{DTPA} *(mg Kg^{-1})*	9.72±5.64	9.23±6.07	7.21±2.20	8.72±4.90
Fe_{DTPA} *(mg Kg^{-1})*	25.8±16.0	24.9±10.8	22.3±8.17	24.3±11.8

** Indicates significant differences at significance level P < 0.05 between values in rows for each parameter*

According to Ebabu et al. (2020) agricultural areas characterized by greater spatial variability of soil properties compared to other natural (undisturbed) soils. Recent research has shown that among the different land uses the same soil variables present different results, indicating that crops not only depend on soil properties, but they can also alter them (Blum, 2013; Kosma et al. 2022; Triantafyllidis et al. 2020). As a result, changes in land use affect agricultural practices soil compaction as well as the input/output fluxes of nutrients in the soil (Yadav et al. 2017).

Similar results were observed in this study showing significant differences in SOM, BD and EC soil values, in different land use/cover in which different management agricultural practices are usually followed. Principal component analysis (PCA) was used to identify and select the most appropriate soil indicators (a minimum data set MDS) from a large dataset that reflect soil function. Under each of the principal components (PC), only the variables with high factor loading were retained as indicators (Triantaffylidis et al. 2018). A minimum data set (MDS) of these indicators could give accurate and up to date information of the soil variability in 30 fields of the study area which can be used as a decision support tool for agriculture management practices. After interpreting all components (Table 3), the results are summarized as follows: PC1 was attributed to soil reaction and its effect on soil micro-nutrients availabilty, explaining 17,1% of variance. PC2 was attributed to to anthropogenic interventions such as mineral fertilization and soil compaction due to increased machinery intensity in agricultural production, explaining 15,8% of variance. PC3 was attributed to geogenic factors such as soil texture and their effect of soil nitrates behavior, explaining 15.0% of variance. PC4 was attributed to electrical conductivity (EC) and the significant correlation with sodium soil concentrtions (Na) , explaining 11,7% of variance. PC5 was attributed to soil fertility by soil organic matter content, explaining 11,2% of variance and PC6 was attributed to agrochemicals application such as P mineral fertilization and Cu fungicides application in agricultural land, explaining 8,9% of variance. However, factor analysis of soil properties in *Stotal* reported that upon varimax rotation, six principal components could explain only 79.659% of the total variance Table 3.

Table 3. Matrix of principal component analysis of normalized physicochemical properties and elemental concentrations of the selected agricultural soils in the study area (significant loading factors are marked in bold)

Soil properties	Rotated component matrix					
	1	2	3	4	5	6
pH	**-,848**					
Mn	,800					
Fe	,753					
Zn	,654	-,439				
Ca		**,879**				
CaCO3		,697				
BD		,654				
Mg		-,653				
Sand			**-,957**			
Clay			,873			
Silt		-,544	,705			
NO_3-N			,538			
Na				**,964**		
EC				,847		
SOM					**,894**	
K					,878	
Cu						**,810**
P	,539					,622
Eigenvalue	3,073	2,851	2,692	2,105	2,012	1,605
% of Variance explained	17,075	15,840	14,957	11,695	11,176	8,916
Cumulative % variance	17,075	32,915	47,872	59,567	70,743	79,659

In total 122 taxa belonging to 30 families were recorded, while the families with the greatest species diversity were Poaceae, Asteraceae and Fabaceae in each land-use (Figure 1). In total, one (1) Greek Endemic taxon (*Heliotropium halacsyi* Riedl) was observed, while in all cases the Mediterranean was the second chorology group after the Widespread species. Therophytes was the dominant life-form followed by the Hemicryptophytes and Geophytes (Figure 2). The high percentage of the Mediterranean taxa in combination with the predominance of Therophytes revealed the Mediterranean character of the flora of these agroecosystems (Zotos et.al., 2021; Blumler, 2018). The predominance of Therophytes can be explained due to their adaptability to survive as seeds under unfavorable dry conditions. Moreover, the limited participation of Phanerophytes combined with the predominance of therophytes indicates the degradation of the agroecosystems caused by anthropogenic interventions.

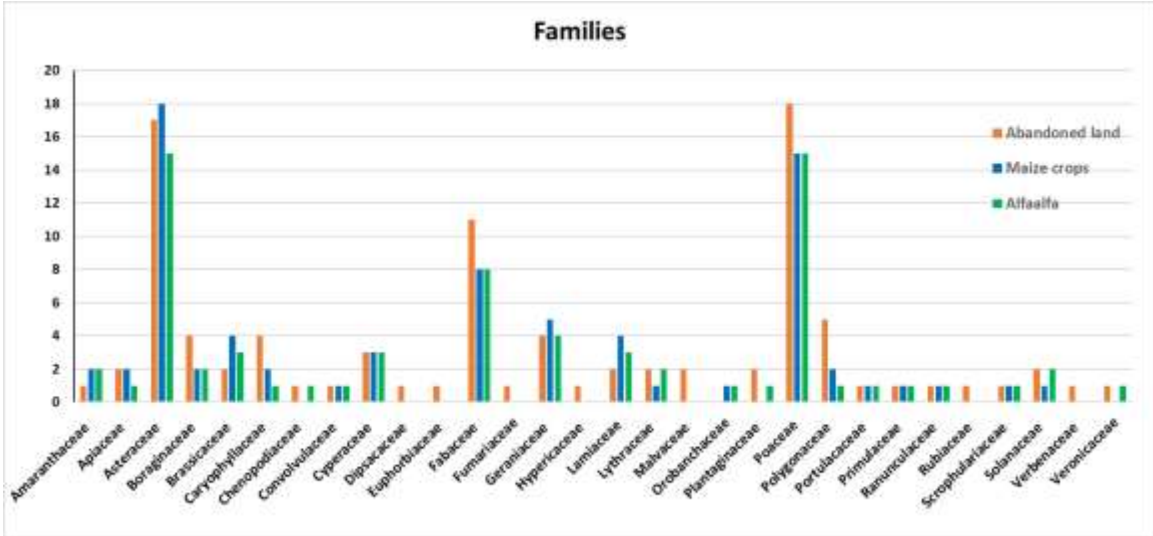

Figure 1. Numbers of species from each family which were collected in the cultivation fields of three different land use types

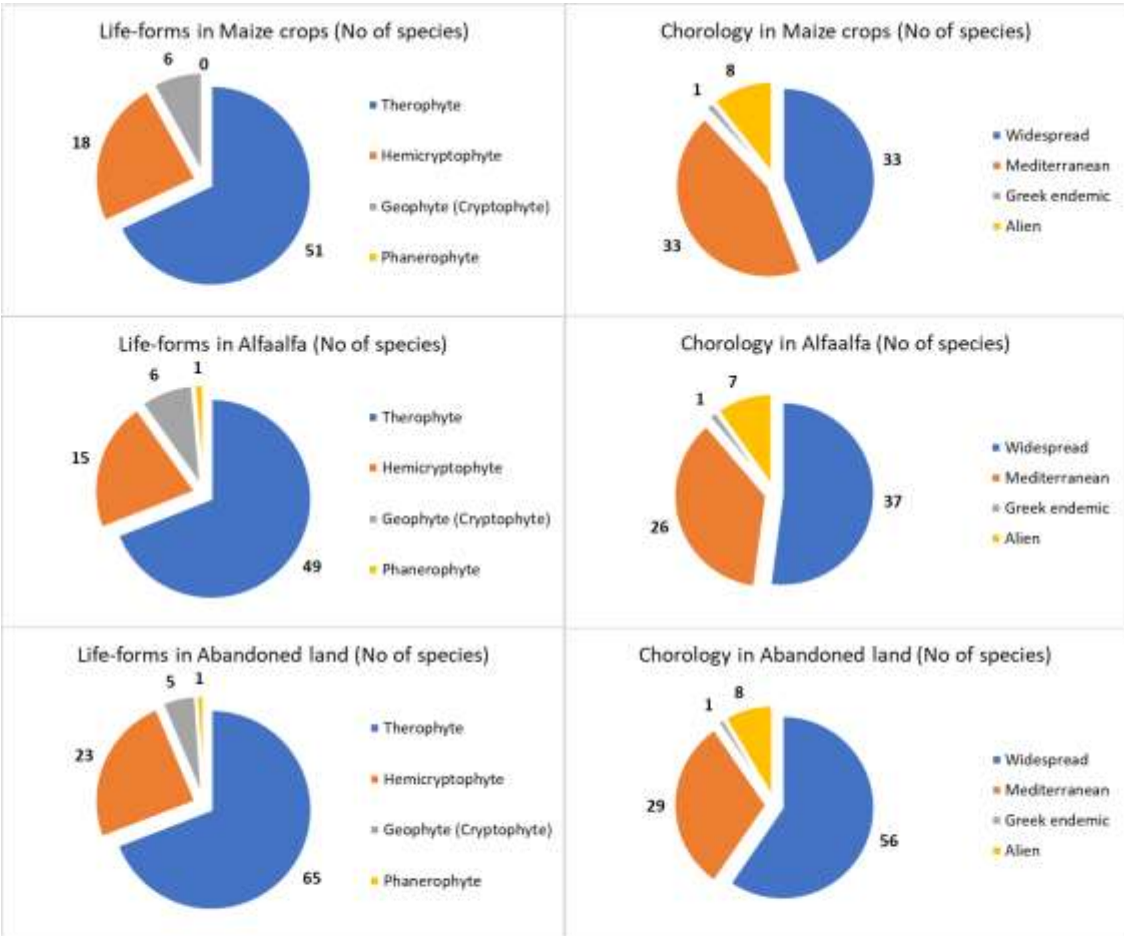

Figure 2. Chorology and Life-form classification of plant species which were collected in the cultivation fields of three different land use types.

The CCA analysis showed a clear distinction among fields cultivated with alfalfa and maize and those of abandoned land Table 4, Figure 3. Abandoned lands are grouped on the left of the diagram, strongly correlated with the soil organic matter, and pH. This positive correlation between soil pH and plant species richness, which occurred in abandoned land, has been reported in many studies (Chytrý et al. 2003; Zotos et al. 2021).

Table 4. Correlations of environmental factors (pH, EC, sand, SOM, NO_3^-, Ca+2, Cu_{DTPA}) with the first two CCA axes, Eigenvalues of the ordination axes and sum of all unconstrained Eigenvalues (total inertia) for CCA analysis

Environmental variables		Axis 1	Axis 2
pH		-0.32	-0.56
EC		0.69	0.01
Sand		0.04	-0.43
SOM		-0.62	0.13
NO_3^-		-0.12	0.71
Ca+2		0.67	0.06
Cu_{DTPA}		-0.19	-0.06
Species-environment correlation		0.94	0.90
Cumulative percentage variance:			
(i) of species data		8.7	13.8
(ii) of species-environment relation		30.6	48.8
Total inertia:	1.07		
Sum of all eigenvalues:	3.80		

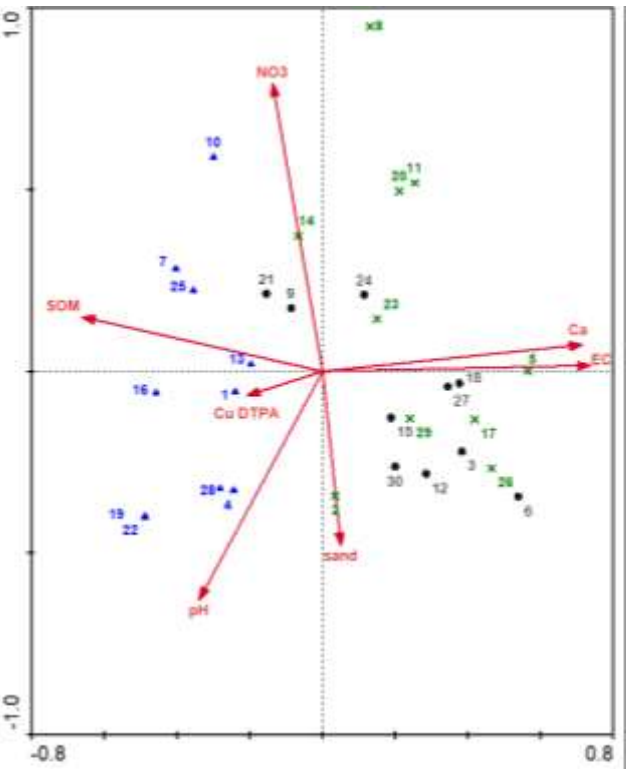

Figure 3. CCA biplot ordination diagram of the first two canonical axes 1,2 with cultivation fields (●) in maize crops, (▲) in abandoned land, and (x) in alfalfa and environmental variables (arrows)

In addition, most fields coming from maize crops and alfalfa are grouped mainly on the lower right part of the diagram and their occurrence is strongly correlated with EC, Ca+2 and sand, while the rest of the maize and alfalfa fields are grouped on the upper right part of the diagram strongly correlating with EC, Ca+2 and NO3-. The intense anthropogenic interventions, and pesticides application in combination with the wide use of nitrogen fertilizers, lead to the accumulation of nitrates reducing at the same time the plant species richness (Triantafyllidis et al. 2020). The same distinction was observed among species which were found in different land uses Figure 4.

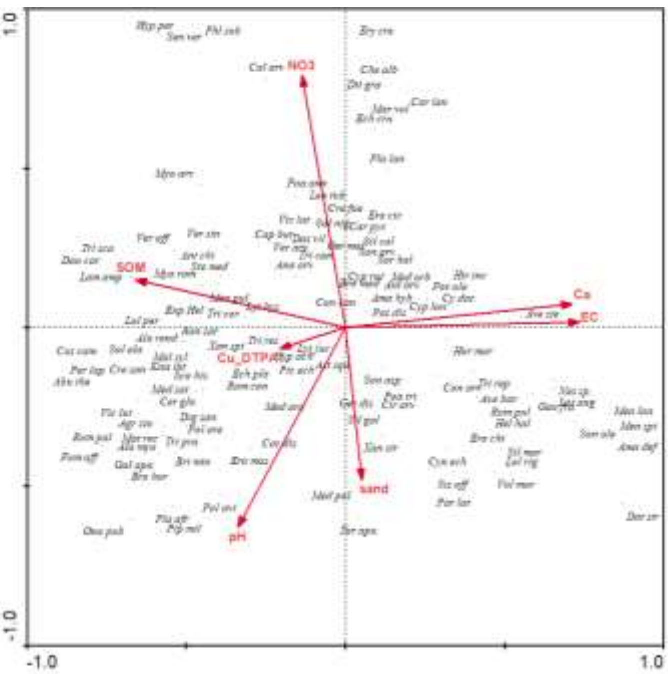

Figure 4. CCA biplot ordination diagram of the first two canonical axes 1, 2 with plant species and environmental variables (arrows) in cultivation fields of three different land use types

CONCLUSIONS

In the Mediterranean agroecosystems due to the intense anthropogenic intervention a gradual change in the soil physicochemical properties as well as a reduction of plant species richness were observed. More specific, the anthropogenic activities such as land-use intensification, soil compaction, fertilization and pesticide application have adverse effects on species diversity reducing the richness of plant species in alfalfa and maize crops in comparison to the abandoned land. The high participation of Therophytes in conjunction with the low participation of Phanerophytes is an indicator of degradation as a result of intense anthropogenic interventions. To conclude, the results of the present study imply that different agronomic practices influence soil quality parameters, which are likely to affect species diversity and the environmental implications among different land uses.

Author Contributions: A.Z, V.K Conceived and designed the analysis; A.Z., V.T, I.R., I.K., C.K, A.M., P.S., D.B. Collected the data; A.Z., V.T, I.R., I.K., C.K, A.M., P.S., D.B. Contributed data or analysis tools; A.Z., V.T, C.K. Performed the analysis; A.Z., V.T, C.K. Wrote the paper. All authors read and approved the final manuscript.

Funding Source: The research leading to these results received funding from program MEDICUS of the University of Patras "ΜΟΔΥ ΕΛΚΕ", research.upatras.gr; under Grant Agreement No 81825- program MEDICUS

Acknowledgments

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of Interest

The authors declare that they do not have any conflict of interest.

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