Nodes of a peri-urban agricultural landscape at local level: an interpretation of their contribution to the eco-structure

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Nodes of a peri-urban agricultural landscape at local level: an interpretation of their contribution to the eco-structure.

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The ecological value of some fine-scale landscape elements tends to be overlooked when they are found in highly human-influenced landscapes, such as peri-urban agricultural ones. These landscapes usually fall beyond the scope of the defined categories of landscape protection, and are thus mapped as areas of little or no ecological interest in the context of extensive analysis. In this paper we present a method for assessing and visualizing the existing nodes in the field pattern of a peri-urban agricultural landscape. Nodes are identified from the field pattern and characterized according to the presence of relevant features and land uses from the viewpoint of their ecological functions. The method is applied in the Vega del Guadalfeo (south of Spain). Our results show an innovative map of the Vega which may be interpreted as its eco-structure; a model based on nodes to represent the ecological value of the peri-urban agricultural landscape.

Keywords: node; peri-urban, agricultural landscape; eco-structure; vega.

1. Introduction

Vegas, a type of Mediterranean huerta (see Meeus, 1995; Mata and Fernández, 2004), are characteristic peri-urban, agricultural landscapes linked to historical irrigation systems in the Spanish Mediterranean area and originate from centuries of human intervention since the Muslim or Roman period (Trillo 2005; Hermosilla and Iranzo 2010). They are agricultural floodplains known for their high fertility and as a part of the landscape trio river-city-vega (LSA 2012) and they have been historically occupied by human use due to their geomorphology and topography, edaphology, agricultural productivity, and water resources. Vegas and huertas also perform ecological functions which are maintained by different landscape elements, most of them resulting from the special co-evolution process between natural and human forces in Mediterranean landscapes (Tello 1999). Nevertheless, the location and sometimes limited area of these landscapes make them tend to be overlooked, falling beyond the scope of the defined categories of landscape protection, and frequently mapped as areas of little or no ecological interest in the context of extensive analysis. Even so, there is a growing recognition of the role of these landscapes which comes from: the acknowledgement of the importance of peri-urban agriculture (EESC 2004; Paül and Haslam 2013; Opitz *et al.* 2016); the understanding of the peri-urban as a new kind of multifunctional territory (Ravetz, Fertner, and Nielsen 2013), a multifunctional rural-urban fringe; the importance given to everyday or even degraded landscapes by the European Landscape Convention (CoE 2000); the insights about multifunctional agriculture as a paradigm (Wilson 2007); the role of agriculture in providing ecosystem services (Swinton *et al*. 2007); the consideration of the specific roles of peri-urban agriculture by means of its multifunctionality (Zasada 2011); and more recently the resilience-based approach towards urban and peri-urban agriculture (Toth, Rendall, and Reitsma 2015; de Zeeuw and Drechsel 2015)

Within this framework, we propose a method to identify and map the eco-structure of a Mediterranean vega. We define the eco-structure as a model based on nodes to represent the ecological value of existing natural and man-made elements in the peri-urban agricultural landscape. Based on nodes as crossing points in the peri-urban agricultural landscape, the eco-structure helps us to visualize and understand the structure of this space from the viewpoint of its ecological value and consider, at the same time, the particular field pattern in a vega and how it is analysed. The ecological value is here understood in general terms as a consequence of the ecological functions that agricultural, natural and semi-natural landscape elements perform. Thus, similarly to the importance generally given to nodes in the urban context (see e.g. Lynch 1960) we claim a local level analysis of nodes in an agricultural landscape and gain insight into its legibility. The reflection on urban structure studies provides the idea of a node as an interconnecting area, which is translated into the peri-urban agricultural context. The characteristic features and land uses existing in the Vega are assessed according to their contribution to the ecological value in the context of the application of some general principle of landscape ecology. To solve the assignment of values (further allowing their mapping) and check the consistency of the assessment, we have applied a pair-wise comparison procedure based on Saaty (1977). Nodes therefore become important from both the ecological and structural point of view, and they are represented showing the eco-structure and visualized through different maps of node value.

Thus, this paper aims to: (i) propose the translation of the notion of node in agricultural peri-urban landscapes; (ii) present the eco-structure model, based on nodes, and a method for its identification and mapping at local level; and (iii) argue for the utility of this model in showing the structure of a vega and its ecological value.

2. Theoretical framework and reflection

We have defined the eco-structure as a model based on nodes to represent the ecological value of existing natural and man-made elements in the peri-urban agricultural landscape, such as field patterns, irrigation networks, crops, remnant vegetation, rural-road networks, and buildings.

The main contributions for the eco-structure come from two main fields: landscape ecology and urban-structure studies.

2.1. From landscape ecology

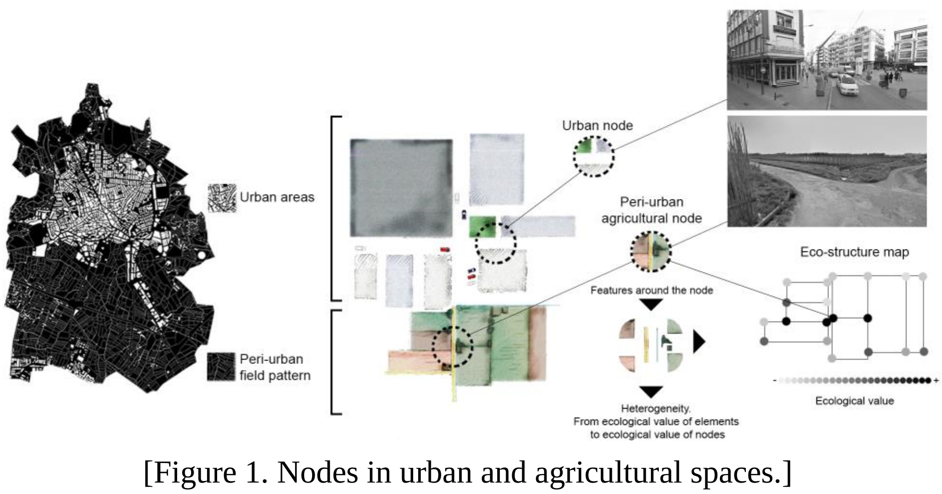
In the more recent view of landscape ecology, its principles may be applied to any mosaic (Dramstad, Olson, and Forman 2005) and its concepts and methods are the basis for solving theoretical and operational approaches concerning greenways, ecological networks, green infrastructure and other instruments that are designed to explain, restore and enhance the ecological functioning of landscapes. Although regional and national scales and natural ecosystems are far more likely to be found in the literature, a comprehensive assessment of landscape elements may be undertaken under the umbrella of landscape ecology. The ecological function that some of these elements perform has been considered in the concept of green veining (Opdam, Grashof, and Wingerden 2000) that is, semi-natural elements of the agricultural landscape (Grashof-Bokdam and van Langevelde 2005) not exactly corresponding to cultivated ones (Opdam *et al.* 2000) and playing ecological roles such as biodiversity maintenance (Bugter 2003), runoff regulation, and wind protection (Baudry, Bunce, and Burel 2000).

The eco-structure takes into account the ecological role of these and other elements linked to the existing agricultural and urban land uses in the peri-urban context. There are some common elements that may be found in practically all types of peri-urban agricultural landscapes (think of rural roads, irrigation networks, hedgerows). But others could be distinctive of a specific landscape (think of e.g. dry stone walls), contributing to the landscape character (Tudor, 2014) and they should be considered if the eco-structure model is to be applied.

Since the eco-structure is a model of the landscape structure at local level, explicit mention is due to the patch-corridor-matrix model (Forman 1995; Forman and Godron 1986) which is considered to be a widely accepted method of describing landscape structure (Bastian 2001) and it is continuously revisited and improved in its applied dimension (see e.g. recent work by Hou and Walz 2016). Being also a spatially-explicit model, the eco-structure does not, however, represent spatially patches, corridors and the matrix as defined in Forman’s model, neither does it describe landscape structures as a mosaic of discretely delineated homogeneous areas, as the patch matrix model does (Lausch *et al.* 2015). Yet, the inspirational principles behind this model take into account the assessment of the ecological value of the agricultural landscape elements in the eco-structure model, especially the concept of a barrier as an artificial land use that creates obstacles to the flow of energy, information, or matter across the matrix (Forman 1995) is taken into account in the eco-structure model.

2.2. From urban-structure studies

In the context of urban-structure analysis we may find concepts such as urban webs (Gehl 1987; Salingaros 2005), pattern languages (Alexander *et al.* 1977), legibility (Lynch 1960), amongst others. Their analyses focus on the idea of nodes, connections and complexity, which are not really far from other similar notions developed in landscape ecology. We propose rethinking and adapting some common concepts in urban structure to be applied in agricultural fields. Both the field pattern in a traditional agricultural space and the urban tissue are constructs; the result of a tight human-environment interaction. But there is a tendency to interpret this interaction just in the urban context. Thus, the importance of crossroads or thematic agglomerations is generally agreed (see Lynch 1960), and the importance of nodes coming from the application of network theory (see Brandes *et al.* 2013). Are, for example, cross-rural-roads thought of similarly (considering, of course, the different intensity of human activity in both cases)? (Figure 1).



[Figure 1. Nodes in urban and agricultural spaces.]

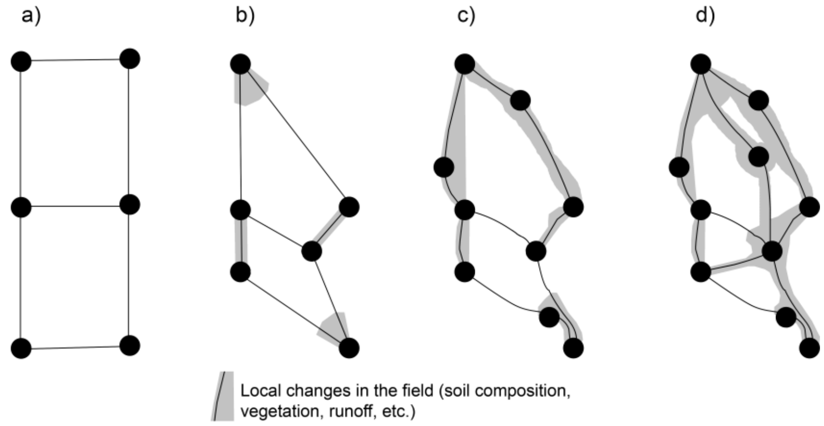
Even if the previous ideas do not address the notion of ecological function or value, they could be adjusted to environments of different scale or function than cities. This is indeed stated by Lynch who proposes the application of his approach to a building, or landscape; a transportation system, or a valley, or a metropolitan region (Lynch 1960: 157).

Finally, an interesting point for a cross view between these "urban" approaches and ecological concerns is the fact that humans engage with the latter at a particular scale, perceiving physical patterns as making up their surroundings (Gobster *et al.* 2007). This becomes obvious in an urban context, but tends to be overlooked in other landscape contexts. Nevertheless, the perceptive and aesthetic experiences can lead to changes affecting ecological aspects (Ibidem). This is one of the reasons why an approach combining the acknowledgement of ecological values at local level together with the spatial-composition experience at the same point may provide new possibilities for analysing and planning landscapes, especially through a design perspective that may extend the landscape ecology paradigm (Nassauer and Opdam 2008).

2.3. Nodes as main components of the eco-structure

As briefly commented in the introduction, the location and sometimes limited area of peri-urban agricultural landscapes make them tend to be overlooked. In addition, the peri-urban agriculture they enclose is usually characterised by its small and fragmented area, being mixed up with urban and infrastructural elements. It is in this scene where eco-structure nodes may offer a suitable approach to assess the ecological value of these landscapes.

The concept of nodes has not been directly taken from urban studies where, e.g., Lynch (1960) defined nodes as "the strategic spots in a city into which an observer can enter", but reinterpreted and adapted. In the eco-structure model, nodes are points where the field borders converge and also where they change direction. In the latter case we were able to observe (both through field work and aerial photography) a different composition of elements around these points. For example, we found how these changes in the direction of borders hamper the performance of farm machinery in the field. It causes local portions of land that are free of crops, where it is more likely to find features such as trees, hedgerows and even little ponds. We consider it as a growing complexity in the field pattern (Figure 2) associated to greater heterogeneity at local level.



[Figure 2. Growing complexity from a) to d) in a field pattern.]

The interpretation of this heterogeneity in the field borders is related to the idea of ecotones. These are boundaries where most interactions between the various components of the landscape occur (di Castri, Hansen, and Holland 1988), having important structural and functional roles in the landscape (Jagomägi, Kulvik, Mander, and Jacuchno 1988) that should also be considered at local scales (see Berger *et al.* 2003; Hou and Walz 2016).

Sometimes field borders run parallel to rural roads or paths, and then an observer could enter, as in urban nodes as defined by Lynch. On other occasions there is neither road nor path, but there may be ditches, hedgerows or just a break line between different land uses. According to Lynch they would be edges, since they are linear elements not used or considered as paths by the observer. In all these cases an observer cannot enter, but water, energy, animals do, so the nodes here located are also considered in the eco-structure model.

Table 1 contains a summary of the main concepts and how they are adapted to the agricultural space.

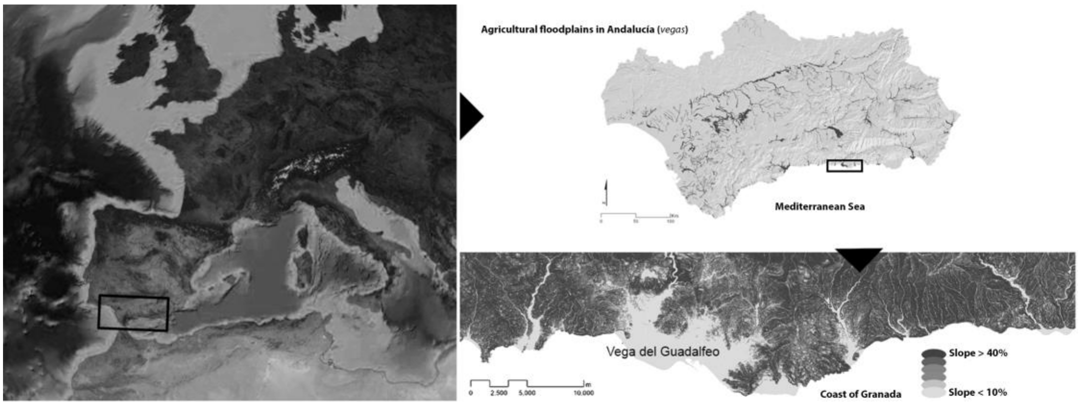
[Table 1 around here]

The concept of landmark, defined by Lynch as external point-reference where the observer does not enter within it, has not been explicitly included in the eco-structure model. Yet, some of the landscape features considered in the model could be, in fact, landmarks (particular tree specimens, ponds, historical buildings and ancient ditches). Districts have not been included either. To a certain extent, they recall an idea of homogeneity, and maybe specific compositions of elements around nodes and their arrangement could define district-like areas. Nevertheless, both landmarks and districts seem to have special connotations for the perception of observers that, rather than contributing to building the eco-structure in this phase, may need some further analysis which could involve some type of testing amongst the population.

One question may arise from the fact of using nodes as the elementary analytical units. Does it prevent a holistic approach of ecological qualities across the entire landscape of the Vega, thus ignoring the connectivity along and between landscape elements? Considering how eco-structure nodes are identified, they fully reflect the field structure. At the same time, the main features of ecological value in the Vega run parallel to field borders (ditches, rural roads, hedgerows, rivers, streams). Thus, the linearity in the arrangement of the nodes informs us about the structure of other features, and the linearity in the disposition of eco-structure nodes with different ecological value informs us about connected and disconnected areas. At this point, we assume that we are using a structural-based approach to connectivity (Taylor, Fahrig, and With 2003). Moreover, nodes as "crossing points" maintain the essence of the local level of the eco-structure model, together with their importance in the mental mapping to better "read" and understand the landscape (as happens in urban environments).

3. Study area: the Vega del Guadalfeo

The Mediterranean coast of the province of Granada is generally mountainous and steeply sloped. Urban areas and the main irrigated agricultural zones are concentrated around plains. The largest plain, the Vega del Guadalfeo (around 35 km^2) irrigated by the Guadalfeo River through a distinctive irrigation network comprises the study area (Figure 3) with two main cities; Salobreña in the west and Motril in the east. The Sierra Nevada, containing the highest mountains in the Iberian Peninsula at more than 3,482 meters a.s.l., runs some 30 km inland parallel to the coastline and protects it from the influence of northern winds, thus giving it a subtropical microclimate unique in Europe (Frontana 1984). This characteristic microclimate has in the past allowed the cultivation of sugarcane and nowadays avocados and custard apples, among other subtropical crops in the Vega del Guadalfeo. The main land uses identified in the Vega del Guadalfeo are subtropical farming, market gardens, greenhouses, abandoned fields and sugar cane. Sugar cane has currently almost disappeared but it has been considered according to the last available land-use map and for its special influence on the field size, since sugar cane harvesting has been associated to a progressive field fragmentation (Moya 1998) that has been inherited up to the present day. The medium field size is 4,600 m^2, three or even four times smaller than the media for other field patterns in Andalucia . The Vega del Guadalfeo conforms a delta at the end of the mouth of the Guadalfeo River, but it is usually more known as a vega (agricultural floodplain) than as a delta.



[Figure 3. Location of the study area.]

4. Materials and methods

The basic material used in this research was a detailed map of land uses at plot level acquired from land registries held by the Spanish Electronic Office of Cadastre and accessed in 2009/2010. The information concerning rural roads, irrigation networks, hedgerows and ponds was completed by interpretation of aerial photographs (2010) from a Web Map Service of the Regional Government of Andalucía, allowing interpretation tasks at 1:500 scale, and fieldwork using a global positioning system.

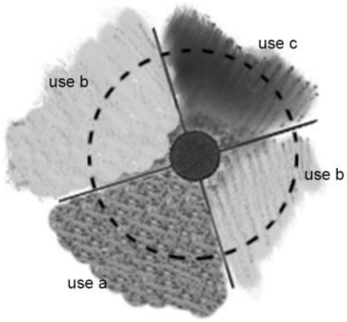
The proposed method to build the eco-structure model consists of three main phases:

(1) Identification and assessment of nodes
(2) Visualization
(3) Interpretation

4.1. Identification and assessment of nodes

Common data management tools contained in geographic information system software allow the identification of nodes and vertices of a polygonal layer (in this case, in the cadastral field layer). Both nodes (those points where field borders converge) and vertices (those points where a field border change direction), are considered as nodes in the eco-structure model (see the explanation in section 2.3). The change of direction is automatically detected by the GIS software, which locates a vertex at that point. Although the width of the angle formed may affect the node (see Figure 2), we have not made specific inquiries to avoid the assessment being too complex.

Once the nodes are identified and before their assessment, we need to know the configuration of the node, i.e., the number of segments and adjacent fields meeting in the node. This configuration is expected to have implications related to the presence of landscape features and land uses. Figure 4 shows a general model of a node with four segments and four adjacent fields.



[Figure 4 around here]

A double assessment is proposed for each node. The first, considering the presence of specific features and their ecological value, and the second considering the ecological role of the adjacent agricultural land uses around the node. In both cases, the assessment is undertaken by the application of an analytic hierarchy process (AHP) (Saaty 1977). In this paper the AHP has been applied just to validate the value assigned by the authors to different landscape features and uses allowing their representation. Thus, just a brief description of AHP is further developed. More complete and updated descriptions may be found in Saaty and Vargas (2012), Brunelli (2015) and a detailed application appears e.g. in Guerra *et al.* (2013).

As a method for relative measurement, the main interest of AHP lies not in the exact measurement of quantities, but in the proportions between them (Brunelli 2015). In this paper the subjective judgments refer to the ecological value we consider for different features and land uses (see section 2.1.). Specific numerical values are assigned to each feature or land use in relation to the other ones, from 1/9 (less contribution to the ecological value) to 1/1 (more contribution to the ecological value). Then, the “eigenvalue” method is used to estimate the relative weights of features and land uses. To analyse the consistency of the assessment, the consistency ratio (C.R.) has been calculated:

$$C.R. = \frac{C.I.}{R.I.}, \qquad (1)$$

where *R.I.* is the average random consistency index, which may be obtained from Saaty and Vargas (2012). *C.I.* is the consistency index:

$$C.I. = \frac{\lambda_{max} - n}{n - 1}, \qquad (2)$$

where λ_{max} is the average value of the eigenvector by the values of the pairwise comparison matrix, and n is the number of input criteria; 10 for the case of features and 8 for the case of land uses.

R.I., obtained from Saaty (2012, 9) is 1.49 for the case of features (n=10) and 1.40 for the case of land uses (n=8).

4.1.1. Assessment of nodes according to the presence of features

The existing features in the landscape of the Vega del Guadalfeo have been described in Table 2 and the pairwise comparison matrix is presented in Table 3, where the consistency ratio has also been calculated. The result informs that our assignation of values in the matrix has been coherent (C.R.<0.1); it means that the pairwise comparison is consistent, thus, the AHP results are considered valid. The weight vector numbers are used to represent the ecological value of each feature.

[Table 2 around here]

[Table 3 around here]

To detect the presence of each feature at node level, we have considered nodes with a 5-metre buffer. This buffer distance has been taken once we know that the minimum distance between two existing nodes in the field pattern is around 10 m. Weights from the AHP are added to each feature and then the final sum is used to characterize the node.

During the research we tried other buffer distances. Less than a 5-metre buffer was not always operative. Many features remained beyond the buffer in the GIS display, but in the "real node" (walking in the field) we could clearly find many more features in the close environment of the node. On the other hand, the test using buffers of more than 5 metres (e.g. 10) resulted in an overlapping of node buffers.

4.1.2. Assessment of nodes according to adjacent land use

The assessment of nodes according to the land use is considered through the analysis of the adjacent fields to the node. The existing land uses are identified and described in Table 4. Table 5 contains the pairwise comparison matrix and the consistency ratio. The result shows that our assignation of values in the matrix has been coherent (C.R.<0.1). The weight vector numbers are used to represent the ecological value of each land use.

[Table 4 around here]

[Table 5 around here]

In this case the node value depends on the area of each land use inside the 5-metre buffer (see Figure 4).

The node value (*V*) is obtained according to the following formula:

$$V = \frac{\sum w_n * A_n}{A_T}, \qquad (3)$$

where w_n is the weight assigned to each land use (the ecological value of each lad use coming from the weight vector in the AHP) , A_n is the area of each land use, and A_T is the total area of the node considering 5-metre buffer.

4.2. Visualization

The results of the assessment according to features and land uses are presented through two partial maps, using five levels in a graduated-colour scale. The final result of eco-structure is also a map of nodes visualized through a multiple attribute system allowed by the GIS software and considering the 5 intervals in the previous partial maps.

4.3. Interpretation

The interpretation of eco-structure might provide information about the following issues:

-Configuration of nodes and its implications regarding landscape structure and ecological values at local level.

-Connected and disconnected areas according to the linearity of nodes.

-Specific node-distribution patterns.

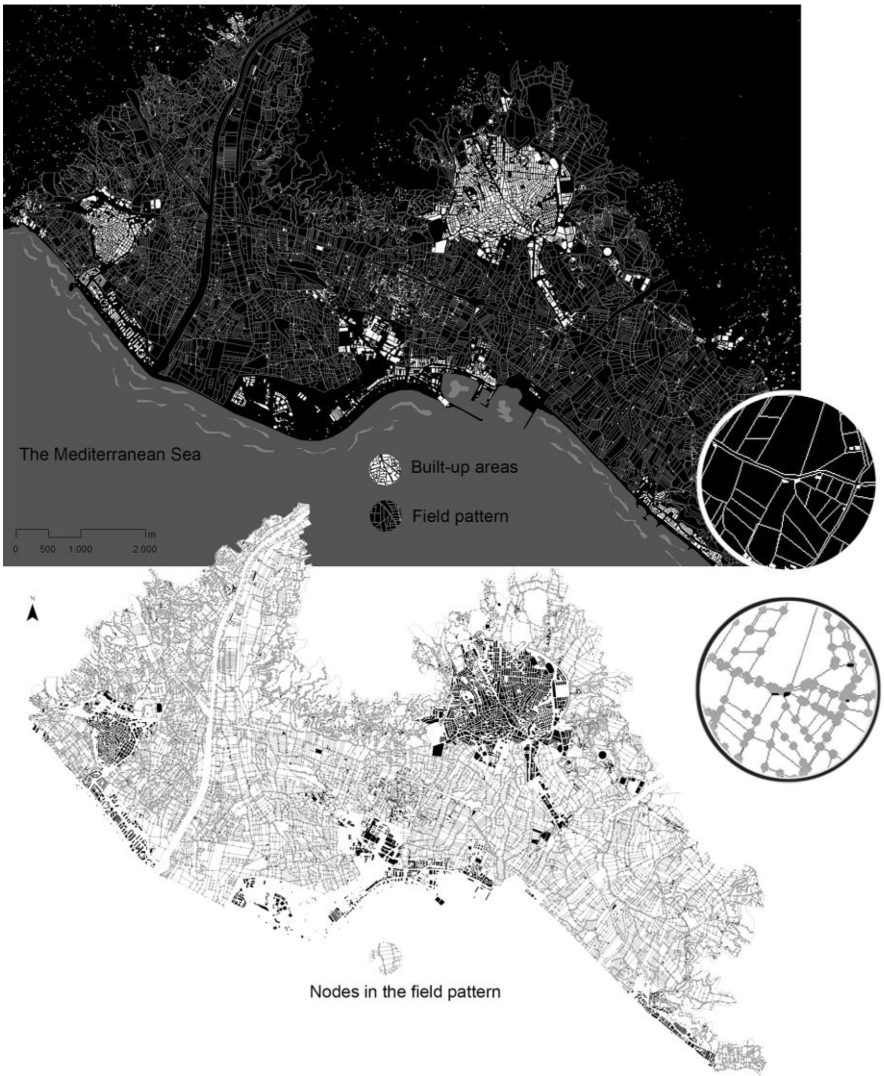
-Characteristics of nodes in the urban edge: possible links between eco-structure nodes and urban nodes.

-Horizontal and transversal eco-structure behaviour in the Vega del Guadalfeo as a landscape unit.

-A model of how the landscape could be experienced by observers.

5. Results

The first result obtained is the total number of nodes existing in the Vega. Figure 5 shows a map containing 33,246 nodes, which in density terms means 740 nodes·km^{-2} (being more than 1,500 in the eastern area of the Vega).



[Figure 5: Nodes identified from the field pattern.]

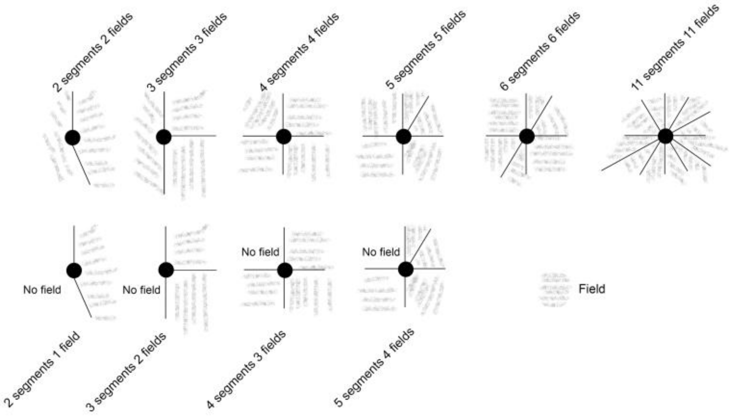
When the presence of landscape features is assessed, we have found out that none of the nodes present all the features together. Indeed, the maximum number of features meeting in the same node is 5 (Table 6) and occurs in just 9 out of 33,246 nodes. Nodes without features represent 47.05% of the total, followed by 35.31% of nodes with just one feature.

[Table 6 around here]

The representativeness of each feature is calculated (Table 7) showing that *acequias*, unsurfaced rural roads and surfaced rural roads may be found in 21.57, 17.82 and 15.14% of nodes respectively. The landscape features appear alone or alongside others features in a range of 118 existing combinations, being especially frequent those combination where *acequias*, surfaced and unsurfaced rural roads are present.

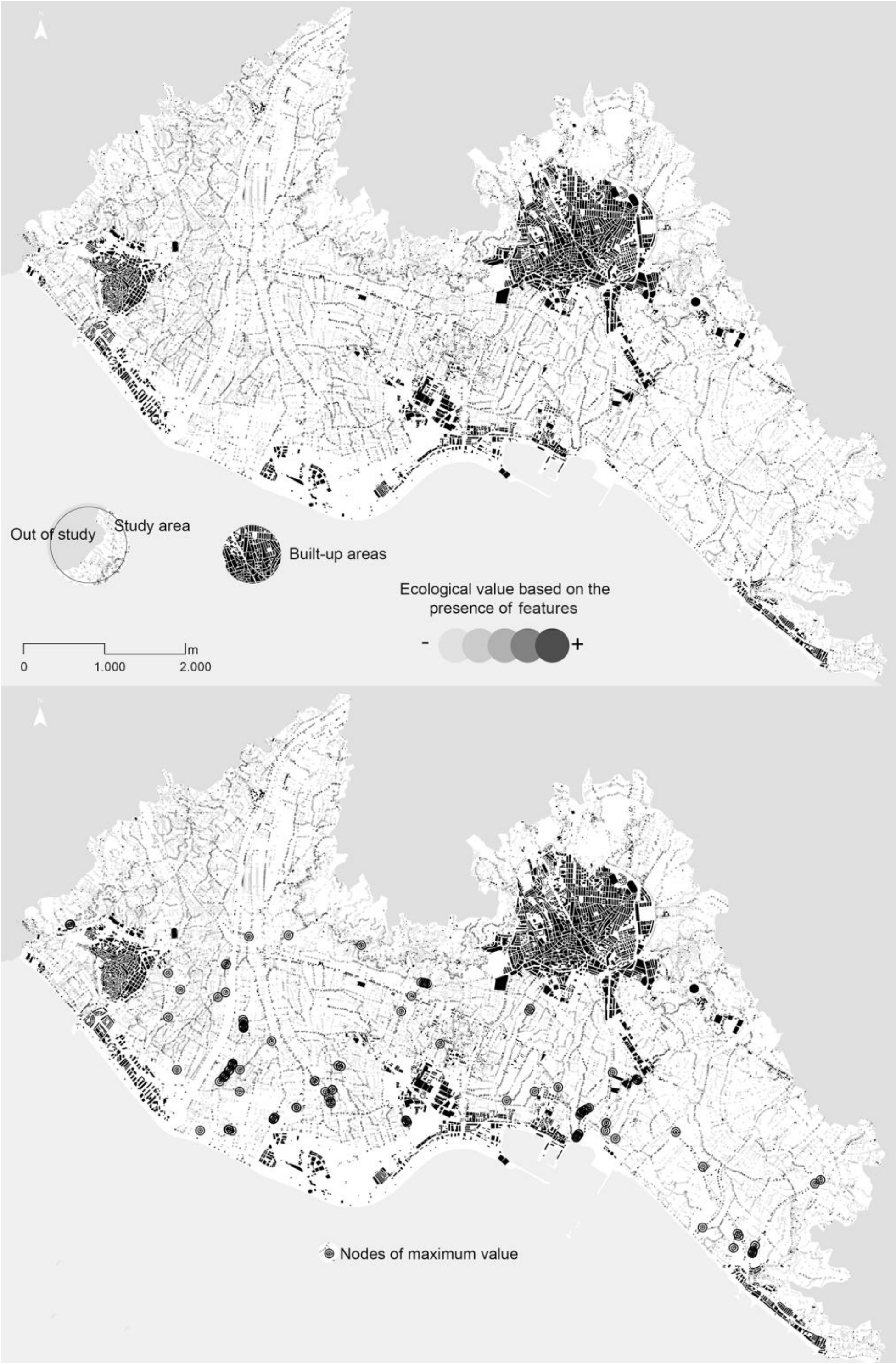
[Table 7 around here]

As far as the configuration of nodes is concerned, ten possible configurations have been identified for the whole study area according to the number of segments and the adjacent fields (Figure 6).



[Figure 6: Configuration of nodes according to the number of segments and adjacent fields.]

Concerning the value of nodes according to the presence of landscape features, we have obtained a partial map 1 (Figure 7), were the top100 nodes of maximum value have been located.



[Figure 7: (Above) Partial map 1: Ecological value based on the presence of features. (Below) Location of the 100 nodes of maximum value.]

The maximum values are found in nodes where hedgerows, *acequias* and ponds meet (see Table 8). In general, the combination of hedgerow, unsurfaced rural road and *acequia* is more likely to be found within the one hundred nodes selected of maximum value (67 nodes out of 100).

[Table 8 around here]

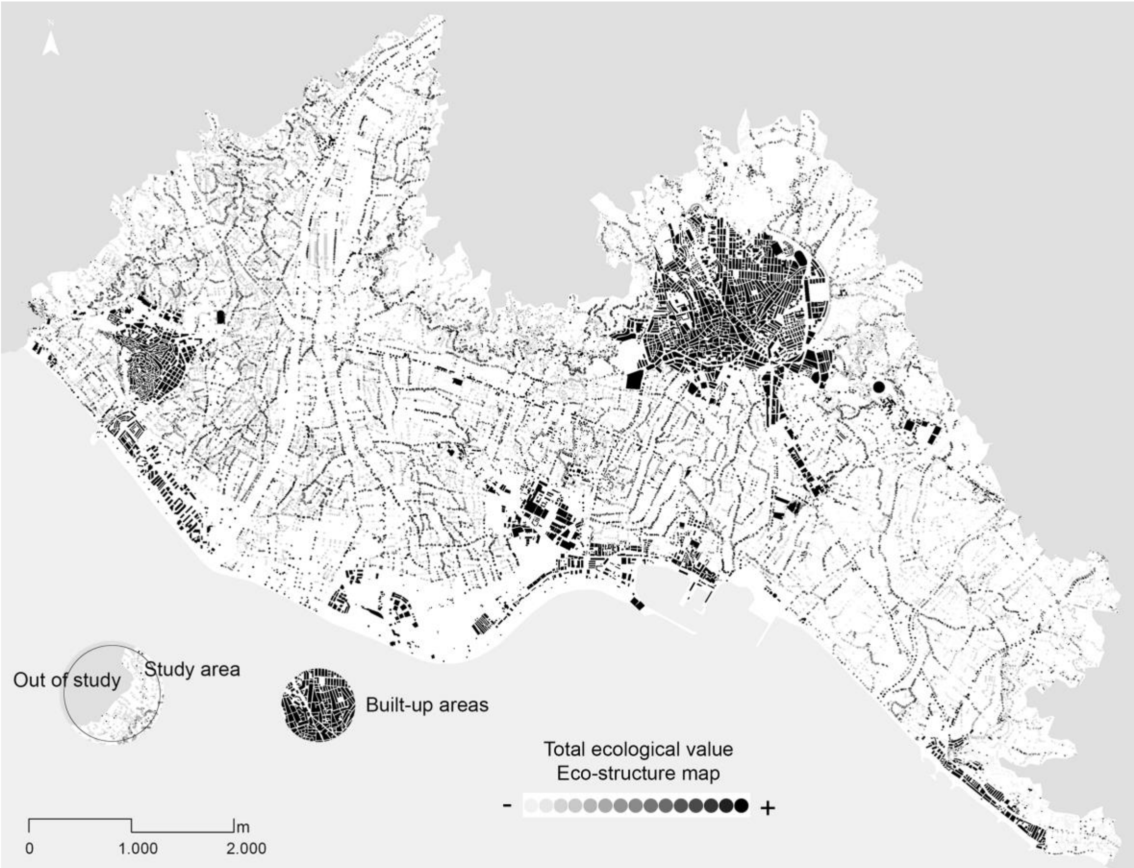
When nodes are assessed according to the adjacent land use (see Section 4.2.2.) we obtain partial map 2 (Figure 8). The configurations 5 segments-5 fields, 6 segments-6 fields and 11 segments-11 fields are worth commenting on, since they are not common in the field pattern. For the first case, nodes with this configuration usually present subtropical, market gardens and sugar-cane fields (typically 3 subtropical/1 market garden/ 1 sugar-cane). The node with 6 segments and 6 fields is composed of 5 subtropical and 1 market-garden fields. Finally, the 11 fields correspond to 10 abandoned fields and 1 built-up garden.

As presented for the partial map 1, the 100 nodes with maximum value have also been located. Their description is also contained in Table 9 with a cross reading of node configuration and value.

[Figure 8: (Above) Partial map 2: Ecological value based on adjacent land uses. (Below) Location of the 100 nodes of maximum value.]

[Table 9: Distribution of top-100 nodes according to configuration]

Finally, the eco-structure map (Figure 9) is presented using unique values from the combination of values in the partial maps. With this combination method, values coming from features and land uses are not added, but combined considering each interval. Thus, a white-black gradation of 25 levels composed of pairs of intervals (coming from 5 intervals set in each partial map) is computed automatically by the symbol property editor of the GIS software. Considering a growing value from interval 1 to interval 5 in both partial maps, the combination e.g. of interval 1 in partial map 1 and interval 5 in partial map 2 is considered to have the same (for representation purposes) final value as the combination of interval 5 in partial map 1 and interval 1 in partial map 2 (and so on). Thus, the final map is represented with 15 value levels. This final map constitutes the eco-structure map, where variable node density, colour intensity and specific patterns may be visualized throughout the map.



[Figure 9: Final node map: Eco-structure.]

6. Discussion

The eco-structure model allows the visualization of the structure of an agricultural landscape, providing interesting readings to understand how landscape features and land uses meet together and form patterns of ecological value.

The early results have shown a highly dense cloud of nodes, which is related to the particular shape and size of fields in the study area. Although no statistical correlations have been calculated, we are able to detect some trends between the configuration of nodes and their values: those nodes having 3 to 4 segments tend to have higher ecological values (see e.g. Table 9) and this value seems to diminish as the configuration of nodes becomes both, more complex (more than 5 segments) and more simple (2 segments). At this point, nodes with 5, 6 and 11 segments are worth mentioning. They are not probably thought of as usual configurations in agricultural fields and these nodes may denote a particularity of this landscape. At this point, the Vega del Guadalfeo was a preferential place to introduce sugar-cane during the Muslim period (García 1972) creating an intricate irrigation network with “hundreds of plots gathered in tight masses" (Mignon, 1982). This particular pattern has been maintained up to the present day in some parts of the Vega, affecting mechanization processes. If we think about this situation from an agricultural managerial perspective, we may find many different interests meeting at a given node. It has also been observed (still not evidenced in a consistent way) during field work that configurations of more than 5 fields usually present metal fencing elements and hedgerow removal. Furthermore, the node with the 11-segment/11-field configuration has 10 out of 11 abandoned fields and 1 built-up garden. In the case of nodes with 2 segments, even if they represent more than 60% of the total, they are not of remarkable value. The interpretation of this may be based on two facts: many of these nodes are located next to urban areas and roads (see configuration in Figure 6); and these nodes respond to less complex configuration (see scheme -a- in Figure 2) with less probability of finding valuable features.

Considering the presence of landscape features and how they appear in different combinations could be a tool to identify both, different patterns at local level in a given landscape and possible differences between the characters of different landscapes. Undeniably, this combination of features around nodes also depends on the original extent and distribution of the existing networks (ditches, hedgerows, rural roads) but thinking of nodes helps us to identify specific spots where and how these features meet each other (locations and combinations).

The ecological value of the agricultural landscape has been shown through the eco-structure partial maps 1 and 2 (Figures 7 and 8 respectively). Since most of the features have linear topology, the distribution of nodes in map 1 also follows linear patterns, not so easy to detect in partial map 2 (Figure 8). The highest values are located in the southern half of the Vega del Guadalfeo, especially in the central open zone among built-up areas. Concerning the adjacent land uses, the highest values are located in the western area (Figure 8). High values are also found on the edge of the study area, concurring with the location of a frame of subtropical trees. As far as the final map is concerned, an area can be clearly identified in the east with low values. It corresponds to a dense area of greenhouses and more intensive land use, where hedgerows have been removed and unsurfaced rural roads have been transformed into surfaced ones. At this level, the connectivity between the central area of the Vega and the eastern territory is expected to be reduced. Around cities and other built-up areas nodes also present low values due to two main circumstances: the presence of more buildings and built-up fields together with major presence of roads and surfaced rural roads; and the presence of more abandoned fields with the subsequent abandonment and disappearance of ditches. Still, some eco-structure nodes with relatively high values are located in the green-house area and in the urban edge, and they could be the starting point to improve connectivity through specific interventions.

Another interesting fact that may be observed in the final map concerns the horizontal and transversal patterns of eco-structure. North-south and north-southeast linear patterns may be detected. It informs us about a particular structural design of the Vega, that may be especially linked to water movement (we recall here that the Vega is also a delta) and also communication and transport activities between the two main cities and from them towards the sea.

The configuration of nodes and the combination of landscape features and land uses around them provide a model that may offer insight into how the landscape could be understood and experienced by observers. Farmers, local visitors, tourists, ecologists, researchers, and planners are to be found in the Vega del Guadalfeo. A perception-based approach to test the eco-structure could provide specific information about the perception of each group.

Other methods could be used to assess the ecological functioning of the landscape, e.g. through ecological connectivity assessment. In many cases these studies, working at regional and sub-regional levels, consider the barrier effect or disturbance of different elements using barrier-effect distances from one to several hundred metres. The work developed by Matarán and Aguilera (2006) on disturbance analysis shows the map of the Vega del Guadalfeo as a place of high disturbance compared to other areas. Nevertheless, the Vega del Guadalfeo might offer other different maps which gain insight into this landscape and its elements at a local level. At this point, the spatially-represented results obtained in this paper differ materially from those obtained through the application of the patch-corridor-matrix. See, e.g. the case of the Barcelona Metropolitan Region (Forman 2004). The differences are not just in the spatial scale (both extent and grain are different between the two study cases) but in the use of nodes as locations of high structural complexity encompassing different levels of ecological value. In addition, nodes concentrate many interactions between different elements and can be related to an interpretation of ecotones at local scales. The concept of the node has also been used in network based models of habitat fragmentation (see Andersson and Bodin, 2009) that represent the habitat patches of a landscape as nodes and links. Again both, the spatial scale and the understanding of nodes as more or less homogeneous habitat patches, are different from the eco-structure model.

The method could be applied to other agricultural landscapes; the consideration of the specific field pattern, its nodes, and the specific elements meeting in the nodes are easy ideas to be applied. Yet, we think that its application in the case of agricultural field patterns characterized by large field sizes might lead to an underestimation of possible interesting landscape elements that may be located inside the fields (e.g. embedding remnant patches of natural vegetation and rocky outcrops) or along field borders. Nevertheless, the final result could provide interesting insight, especially concerning the idea of nodes as points of structural complexity. Further research is needed at this point, and the test of the eco-structure in other agricultural landscape could offer interesting comparison of differences and similarities in the model performance. With this regard, the buffer distance to be selected in the analysis should also be a point for discussion. We recommend taking into account the size and field pattern and, in any case, to select a buffer distance considering an observer scale.

Finally, it may also be noticed that the proposed method does not necessarily have to aim at following an ecological approach. The method constitutes an innovative attempt of rethinking the agricultural landscape structure at local level, following the notion of the node and describing its immediate environment for many possible objectives. Eco-structure is in fact the result of a landscape heterogeneity analysis at node level, focusing, in this case, on the contribution of landscape features and land uses to some aspects of the ecological functioning of the agricultural landscape. Other objectives could be reached by following the general method.

7. Conclusions

Adapting Lynch's definition of nodes and assessing the ecological value of landscape features and land uses, we have proposed the eco-structure model, which has been inspired by and applied in a particular landscape: the Vega del Guadalfeo.

Local planning could benefit from the application of this model, since local planners, landscape architects and other professionals involved in local plans and projects have to deal with the existing local elements, structures and particular functions in a given landscape. The eco-structure could help decision making concerning land use allocation; could support in the itinerary design of open spaces and could be the starting point to undertake interventions to improve green infrastructure at a local level and its urban/peri-urban connection. The eco-structure also provides interesting facts for agroecosystem design, where scarce attention has been paid to the extent and arrangement of individual spatial features in the agricultural landscape (Lovell *et al.* 2010). The eco-structure could contribute to enhancing an ecological-environmental approach towards agricultural spaces, which is one of the ways to achieve their recognition and protection (Zazo 2015). In addition, the application of the model could aid the process of projecting the structure of an agricultural park, which is considered a pending subject in the definition of a planning project for this type of park (Sabaté 2015). The ecological values of peri-urban agriculture could be increased through an adequate planning and management of configurations, features and land uses. At this point, local ordinances concerning e.g. re-parcelling operations could consider the most valuable configurations and avoid great alterations of the traditional irrigation system. Another possible application concerns the scheduled -greenhouse ordinance- in the Vega, which establishes the obligation of setting free from the greenhouse structure at least 10% of the field devoted to this land use. Furthermore, plans for the promotion of crops could take into account those that contribute most to the ecological value in the area. Finally, the eco-structure of an agricultural landscape could serve as reference for possible agri-environment measures, concerning e.g. the maintenance of hedgerows, ditches, and high-value habitats such as ponds.

Although the model could be further developed in some aspects, we assume that the strength of the eco-structure does not lie in its accuracy, but rather in its original approach for reading the peri-urban agricultural landscape, considering its structure at local level and its ecologically valuable elements. A suggested future line of inquiry is the combination of the eco-structure model and spatial network analysis, which has hardly been applied beyond urban environments (Pérez, Abarca, and Talavera 2016). Montasell and Callau (2015) have recently introduced the concept of "alimentary nodes", defined as strategic points regarding production, concentration and distribution of agricultural products. Though different in approach, alimentary nodes and eco-structure nodes may relate in the context of spatial network analysis. The location and design of alimentary nodes in agricultural spaces could benefit from the information provided by eco-structure nodes, which could be analysed e.g. through centrality measures of the rural-road network or, even better, a mixed urban-rural road network.

To sum up, the eco-structure model has made nodes in the agricultural landscape gain much more consideration, becoming as important in the agricultural landscape context as the nodes in the urban landscape context are. We hope this study might inspire future research and debate, especially as far as small peri-urban agricultural landscapes are concerned.

References

Alexander, C., S. Ishikawa, and M. Silverstein. 1977. *A Pattern Language: Towns, Buildings, Construction*. New York: Oxford University Press.

Andersson, E., and O. Budin. 2009. "Practical Tool for Landscape Planning? An Empirical Investigation of Network Based Models of Habitat Fragmentation". *Ecography* 32: 123-132. doi- 10.1111/j.1600-0587.2008.05435.x

Bastian, O. 2001. “Landscape Ecology-Towards a Unified Discipline?” *Landscape Ecology* 16: 757-766.

Baudry, J., R.G.H. Bunce, and F. Burel. 2000. “Hedgerows: An International Perspective on their Origin, Function and Management”. *Journal of Environmental Management* 60: 7-22. doi - 10.1006/jema.2000.0358.

Berger, G., H. Pfeffer, H. Kächele, S. Andreas, and J. Hoffman. 2003. “Nature Protection in Agricultural Landscapes by Setting aside Unproductive Areas and Ecotones within Arable Fields (Infield Nature Protection Spots)”. *Journal for Nature Conservation* 11: 221-233.

Brandes, U., G. Robins, A. McCranie, and S. Wasserman. 2013. “What is Network Science? *Network Science* 1 (1): 1-15. doi- 10.1017/nws.2013.2.

Brunelli, M. 2015. *Introduction to the Analytic Hierarchy Process*. Aalto: Springer.

Bugter, R. 2003. “*Vulnerability of Biodiversity in the Agricultural Landscapes of Western Europe: The EU Project “GREENVEINS””.* Paper presented at the IALE World Congress, Darwin, July 13-17.

CoE. 2000. European Landscape Convention. Council of Europe. European Treaty Series-No.176. Florence.

de Zeeuw, H., and Drechsel, Pay. (Eds.) 2015. Cities and Agriculture: Developing Resilient Urban Food Systems. Oxon, UK: Routledge - Earthscan. 431p.

di Castri, F., A.J. Hansen, and M.M. Holland. 1988. A New Look at Ecotones. Emerging International Projects on Landscape Boundaries. IUBS. Biology International. Special Issue 17.

Dramstad, W.E., J.D. Olson, and R.T.T. Forman. 2005. *Landscape Ecology Principles in Landscape Arquitecture and Land-Use Planning*. Washington: Island Press.

EESC (European Economic and Social Committee). 2004. Agriculture in Peri-urban Areas. NAT/204 EESC-2004-1209. European Economic and Social Committee.

Forman, R.T.T., 1995. Land Mosaics. The Ecology of Landscapes and Regions. Cambridge University Press, Cambridge .

Forman, R.T.T. 2000. “Estimate of the Area Affected Ecologically by the Road System in the United States”. *Conservation Biology* 1: 31-35.

Forman, R.T.T. 2004. *Mosaico Territorial para la Región Metropolitana de Barcelona*. [Territorial Mosaic for the Metropolitan Region of Barcelona] Gustavo Gili: Barcelona.

Forman R.T.T., and Godron M. 1981. Patches and Structural Components for a Landscape Ecology. BioSci. 31: 733–740.

Forman, R.T.T., and Godron, M. 1986. Landscape Ecology. John Wiley & Sons, New York, NY, USA.

Frontana, J. 1984. *El Clima de la Costa del Sol de Granada. Aplicaciones Socioeconómicas* [*The Climate of the Costa del Sol of* Granada. Socio-economic applications]. Granada: Universidad de Granada.

García, E. 1972. *Los cultivos subtropicales de la costa granadina* [*The Subtropical Farming in the Coast of* Granada]. Granada: Gráficas del Sur.

Gedan, K.B., M.L. Kirwan, E. Wolanski, E.B. Barbier, and B.R. Silliman. 2011. “The Present and Future Role of Coastal Wetland Vegetation in Protecting Shorelines: Answering Recent Challenges to the Paradigm”. *Climatic Change* 106:7-29.

Gehl, J. 1987. *Life Between Buildings*. New York: Van Nostrand Reinhold.

Gobster, P.H., J.I. Nassauer, and T.C. Daniel. 2007. “The Shared Landscape: What does Aesthetics have to do with Ecology? *Landscape Ecology* 22: 959-972. Doi-10.1007/s110980-007-9110-x.

Grashof-Bokdam, C.J., and F. Langevelde. 2005. “Green Veining: Landscape Determinants of Biodiversity in European Agricultural Landscapes”. *Landscape Ecology* 20: 417-439. doi – 10.1007/s10980-004-5646-1.

Guerra, C., M.J. Metzger, J. Honrado, and J. Alonso. 2013. “A Spatially Explicit Methodology for a Priori Estimation of Field Survey Effort in Environmental Observation Networks”. *International Journal of Geographical Information Science* 27(10): 2077-2098. doi – 10.1080/13658816.2013.805760.
Hermosilla, J., and E. Iranzo. 2010. “Censo de Hidráulica Tradicional en el Mediterráneo Peninsular” [Inventory of the Traditional Irrigated Land Systems in the South-East of the Iberian Peninsula]. *AREAS, Revista Internacional de Ciencias Sociales* 29: 73-89.
Hou, W., and U. Walz. 2016. “An Integrated Approach for Landscape Contrast Analysis with Particular Consideration of Small Habitats and Ecotones”. *Nature Conservation* 14:25-39. doi-10.3897/natureconservation.14.7010.
Jagomägi, J., M Külvik, U Mander, and V Jacuchno 1988. The Structural-functional Role of Ecotones in the Landscape. *Ekologia(cssr)/Ecology*(CSSR) 7 (1):81-94.
Lausch, A., T. Blaschke, D. Haase, F. Herzog, R. Syrbe, L. Tischendorf, and U. Walz. 2015. “Understanding and Quantifying Landscape Structure-A Review on Relevant Process Characteristics, Data , Models and Landscape Metrics”. *Ecological Modelling* 295: 31-41. doi-10.1016/j.ecolmodel.2014.08.018 0304-3800.
Lovell, S.T., S.R. Desantis, C.A. Nathan, M.B. Olson, V. Ernesto Méndez, H.C. Kominami, D.L. Erickson, K.S. Morris, and W.B. Morris. 2010. “Integrating Agroecology and Landscape Multifunctionality in Vermont: An Evolving Framework to Evaluate the Design of Agroecosystems”. *Agricultural Systems* 103: 327-341. doi - 10.1016/j.agsy.2010.03.003.
LSA. 2012. Landscape Strategy for Andalucía. Junta de Andalucía. Retrieved from - http://www.juntadeandalucia.es/fomentoyvivienda/portal-web/web/texto/840537df-22ba-11df-99ab-555105b916a8.
Lynch, K. 1960. *The Image of the City*. Massachusetts: Joint Center for Urban Studies.
Marull, J., and J.M. Mallarach. 2005. “A GIS Methodology for Assessing Ecological Connectivity: Application to the Barcelona Metropolitan Area”. *Landscape and Urban Planning* 71: 243-262. doi – 10.1016/j.landurbplan.2004.03.007.
Mata, R., and S. Fernández. 2004. “La Huerta de Murcia: Landscape Guidelines for a Peri-uban Territory”. *Landscape Research* 29 (4): 385-397. doi-10.1080/0142639042000289028.
Matarán, A., and F. Aguilera. 2006. “*Determinación de Conflictos Ambientales para la Planificación Territorial Mediante Análisis Espaciales Simples”* [Identifying Environmental Conflicts in Spatial Planning through Simple Spatial Analysis]. Paper presented at XII Congreso Nacional de Tecnologías de la Información Geográfica, Granada, September 11-22.
Meeus, J.H.A. (1995): “Pan-European Landscapes”, *Landscape and Urban Planning*, 31: 57-79.
Mignon, C. 1982. *Campos y Campesinos de la Andalucía Mediterránea* [Farms and Farmers from the Mediterranean Andalucía]. Madrid: Servicio de Publicaciones Agrarias, Ministerio de Agricultura.
Montasell, J., and S. Callau. 2015. “Células Alimentarias. Un Nuevo Instrumento de Planificación y Gestión” in Yacamán, C. and A. Zazo, *El Parque Agrario. Una Figura de Transición hacia Nuevos Modelos de Gobernanza Territorial y Alimentaria*. Madrid: Heliconia S. Coop. Mad. pp. 143-164.
Moya, G. 1998. *Cambios Económicos y Comportamientos Sociales en la Agricultura de la Costa Granadina. Distorsiones y Pervivencias de una Comunidad Campesina (1930-1981)* [Economic Changes and Social Behaviour regarding the Agriculture on the Coast of Granada. Distortions and Continuity of a Rural Community]. Granada: Universidad de Granada. Retrieved from - http://digibug.ugr.es/handle/10481/14577.
Nassauer, J.I., and P. Opdam. 2008. “Design in Science: Extending the Landscape Ecology Paradigm. *Landscape Ecology* 23: 633-644. Doi-10.1007/s10980-008-9226-7.

Opdam, P., C. Grashof, and W.V. Wingerden. 2000. “Groene Dooradering. Een Ruimtelijk Concept voor Functie Combinaties in het Agrarisch Landschap” [Green Veining. A Spatial Concept for Function Combinations in the Agricultural Landscape]. *Landschap* 17: 45-51.

Opitz, I., R. Berges, A. Piorr and T. Krikser (2016). “Contributing to Food Security in Urban Areas: Differences Between Urban Agricultura and Peri-urban Agriculture in the Global North”. *Agriculture and Human Values* 33 (2): 341-358. doi-10.1007/s10460-015-9610-2.

Paül, V., and F. Haslam. 2013. “Peri-urban Farmland Conservation and Development of Alternative Food Networks: Insights from a Case-study Area in Metropolitan Barcelona (Catalonia, Spain)”. *Land Use Policy* 30: 94-105. doi-10.1016/j.landusepol.2012.02.009.

Pérez-Campaña, R., F. Abarca and Talavera-García, R. 2016. “Centralities in the City Border: A Method to Identify Strategic Urban-rural Interventions”. *Ri-Vista* 2 (2016): 38-53. doi-10.13128/RV-19370

Pretel, R.M., C. Duque, and M.L. Calvache. 2010. “Efecto de los Cambios de Usos del Suelo sobre la Recarga del Acuífero Motril. Salobreña” [Land Uses Changes Effect over Motril-Salobreña Aquifer Recharge]. *Geogacet* 49: 111-114. Retrieved from - http://hdl.handle.net/10272/7464.

Ravetz, J., C. Fertner, and T.S. Nielsen. 2013. The Dynamics of Peri-Urbanization. In *Peri-urban futures: Scenarios and Models for Land Use Change in Europe*, edited by K. Nilsson, S. Pauleit, S. Bell, C. Aalbers, and Th.A. Sick Nielsen,13-44. New York: Springer.

Saaty, T.L. 1977. “A Scaling Method for Priorities in Hierarchical Structures”. *Journal of Mathematical Psychology* 15: 234-281. doi - 10.1016/0022-2496(77)90033-5.

Saaty, T.L., and L.G. Vargas. 2012. *Models, Methods, Concepts & Applications on the Analytic Hierarchy Process*. New York: Springer.

Sabaté, J. 2015. “Reflexiones en torno al Proyecto Urbanístico de un Parque Agrario”, in Yacamán, C. and A. Zazo, *El Parque Agrario. Una Figura de Transición hacia Nuevos Modelos de Gobernanza Territorial y Alimentaria*. Madrid: Heliconia S. Coop. Mad.   pp. 93-112.

Salingaros, N.A. 2005. *Principles of Urban Structure*. Amsterdam: Techne Press.

Swinton, S.M., F. Lupi, G.P. Robertson, and S.K. Hamilton. 2007. “Ecosystem Services and Agriculture: Cultivating Agricultural Ecosystems for Diverse Benefits”. *Ecological Economic* 64: 245-252.

Taylor, P.D., L. Fahrig, and K.A. With. “Landscape Connectivity: A Return to the Basics” in Kevin R. Crooks and M.Sanjayan, *Connectivity Conservation*. Cambridge University Press. Pp. 29-43.

Tello, E. 1999. “La Formación Histórica de los Paisajes Agrarios Mediterráneos: Una Aproximación Coevolutiva” [Historic Background of Mediterranean Agricultural Landscapes: A Co-evolutive Approach]. *Historia agraria: Revista de agricultura e historia rural, 19*, 195-214. Retrieved from - http://www.historiaagraria.com/numero.php?n=19

Toth, A., S. Rendall, and F. Reitsma. 2016. “Resilient Food Systems: A Qualitative Tool for Measuring Food Resilience”. *Urban Ecosystems* 19:19-43. doi-10.1007/s11252-015-0489-x.

Trillo, C. 2005. “A Social Analysis of Irrigation in Al-Andalus: Nazari Granada (13th- 15th centuries)”. *Journal of Medieval History* 31: 163-183. doi - 10.1016/j.jmedhist.2005.03.001.

Tudor, C. 2014. An Approach to Landscape Character Assessment. Natural England. NE579. Retrieved fromhttps://www.gov.uk/government/uploads/system/uploads/attachment_data/file/396192/landscape-character-assessment.pdf

Valenzuela, L.M., A. Matarán, and R. Pérez. 2007. *Estrategia Multifuncional y Modelo de Uso y Gestión del Parque Agrario de la Vega del Guadalfeo.* [*Multifunctional Strategy and Model of Management and Use for the Agricultural Park of the Vega del Guadalfeo*]. Research Project Results. Granada: Universidad de Granada.

Wilson, G.A. 2007. *Multifunctional Agriculture – A Transition Theory Perspective.* London: Cabi.

Zasada, I. 2011. "Multifunctional Peri-urban Agriculture-A Review of Societal Demands and the Provision of Goods and Services by Farming". *Land Use Policy* 28(4): 639-648. doi:10.1016/j.landusepol.2011.01.008.

Zazo, A. 2015. "Reflexiones sobre la Protección de la Base Territorial del Parque Agrario: La Institucionalización de su Espacio Agrario Periurbano", in Yacamán, C. and A. Zazo, *El Parque Agrario. Una Figura de Transición hacia Nuevos Modelos de Gobernanza Territorial y Alimentaria*. Madrid: Heliconia S. Coop. Mad. pp. 73-92.

Table 1
Analogy between elements in urban and agricultural space structure.

URBAN STRUCTURE		AGRICULTURAL SPACE STRUCTURE (ECO-STRUCTURE MODEL)	
Nodes	Nodes are the confluence of paths or thematic concentrations (Lynch 1960). Nodes are human activity points whose interconnections form the urban web (Salingaros 2005). In Alexander *et al.* (1977), activity nodes are defined as zones where the main paths or roads converge.	**Nodes**	Nodes are the points where the lines of the plot structure converge or where these lines show a drastic change in their direction. These nodes may, at the same time, be nodes of the rural road network, the irrigation networks or other elements. (See Figures 1 and 4)
Paths, connections,	Paths are elements where the observer can move along (Lynch 1960) such as streets, transit lines, channels, etc. Connections are elements joining two nodes (Salingaros 2005).	**Segments**	They are the lines of the plot structure which may coincide at the same time with other linear elements, such as rural roads (then they would be -paths- in Lynch's approach) and ditches.
Edges	Linear elements not used or considered as paths by the observer (Lynch 1960).		
Hierarchy	Connections may be ordered in different levels (Salingaros 2005). Alexander *et al.* (1977) consider hierarchy as one of the patterns that composes the language of the city structure.	**Complexity**	In the eco-structure model, complexity refers to the configuration of the node, taking into account the elements and the adjacent land-uses. At this point, complexity is also going to be related to the number of segments meeting in a node. (See Figures 4 and 6)

Table 2
Identification and description of features.

Features		**Description**
Trees, hedgerows, remnant vegetation.		They provide biodiversity refuge, runoff regulation, microclimate and act as corridors at local scale, especially when they follow linear dispositions. They are considered elements of the green veining in agricultural landscapes (Grashof-Bokdam and van Langevelde 2005)
Rural roads	Unsurfaced	Their surface allows water infiltration and the presence of vegetation acting as corridors. They may be considered as small roads with no intense traffic and with low barrier effect (Marull and Mallarach, 2005)
	Surfaced	Cement reduces water infiltration and there is a lower presence of vegetation. Surfaced rural roads tend to present higher traffic levels. The barrier effect may be considered higher than for unsurfaced roads.
Acequias (ditches)		They are traditional irrigation networks. They contribute to the water cycle in the area and to the recharge of the aquifer and channel runoff. They are corridors and are also considered as green veining components (Grashof-Bokdam and van Langevelde 2005)
Ponds		As small wetlands, they constitute especial biodiversity hot points. They have a role regarding water purification and nutrient retention, together with protection from erosion and storm surge (Gedan *et al.* 2011)
Rivers		They are, by definition, natural corridors. River corridors area major component of the landscape (Forman and Godron 1981)
Streams		They are also natural corridors but with a non-permanent presence of water.
Beaches		They develop related functions e.g. to the saline wedge. They are also the habitat of specific bird species.
Roads		They constitute barrier elements increasing fragmentation processes and have a high barrier effect (Marull and Mallarach 2005)
Urban and industrial buildings		They also constitute barrier elements, even when they are scattered in the area (Marull and Mallarach 2005).

Table 3
Pairwise comparison matrix for features.

		a	b	c	D	e	f	g	h	i	j	Weight vector
Pond	a	1										0.26
Hedgerow	b	1/2	1									0.18
Acequia (ditch)	c	1/2	1	1								0.18
Beach	d	1/3	1/2	1/2	1							0.12
Unsurfaced rural road	e	1/4	1/3	1/3	1/2	1						0.09
River	f	1/5	1/4	1/4	1/3	1/2	1					0.06
Stream	g	1/6	1/5	1/5	1/4	1/3	1/2	1				0.04
Cemented rural road	h	1/7	1/6	1/6	1/5	1/4	1/3	1/2	1			0.03
Building	i	1/8	1/7	1/7	1/6	1/5	1/4	1/3	1/2	1		0.02
Road	j	1/9	1/8	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	0.02

Consistency ratio: 0.032 (<0.1)

Table 4
Identification and description of land use.

Land use	**Description**
Sugar cane	30% of irrigation water returns to the aquifer in this type of crop (Pretel, Duque, and Calvache 2010). Its vegetation structure contributes especially to the biodiversity in the Vega (Valenzuela, Matarán, and Pérez 2007)
Built-up plot	The plot is almost or completely built on. It is practically impermeable (there is scarce water infiltration) and enclosed. They may be considered to produce a barrier effect (Marull and Mallarach 2005).
Abandoned	There is no agricultural use. It is used as temporal store of materials, vehicles, tyres and also as spontaneous car parks. Still they present higher biodiversity than e.g. built-up plots (Valenzuela, Matarán, and Pérez 2007)
Market garden	Market gardens allow 25% water return to the aquifer (Pretel *et al.* 2010) and contribute to the biodiversity in the Vega (Valenzuela, Matarán, and Pérez 2007)
Built-up garden	The characteristics of these fields are between a market garden and a built-up plot. They present impermeable areas up to 30% and cultivated land on the rest of the plot.
Greenhouse	They are built-up structures using artificial substrates and normally occupy the entire plot. They may be considered one of the main barriers (see definition of barrier given in section 2.1) in the area. Greenhouses allow less than 5% water return to the aquifer (Pretel *et al.* 2010). Together with built-up plots, this land use does not contribute significantly to the biodiversity (Valenzuela, Matarán, and Pérez 2007)
Scrub	Natural and semi-natural vegetation may be found in these fields, sometimes perforated with small cultivated areas.
Subtropical	Subtropical land use allows up to 20% of water return (Pretel *et al.* 2010). Its tree structure also allows natural and semi-natural vegetation under the canopies. After the sugar cane, this is the most biodiverse land use (Valenzuela *et al.* 2007).

Table 5
Pairwise comparison matrix for land use.

		a	b	c	d	e	f	g	h	Weight vector
Sugar cane	a	1								0.33
Market garden	b	1/2	1							0.20
Subtropical	c	1/3	1	1						0.20
Built-up garden	d	1/4	1/3	1/3	1					0.09
Scrubland	e	1/5	1/4	1/4	1/2	1				0.07
Abandoned	f	1/7	1/5	1/5	1/3	1/2	1			0.04
Greenhouse	g	1/8	1/7	1/7	1/4	1/3	1/2	1		0.02
Built-up plot	h	1/9	1/8	1/8	1/5	1/4	1/3	1/2	1	0.02

Consistency ratio: 0.006 (<0.1)

Table 6
Distribution of nodes according to the number of features.

Number of features	Number of nodes	%
0	15,642	47.05
1	11,738	35.31
2	4,642	13.96
3	1,093	3.29
4	122	0.37
5	9	0.03
	33,246	

Table 7
Representativeness of each feature.

Feature	Presence in nodes	%
Pond	12	0.04
Hedgerow	1,988	5.98
Acequia (ditch)	7,171	21.57
Beach	86	0.26
Unsurfaced rural road	5,924	17.82
River	393	1.18
Stream	534	1.60
Surfaced rural road	5,035	15.14
Building	1,341	4.03
Road	2,350	7.07

Table 8
Combination of features in the 100 nodes of maximum value.

Number of nodes	Hedgerow	Unsurfaced rural road	Beach	Acequia	River	Stream	Pond	Surfaced rural road	Road	Building
5	✓	-	-	✓	-	-	✓	-	-	-
67	✓	✓	-	✓	-	-	-	-	-	-
7	✓	✓	-	✓	-	-	-	-	✓	-
1	✓	✓	-	✓	-	-	-	-	✓	✓
7	✓	✓	-	✓	-	-	-	✓	-	-
2	✓	✓	-	✓	-	-	-	✓	✓	-
10	✓	✓	-	✓	-	✓	-	-	-	-
1	✓	✓	-	✓	✓	-	-	-	-	-
100										

Table 9
Distribution of top100 nodes according to configuration.

	Distribution of nodes according to configuration		**Configuration, land uses and features for the selected 100 nodes of maximum value.**	
Configuration	**Number of nodes**	**%**	**Number of nodes within the 100 nodes of maximum value**	**Land uses (fields)**
2 segments 1 field	11,577	34.82	1	1 node with 1 sugar-cane field
2 segments 2 fields	8,630	25.95		-
3 segments 2 fields	6,297	18.94	57	57 nodes with 2 sugar-cane fields
3 segments 3 fields	6,003	18.06	18	16 nodes with 3 sugar-cane fields 2 nodes with 2 sugar-cane & 1 subtropical field
4 segments 3 fields	191	0.57	12	10 nodes with 3 sugar-cane fields & 2 with 2 sugar-cane & 1 subtropical field
4 segments 4 fields	527	1.59	10	8 nodes with 4 sugar-cane fields & 2 nodes with 3 sugar-cane and 1 subtropical field
5 segments 4 fields	4	0.01	2	2 nodes with 4 sugar-cane fields
5 segments 5 fields	15	0.05		-
6 segments 6 fields	1	0.00		-
11 segments 11 fields	1	0.00		-
Total	33,246	100	100	

Figure 1: Nodes in urban and agricultural spaces.

Figure 2: Growing complexity from a) to d) in a field pattern.

Figure 3: Location of the study area.

Figure 4: Land uses inside the node.

Figure 5: Nodes identified from the field pattern.

Figure 6: Configuration of nodes according to the number of segments and adjacent fields.

Figure 7: (Above) Partial map 1: Ecological value based on the presence of features. (Below) Location of the 100 nodes of maximum value.

Figure 8: (Above) Partial map 2: Ecological value based on adjacent land uses. (Below) Location of the 100 nodes of maximum value.

Figure 9: Final node map: eco-structure.