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Assessing the ecological integrity of landscapes in Cyprus.

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Abstract

Landscape Character Assessment (LCA) has gone a long way since its early development in NW Europe. LCA should go beyond the simple characterisation of landscapes and must support reasonable judgements about the condition of the landscape, including its ecological integrity. Although some progress has been made in this direction, what still remains understudied -at least in a Mediterranean context-is the validity of the framework in general and for ecological applications in particular. This paper explores whether, in the absence of detailed habitat mapping, LCA can be used as a surrogate for assessing ecological integrity. In other words, how well does the countryside function as habitat for wildlife? The paper attempts to answer the above question using Cyprus as a case study, a country where there is a significant gap in detailed habitat mapping. Cyprus has recently completed a landscape map for the whole island based on mapping natural (soils, geology & landform) and cultural (land cover, settlement pattern) variables. Ecological integrity was measured in the field, to capture important properties of broad habitat types such as composition and spatial configuration, and management intensity. The results based on a statistical comparison between ecological integrity condition and landscape character types (LCTs), demonstrate a significant relationships. This confirms that potentially LCA, coupled with rapid habitat surveys can deliver an effective and reliable tool for assessing the ecological integrity of different landscapes.

Introduction

Landscape Character Assessment (LCA) has come a long way since its early development in NW Europe, in particular in the UK (e.g. Griffiths et al. 2004; Warnock and Griffiths, 2015) and it has recently been employed in the Mediterranean (Vogiatzakis 2011). Essentially, LCA process involves the distinct stages of characterisation, evaluation and decision-making and enables the assessment of character, condition and changes in the landscape. However, it is now widely accepted that LCA should go beyond the simple characterisation of landscapes and support reasonable judgement about the condition of the landscape, including its ecological integrity (Griffiths et al. 2004; Swanwick 2004).

Although some progress has been made in this direction the validity of such a framework and its ecological applications still remains understudied, at least in a Mediterranean context. Therefore, a question arises: can landscape character mapping be used as a surrogate for assessing ecological integrity in the absence of a detailed habitat mapping? In other words how well does the countryside function as a habitat for wildlife?

Building on the related concepts of biological integrity and ecological health, ecological integrity is a broad and useful endpoint for ecological assessment and reporting (Harwell et al. 1999). "*Integrity*" is the quality of being unimpaired, sound, or complete. Ecological integrity can be defined as "the structure, composition, and function of an ecosystem operating within the bounds of natural or historic disturbance regimes" (Lindenmayer and Frankin 2002; Young and Sanzone 2002; Parrish et al. 2003).

An ecosystem with ecological integrity should be relatively unimpaired across a range of ecological attributes in spatial and temporal scales (De Leo and Levin 1997). The notion of ecosystem naturalness depends on the understanding of how the presence and impact of human activity relates to natural ecological patterns and processes (Kapos et al. 2002). The interpretation of ecological integrity could also be based on the identification of reference or benchmark conditions based on natural or historic ranges of variation, although challenging (Swetham et al 1999).

In the absence of time and resources for habitat inventory, rapid survey techniques are becoming invaluable tools for nature conservation (Fennessy et al. 2007; Vogiatzakis et al. 2015). Most of the efforts for ecological integrity assessment have, so far, been species-based (and quantitative) (Medeiros and Torezan 2013). Although some ecological integrity frameworks at the landscape level have been proposed (Theobald 2013), validation of the approach is limited. Rapid assessment methods facilitate condition assessment and require less time in the field and less taxonomic expertise than quantitative methods, resulting into significant cost savings and increased sample sizes (Fenessy et al. 2007).

Although Cyprus is a renowned biodiversity hotspot (Myers et al. 2000) however, a gap in detailed habitat and species distribution mapping exists. Recently, a first landscape character mapping exercise employing a hierarchical approach based on the so-called "definitive attributes" (Table 1) of both physical and cultural dimension of the landscape, resulted in two landscape maps at different scales (1: 250 000 and 1: 50 000) (Warnock et al. 2008; Symons et al. 2013).

In the current study, a parsimonious series of qualitative indicators of ecological integrity, easily measured in the field were tested using Landscape Character Types (LCTs) at scale 1:50 000 as a spatial framework. In this paper the preliminary results of the assessment for three LCTs namely "*lowland village farmlands*", "*low hill maquis*", and "*low hill forests*" are presented.

Materials and Methods

Study area

Cyprus, the third largest Mediterranean island (Fig. 1), is situated in the north-eastern Mediterranean with an area of 9,251 km^2, of which 1,733 are forested. The current landscape of Cyprus is the product of the influence of a long and varied history superimposed onto a physical background of diverse natural features. The physical environment is characterized by a rugged morphology and varied geology and thus the island is divided into three geomorphological zones: the Troodos Mountain; the Pentadaktylos Range and the Mesaoria plain (Fig.1). The climate of Cyprus is, in general, at the drier end of the Mediterranean-type climates. The biotic elements are characterized by considerable diversity and endemism taking into account the size of the island. The rural landscape is dominant and usually intermixed with natural elements. The most remarkable recent landscape changes in Cyprus have

Table 1 Definitions of commonly used terms in Landscape Character Assessment (LCA)

Term	Description
Landscape Character Assessment (LCA)	A set of techniques used to classify, describe and understand the evolution, physical and cultural characteristics of landscape.
Landscape mapping process	A procedure of data acquisition, processing and synthesis to produce a series of character based overlays incorporating the key factors that contribute to landscape character.
Landscape character	A distinct, recognizable and consistent pattern of elements in the landscape that makes a landscape different to another.
Definitive attributes	Attributes which define spatial units on the ground based on patterns that can be delineated from map information, they define the extent of each spatial unit.
Landscape Description Units (LDUs)	Distinct and relatively homogeneous units of land, each defined by a series of definitive attributes.
Landscape Character Types (LCTs)	Repeatable spatial land units relatively homogeneous in character.

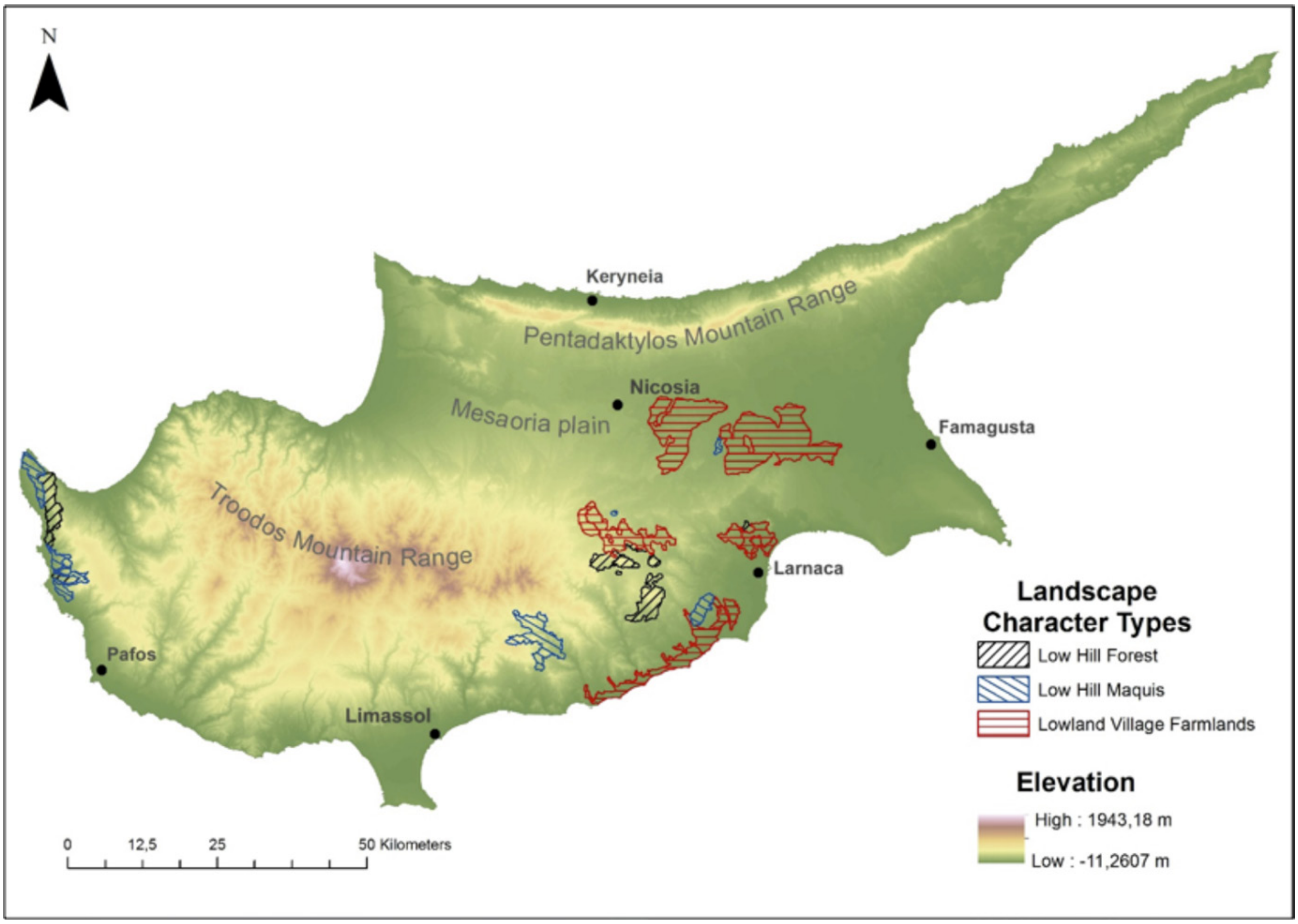

Fig. 1. Location of the studied Landscape Character Types (LCTs)

been brought about by overexploitation of the coastal areas, urbanization, massive population movement, water exploitation, the shift from agricultural to tourism economy and by an effort towards reforestation and by recent sustainable development policies.

Data collection

Following desktop mapping at Level 2 (Symons et al. 2013), a thorough fieldwork exercise was undertaken across the island to review and refine the draft Landscape Character Types (LCT) classification. The field surveys aimed to identify the key characteristics that contribute to local distinctiveness and sense of place and to include the visual dimension of the landscape in order to complete the typology.

For that reason detailed notes on the landscape character (key characteristics, visible forces for change, information on naturalness) and photographs across each LDU, were used to write character profiles for each unit and therefore to each Landscape Character Type (LCT). GPS position was used to locate every photograph. Furthermore, during fieldwork, a number of ecological integrity indicators (Table 2) were visually assessed in a rapid and consistent way without requiring expert ecological knowledge.

Ecological Integrity Assessment

Ecological integrity of different Landscape Character Types (LCTs) was based on a series of naturalness indicators recorded in the field, that capture important properties of broad habitat types in a landscape such as area and spatial configuration, habitat continuity and connectivity as well as management intensity (Table 2). As a spatial framework for the ecological integrity assessment Landscape Character Types were used as derived by the desk study work of Symons et al. (2013).

The landscape mapping in Cyprus (Warnock et al. 2008; Symons et al. 2013) was based on key physiographic characteristics (geology, soils, relief) together with broad-scale ecological/cultural patterns of land-use (e.g. forest, scrub, arable farming, vineyards, olive groves, etc) and broad patterns of settlement. Current work at 1: 50 000 scale generated 600 Land Description Units (LDUs) classified in c.70 LCTs at this level (unpublished data). The derived LCTs were generated by grouping together LDUs with the same prominent definitive attribute, and then be confirmed during the field validation by the prominent visual characteristics.

In the current paper the preliminary results of the assessment are presented for three common Landscape Types namely "*lowland village farmlands*", "*low hill*

Table 2. Definition and measurement scale of the Ecological Integrity indicators recorded during fieldwork.

Indicator	Definition	Scale
Naturalness	How close a landscape is to a perceived natural state as shown by the principal land use.	1. Mostly urbanised 2. Mostly cultivated 3. Mixture of natural and cultivated 4. Mostly natural
Overall Habitat Continuity	The continuity of natural/semi-natural habitats as a whole within the overall matrix of a particular landscape unit.	1. Fragmented 2. Separate patches 3. Linked patches 4. Continuous
Dominant Habitat Type	Dominant habitat type covering >75% of the landscape unit. Habitat types are defined on the basis of the principal life form.	1. Herbaceous 2. Dwarf shrub 3. Low shrub 4. Tall shrub 5. Woodland
No of main habitat types	Number of habitat types present in a landscape unit.	1-5
Management Intensity	An assessment of visible human modifications on a landscape unit coupled with any associated field observations.	1. Low 2. Medium 3. High 4. Very high

maquis", and "*low hill forests*" with 12, 11, 10 samples respectively.

Statistical Analysis

A Kolmogorov-Smirnov statistical test was applied for assessing normality. Kendall's correlation coefficient (tau_b) was employed to examine the correlation among the ecological integrity indicators and the three LCTs. For the comparison of the ecological integrity indicators among types the non-parametric Kruskal-Wallis test (sig. level <0.05) was used. Statistical differences between the pairs of LCTs were detected using non-parametric Mann-Whitney test with Bonferroni correction (sig<0.017), i.e. Mann-Whitney independent tests were performed 3 times for pairs: LCTs: 1-2; LCTs: 1-3; LCTs: 2-3 (Field 2009).

Principal Component Analysis (PCA) was applied as a clustering method in order to reduce the dimensionality of our multivariate data related to ecological integrity indicators (Table 2) while preserving most of the variance with-in it. According to the clustering of the ecological integrity indicators (Table 2) along the first axis (PC1) a gradient was identified. For the estimation of this gradient that represents the ecological integrity gradient the sample scores were used. In the analysis only indicators (ecological integrity variables) with significant correlation with the first axes of the PCA (r>0.6, r automatically obtained by the statistical software) were included. The descriptive statistics were performed using SPSS 21 while the multivariate analysis was conducted using CANOCO 4.5.

Results

All ecological integrity indicators appeared to be strongly inter-correlated except for the *Habitat dominant type* and the *Integrity of management* (Table 3). The non-parametric Kruskal-Wallis test indicated that all tested variables (ecological integrity indicators) showed statistically significant differences (sig. level <0.05) between LCT 1 and 3, while LCT 1 and 2 are statistically different (sig. level <0.05) regarding *Naturalness*, *Habitat continuity*, *Intensity of management* (Table 4). Data showed statistically significant differences between LCT 2 and 3 with respect to *Dominant habitat type* (Table 4).

PCA analysis showed that the main axis (PC1) explains 71% of the total inertia and is positively correlated with *Intensity of management* and negatively correlated with *Naturalness*, *Habitat continuity*, *No of main habitat types* and *Dominant habitat type*. Along axis 1 (PC1), the ecological integrity of a unit increases (right to left side of the plot) (Fig. 2). Therefore, PC1 probably represents an ecological integrity gradient. Figure 3 scores of each sampling unit on PC1 are plotted showing the separation between semi-natural and

Table 3. Kendall's non-parametric correlation coefficient (tau_b) among ecological integrity indicators and LCTs. [Correlation is significant at the 0.01 level (2-tailed); NS: Non significant; LCTs: (1= Lowland village farmland; 2=Low hill maquis; and 3=Low hill forest).

	Habitat continuity	Nº of main habitat types	Dominant habitat type	Intensity of management	LCT
Naturalness	.870**	.585**	.443**	-.766**	.753**
Habitat continuity	1.000	.604**	.443**	-.599**	.703**
Nº of main habitat types		1.000	.524**	-.488**	.603**
Dominant habitat type			1.000	NS	.744**
Intensity of management				1.000	-.506**

Table 4. Kruskal-Wallis and Mann-Whitney U test results for the components of ecological integrity among the three Landscape Character Types (LCT).

	Kruskal-Wallis test		Mann-Whitney U test		
			LCTs 1-2	LCTs 1-3	LCTs 2-3
	[a]Chi-Square	[b]Asymp. *Sig.*	Asymp. *Sig.*		
Naturalness	27.323	**.000**	**.000**	**.000**	1.000
Habitat continuity	22.204	**.000**	**.000**	**.000**	.326
No of main habitat types	13.999	**.001**	.038	**.001**	.022
Dominant habitat type	22.377	**.000**	.039	**.000**	**.000**
Intensity of management	16.603	**.000**	**.000**	**.002**	.469

agricultural landscape character units with the former having a higher ecological integrity. However, whereas semi-natural landscapes show a uniform ecological integrity, within the agricultural units there is great variation (Fig. 3). Agricultural landscapes are associated with management intensity while forest and maquis landscapes are associated with habitat continuity and support more habitats (Fig. 3).

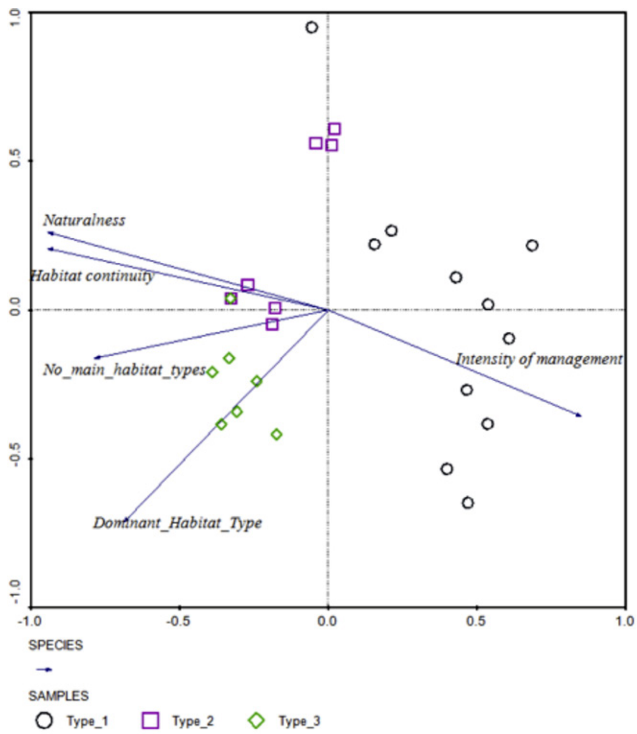

Fig. 2. PCA of the landscape description units (LDUs) for the three Landscape Character Types (LCTs) examined. Diamond=Low hill forest, square=Low hill maquis and circle=Lowland village farmlands.

Discussion and Conclusions

The European Landscape Convention (Council of Europe 2000) makes explicit reference not only to the identification of landscapes but also to the need for monitoring the associated changes in these landscapes. The current anthropogenic pressures in the Mediterranean threaten the fine-grained multifunctional nature of the Mediterranean landscapes and their ecological condition and integrity. Several ecological applications of the landscape typology have been documented including spatial planning for habitat restoration (Griffiths et al. 2011), identification of a landscape's ecological properties and design of ecological networks (Blasi et al. 2008; Blasi et al. 2000). What still remains to be answered is whether LCA process could also be used for rapid assessment of ecological integrity, as expressed by a set of ecologically meaningful and easy to assess in the field parameters.

The results of this study corroborated the lower ecological integrity of agricultural compared to semi-natural landscapes as measured by the indicators employed. The variation of the ecological integrity within semi-

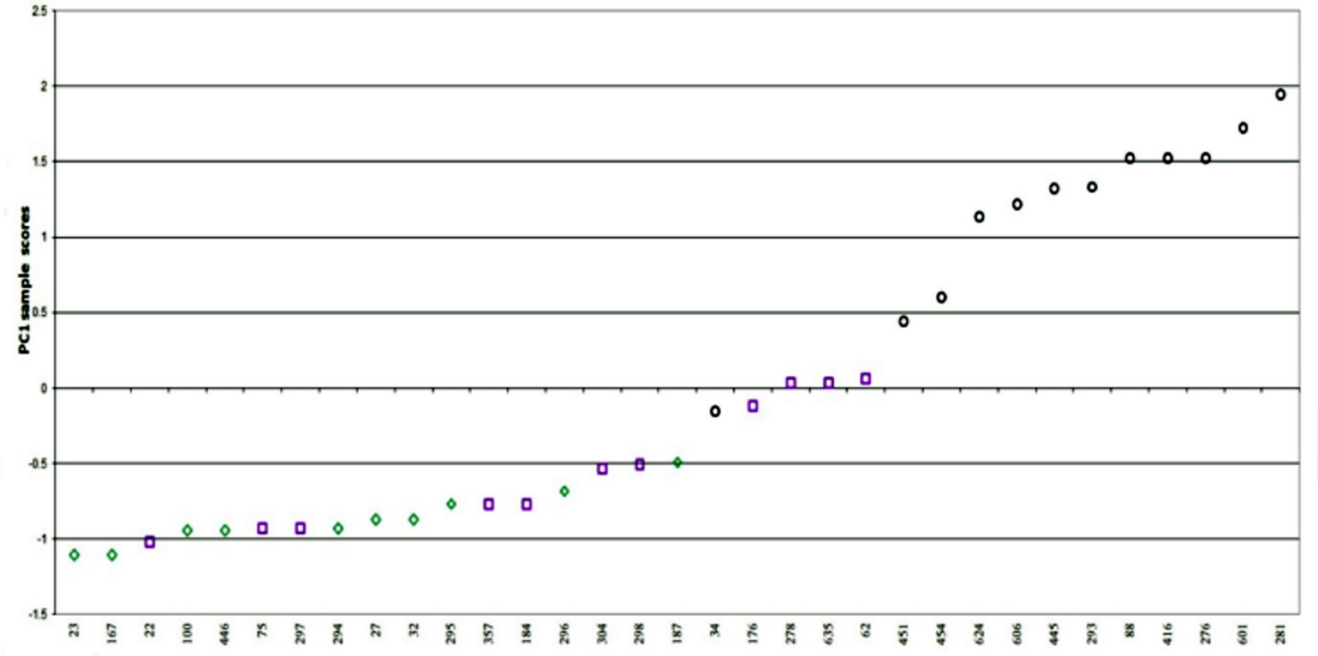

Fig. 3. PC1 scores of all samples (Black colour indicates LDUs that belong to LCT 1= Lowland village farmland, Purple to LCT 2=Low hill maquis and Green to LCT 3=Low hill forest).

natural landscapes was lower than the variation of the landscapes dominated by maquis, whereas there is great variation within agricultural landscapes. Moreover, in some cases the ecological integrity of the maquis landscapes was higher than forested landscapes. The greater variation in the ecological integrity of agricultural landscapes might be the result of the different degrees of management intensity and cultivation patterns and therefore supported habitats and species. In Cyprus for example, agricultural landscapes along the coast as well as in the Messaoria plain are more intensively managed compared to traditional agricultural landscapes with carobs, olives and vineyards (particularly in the upland areas). The latter are ecologically important and form the backbone of High Nature Value Farmlands on the island (Paracchini et al. 2008). The main definitive attributes of the typology related to these results, for the landscape types examined in this study, are land cover as well as settlement pattern. This is somewhat expected since these attributes are the building blocks of the validation process underpinning directly or indirectly the definitions of the ecological integrity metrics assessed in the field. Land cover within a landscape type defines the extent and ecology of the matrix while settlement pattern attests to the human imprint in the area.

Irrespectively of the reasons for these marked dissimilarities among the different landscape character types (a subject of further study), the method employed shows great promise as a reliable, consistent and inexpensive manner for assessing ecological integrity. Therefore in the absence of detailed habitat and biodiversity datasets rapid assessment can provide a reliable alternative for establishing a baseline for monitoring changes in different landscapes along a composite gradient of naturalness within a range of spatial scales.

This rapid survey although not explicitly addressing habitat quality or biodiversity richness, demonstrates a significant pattern with the character of the landscape as identified and mapped confirming LCA's role as a spatial planning tool. Landscape Character mapping coupled with rapid habitat surveys can deliver an effective and reliable tool for monitoring ecological change in a landscape. In Cyprus, future work will focus on assessing the ecological integrity of all recognized landscape character types (LCTs) on the island as well as on testing the validity of the framework against biodiversity distribution data.

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