A GIS-Supported Approach with AHP & OWA for Site Suitability Evaluation of Sustainable Rural Housings towards Ecotourism

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***Abstract*—**The main objective of this proposed article is to verify, evaluate and prioritize the sustainable rural housing sites for potential ecotourism under increasing pressure of recreational and tourist awareness. The research is based on the understanding of all possible aspects and implications using Geographic Information Systems (GIS) and Analytical Hierarchy Process (AHP) in a case study area, La Vera, Spain. The evaluating process for sustainable rural housings site on ecotourism is also based on Multi-Criteria Decision Analysis (MCDA). It conducted with eighteen criteria, which are involved in the computation process distinguished in four main groups: constraints, tourism resource, environmental and social-economic criteria. Those factors were selected and weighted according to a field survey of local residents and a professional expert's discussion. Then, they evaluate the suitability of the case study area on ecotourism in order to suitably site rural buildings with the aid of Ordered Weighted Averaging (OWA) operator weighing functions together with constant value of 'orness' and 'maximum entropy'. The methodology proposed herein was valuable to identify sustainable rural housings sites on ecotourism by linking the criteria deemed important with the actual resources of the case study area. The assessment results present a new empirical approach and valuable management tool for evaluating the existing infrastructure and environment and for predicting their future improvements, which can be reapplied to other destinations with similar geographical characteristics. Particularly, this method analysis proposes an approach to enhance the participatory attitudes of local residents in the sustainable assessment management.

***Keywords*—**Suitable site assessment, Sustainable rural housings, Spatial planning, Regional geographical characteristic, Ecotourism, Fuzzy logic and set, Hybrid GIS-AHP/OWA, Decision-makings.

I. Introduction

THE approaches with Geographic Information System (GIS) have been applied to evaluate rural housings planning and development potentials with a wide range of techniques [1-3]. Also, the GIS as an analytical tool allows to examine a huge volume of spatial data, which is the geographical expression in ecological, cultural, social and economic extent of a society [4-6]. The mixture of the GIS and Multi-Criteria Decision Analysis (MCDA) is the most frequently applied model to rural housing planning and development on ecotourism [7,8]. Analytical Hierarchy Process (AHP) embraced with the GIS models produces a flexible manner of combining many criteria in the siting suitability process [9,10]. OWA technique as a class of multi-criteria operators is used for positioning criteria and addressing the uncertainty from their interactions [11]. The advantages of operational model mentioned therefore are comparability and flexibility, and network criteria combination in the GIS, including a new value to the evaluation of problems related to housings planning and development of Spanish rural region on ecotourism [12]. Precisely, this method enables to use distinctive benefits and also to build a more complete view within certain decision-making process [13,14]. Then, the participatory method is the management of group decisions that will obtain credence amongst decision-makers, because the proposed model reflects the criteria evaluation by a large number of decision-makers [15]. Hence, the proposed model is further used for gaining the final suitable maps for housings planning and development in a specified area towards ecotourism.

Housing with the sustainable and resilient planning into the environments is a challenging job, as most of the times many controversial factors have to be reflected [3,16]. The highlighting on the local municipal as to conserve local resources and increase local benefits focuses on the close association between ecotourism and decision-makers who are one of the essential stakeholders' groups from current local planning and development modeling [17,18]. In this condition, decision-makers can devise more appropriate and efficient managing strategies and can handle possible conflicts between local resources conservation and economic developments [3,19]. In the case of residents' attitudes, they have closely examined to understand the support level for tourism, its relationship with perceived impact from tourism being among the most studied [20]. Taking into account residents' attitudes on ecotourism is a prerequisite to incorporate their participation [21]. Understanding the residents' attitude on ecotourism management principles can support decision-makers who formulate more proper and efficient management strategies and take care of potential conflicts between economic developments and local resources conservation [19]. Correspondingly, considering with these evidences, stakeholders can find some ideas of future condition and the current situation of affairs, preferably the possible consequences of the policies and plans

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under deliberation and participation who contributes a significant quality in ecotourism management [3,22].

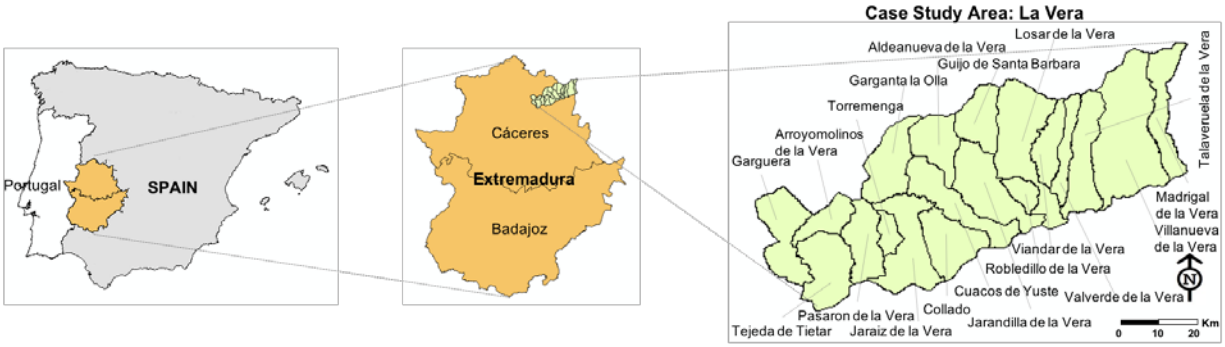

Fig. 1. The case study area, which the light green area illustrates the study area extent with nineteen municipalities

Ecotourism in the context proposed is a significant issue, which has been acknowledged as a sustainable and resilience tourism form that contributes both to the economy in the tourism industry and environmental conservation, and therefore is dedicated like a sustainable means to improve regions with rich tourism resources [23,24]. In tourism sector, sustainable planning and development has been comprehensively deliberated since such development can satisfy the demands of tourists, can protect physical locations, supplies opportunities to improve economic growth, and can improve the residents' life quality throughout the coexistence of environmental quality and tourism development [16,25]. With increasing ecological interests and cultural heritages, the local environment quality improvements grow the visual attraction and also enhance the aesthetic and recreational values of its environments [23].

This research presents a planning approach for verifying rural housings' suitable sites in a case study area under ecotourism of Spanish region based on the operational model. A case study area concerning the model is La Vera, Caceres, Spain, which is experiencing significant construction sprawls with ecological consequences in the ecological and economic context. Here, the six constraints and twelve criteria gathered into four groups were determined after analyzing a multitude of inter-related variables with an aid of local residents' field survey and decision-makers' discussion, reducing possible authors' subjectivity. The utilization of sophisticated spatial statistics methods is an innovation in the sustainable rural housings siting process on ecotourism, giving some efforts in the analysis of the results, showing the tools provided by the GIS and spatial statistics are very important. Particularly, the proposed methodology presented uses the AHP and the OWA operators with continuous value of 'orness' and 'maximum entropy' OWA of multi-criteria modeling evaluating the complete study area of a common categorizing scale in a GIS environment. The final map for sustainable rural housings planning and development on ecotourism in the area was presented, inappropriate to appropriate areas (on grading scale of 0 to 255), by the use of the OWA and the sensitivity analysis with various scenarios ('orness' and 'maximum entropy'). This work furnished to clarify a new decision-support method for sustainable and resilient housings planning, which filling a niche of multi-criteria techniques, spatial analyses and ecotourism management in the area proposed. Accordingly, the mechanism behind participation intention can be identified through the results and is instructive towards enhancing the participatory attitudes of local residents in ecotourism management.

II. A Case Study Area

The case study area (see Fig. 1), the county of La Vera with the area of 888 km2, is situated at the province of Caceres, Extremadura region of Spain. The La Vera county consists of 19 municipalities as follow: Aldeanueva de la Vera, Arroyomolinos de la Vera, Collado de la Vera, Cuacos de Yuste, Garganta la Olla, Garguera de la Vera, Guijo de Santa Barbara, Jaraiz de la Vera, Jarandilla de la Vera, Losar de la Vera, Madrigal de la Vera, Pasaron de la Vera, Robledillo de la Vera, Talaveruela de la Vera, Tejeda de Tietar, Torremenga, Valverde de la Vera, Viandar de la Vera, and Villanueva de la Vera.

In the case study area proposed, for the past two decades, these municipalities have experienced vast holiday residences' growth and subsequent service facilities attracting tourists' interests. Precisely, its closeness to Madrid has turned into the region for the place increasingly destined for weekend housing. The rural housings thus are an integral part of the historical and contemporary rural recreational countryside [26]. This growth has encouraged main changes in land use patterns, which are leading and causing their consequent impacts widespread.

III. Research Methods

In order to identify sustainable suitable location and/or locations for rural housings concerned with ecotourism in the case study area, a substantial multi-disciplinary evaluation procedure with the multiple set of criteria is applied through the use of the spatial analysis tools provided by the GIS with the MCDA method, enhanced by fuzzy factor standardization, based on certain evaluation criteria such as tourism resource, environmental and socio-economic criteria. To attain a

consensus criteria weight, a field survey with local residents and a group discussion to a panel of experts are performed for an analytical procedure, making this process more objective aforementioned. Particularly, in this work, the OWA technique is went for the assessment of the final suitability list to decide the multiple criteria problems [11]. Subsequently, the mixture of the criteria weights and attribute values in the OWA can generate suitability scores of the case study area and can represent the suitable areas, which resolve the multiple criteria problems [27]. The research procedures are presented in the following sections.

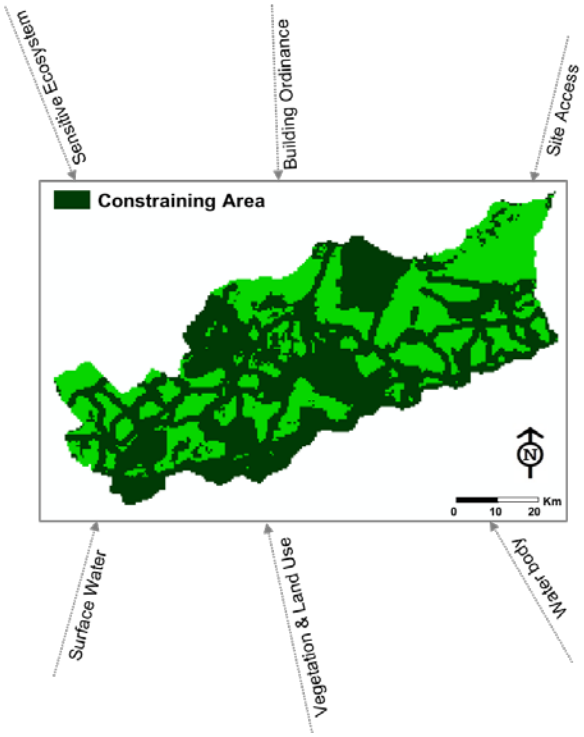

Fig. 2. Areas resulted after computing six constraints assessment

A. Evaluation criteria identification with various participation

A sustainable rural housing siting process under ecotourism measuring regional geographical characteristics requires consideration of extensive criteria and evaluation steps to identify the best available location and/or locations and to eliminate subsequent impacts and adverse long term effects such as debasement of recreational value and deterioration of land use. The evaluation criteria are classified into four main categories: first, constraints; second, tourism resource; third, environmental; and fourth and final, social-economic criteria, in accordance with the pertinent literatures, local residents' survey, experts' panel discussion and consultation, regional and local polices, and European Union (EU) legislations and directives. Especially, to measure residents' attitude to find out the proper criteria of rural housings planning on ecotourism, participants were interviewed to show their attitude and opinion, and to evaluate their intention to contribute in various levels of decision-making process. Together with residents' participation, decision-makers' participation in ecotourism management can occur on different stages offering input for ecotourism planning and management and partaking in decision-makings on the organization committee.

B. Description of constraining criteria

The first group includes six constraining criteria that limit the analysis to the particular geographic areas (refer to Fig. 2). Sensitive ecosystems are the areas environmentally protected by the European commission legislation and regulation for biodiversity & nature policies, NATURA 2000. Local building ordinances are the areas prohibited for constructing buildings, which can degrade natural environments or areas by the local building ordinance legislation. Important aquifers are the areas in ground water wells and/or springs with high groundwater pollution risk. Surface water bodies are the areas with minimum distance from main and secondary stream to avoid water surface pollution monitored by EU Water Framework Directive (Directive 2000/60/EC) legislations and obligations. Specific vegetation and land use types are the areas with dense vegetation formation using Normalized Difference Vegetation Index (NDVI) following the Landsat satellite images of Digital Elevation Model (DEM). Highways and railways are the areas measured by legal restrictions of minimum interval from highways and railways.

C. Description of tourism resource criteria

The second group includes criteria related to tourism resource parameters (refer to Fig. 3a). Vegetation covers and types are the parts comprising an evaluation based on the ecological distinctiveness of the spatial coverage and deforested vegetation of these natural formations based on the NDVI (assigned weight is 0.57). Proximities of surface water are the areas calculated using Euclidean distance functions, which are the radial distance from surface water resources, lakes and/or rivers with continuous water flows (assigned weight is 0.25). Proximities of water bodies are the areas calculated using Euclidean distance functions, a straight distance from water bodies, springs and/or wells (assigned weight is 0.12). Visibilities from roads and railroads are the areas aiming to the aesthetic protection using the radial and visible intervals from location accessing parts such as roads (highways and local roads) and railroads (assigned weight is 0.06).

D. Description of environmental criteria

The third group considers with criteria related with environmental parameters (refer to Fig. 3b). Proximities of sensitive ecosystem are the areas calculated using Euclidean distance functions, which are the radial distance of sensitive ecosystem based on the European commission regulation of nature & biodiversity policy, NATURA 2000 (assigned weight is 0.56). Land use and cover type are the areas aiming economic development covering different land use and cover types (LESOTEX) (assigned weight is 0.25). Slopes of the land surfaces are the areas presenting the derivation of

environmental attributes and landscape processes of land surface flow, expressed in degrees (assigned weight is 0.07). Elevations are the areas describing the basic parameter of terrestrial surface and atmospheric procedure for environmental attributes' derivation (assigned weight is 0.12).

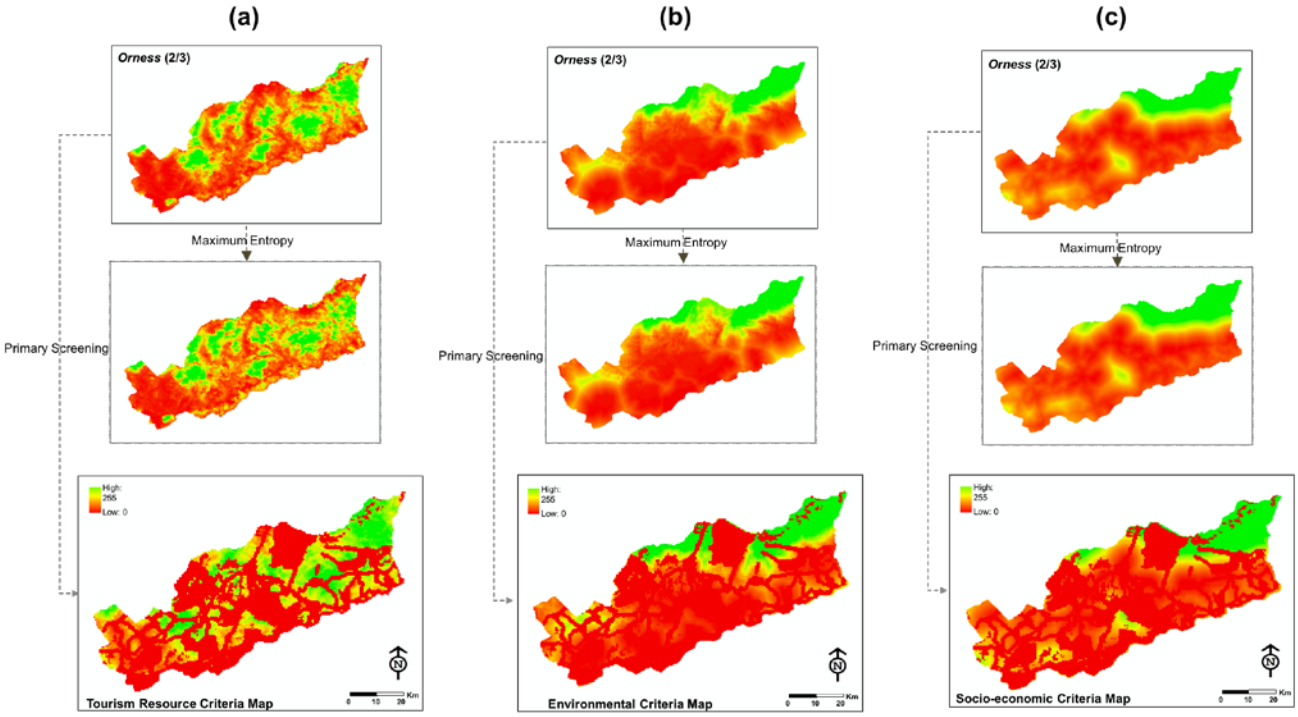

Fig. 3. Intermediate maps ('orness' and 'maximum entropy') extracted from three examined groups and from applied the exclusionary criteria

Table I
Relative importance of pair-wise comparison and their numerical rate [27]

More important intensity	Definition	Less important intensity
1	Equal importance or preference	1
2	More or less equal to moderate importance or preference	1/2
3	More or less moderate importance or preference	1/3
4	More or less moderate to strong importance or preference	1/4
5	More or less strong importance or preference	1/5
6	More or less strong to very strong importance or preference	1/6
7	More or less very strong importance or preference	1/7
8	More or less very to extremely strong importance or preference	1/8
9	More or less extreme importance or preference	1/9

E. Description of social-economic criteria

The fourth group includes criteria relevant to social-economic parameters (refer to Fig. 3c). Proximities to residential areas are the areas calculated using Euclidean distance functions, the radial distance from cities, towns and villages representing a high concentration of human activities (assigned weight is 0.13). Proximities to urban areas are the areas calculated using Euclidean distance functions, the direct distance from urban areas based on land use and cover type (assigned weight is 0.26). Site accesses are the areas calculated using Euclidean distance functions, the direct distance from the sources of site access infrastructure such as local roads, highways, and train railways (assigned weight is 0.56). Population densities are the areas showing the influence zone around town, city, and human settlement related with economic

distance with regard to National Statistical Institute (NSI) of Spain (assigned weight is 0.05).

F. Procedure of suitability on rural housing planning and development

In this section, the methodologies were used to associate the evaluation criteria controlling the site suitability for rural housings concerned with spatial planning and sustainable development towards ecotourism. Starting with the AHP and the MCDA, we got the relative importance weight with the PCM and the grading values as judging and examining the current conditions under each criterion. Then, the OWA weighting method mentioned earlier was utilized for the suitability index calculations [11,27]. First screening using constraining criteria of group can represent as dividing the study area in two land categories: appropriate (suitability index 1) and inappropriate (suitability index 0). The mathematical forming for area suitable selection, using constraining criteria only, is in the Equation (1):

$$SI = \prod_{k=1}^{l} y_k \quad (1)$$

where: SI was general suitability index value, which was 0 or 1; y_k was criterion score of constraint k ; l was number of constraining criteria.

Table II
The OWA weights applied to regulate the suggested criteria [29]

	Order weights			
Orness (2/3)	0.4000	0.3000	0.2000	0.1000
Maximum entropy (2/3)	0.4210	0.2770	0.1820	0.1200
Orness (3/4)	0.5208	0.2708	0.1458	0.0625
Maximum entropy (3/4)	0.5260	0.2680	0.1370	0.0690
Rank	1st	2nd	3rd	4th

As shown as Fig. 2, six constraining criteria are assessed in the study presented. The value 0 highlighted in the dark green color stands for the areas, which are excluded from consideration, while the assigned value 1 highlighted in the light green color has a possibility for further assessment.

The AHP as the MCDA technique was utilized to excerpt the relative importance weights of criteria and was applied for formulating the assessment system in a specified decision-making problem [10]. This method based on the PCM is to identify the hierarchical structure, to regulate the relative importance weights of the criteria and sub-criteria, and to allocate preferred weights of each alternative and control the final score. The PCM organized by the local residents and experts group is liable on the observed importance of criteria based on certain prearranged points of scale as shown in Table 1.

Then, the OWA operator method is a technique to rank criteria and address the uncertainty from their interaction and to aggregate multiple commitments that lie on between max and min operators. This operator method as the expression 'ordered' means objects a non-linear aggregation of objects reflected, which is different from the existent multi-criteria aggregation methods [28]. The key reason to use this method proposed in various areas is its huge flexibility for modeling aggregators' variety, as its nature is described by a weighting vector, and not by a single parameter [29,30]. By correctly choosing the weighting vector, it is probable to model different types of relationships among the criteria combined. In this spatial implementation, the OWA is outlined with an i-th site, raster cell, and an ordered weighted set, w = w1, w2, … , wn such that:

$$w_j[0,1] \text{ where } 1, 2, \ldots, n \text{ and } \sum_{j=1}^{n} w_j = 1 \quad (2)$$

Particular, weights were allocated in each criterion group according to how significant each criterion is reflected to be. Given the attribute values set ai1, ai2, … , ain at the i-th position, a set of n criterion maps characterized by raster. The mathematical equation was used for the consignment of the general suitability index, which applying both constraining and non-constraining criteria, is:

$$SI_i = \sum_{j=1}^{n} w_j x_{ij} \cdot \prod_{k=1}^{l} y_k \quad (3)$$

This aggregation technique above multiplies first scores of factors by their weight and then sums the products to produce the final suitability score as described by Equation (3). In this research, we describe analytic formulas of weighting functions of the OWA operator, which each of them has such belongings as ranking-based weights and constant value of 'orness', regardless of objectives' number, which is aggregated (refer to Table 2). Explicitly, we suggest the analytic formulas of the OWA weighting functions, which can be situated at 0.667 (2/3) and 0.75 (3/4) on the 'orness' measure.

IV. Results and Discussion

Several methods have been presented for rural housing planning and development using the GIS and the MCDA in the recent studies [3,7,25]. In the study presented, however, besides proposing all the benefits of the techniques above-mentioned, a vital contribution has been achieved through the application of the sensitivity analysis, which offers weight coefficients

calculation of the criteria according to their impact and sensitivity. In the present study, furthermore suggesting all the rewards of the techniques, a vital influence has been realized through the application of the ordered weights, which proposals ranking-based weights and constant value of 'orness', which is irrespective of number of objects combined. Besides, the peculiarity of the parameters was related with the process of siting to four groups, i.e., constraints, which are not included in the weighting process, tourism resource parameters, environmental criteria and social-economic measures.

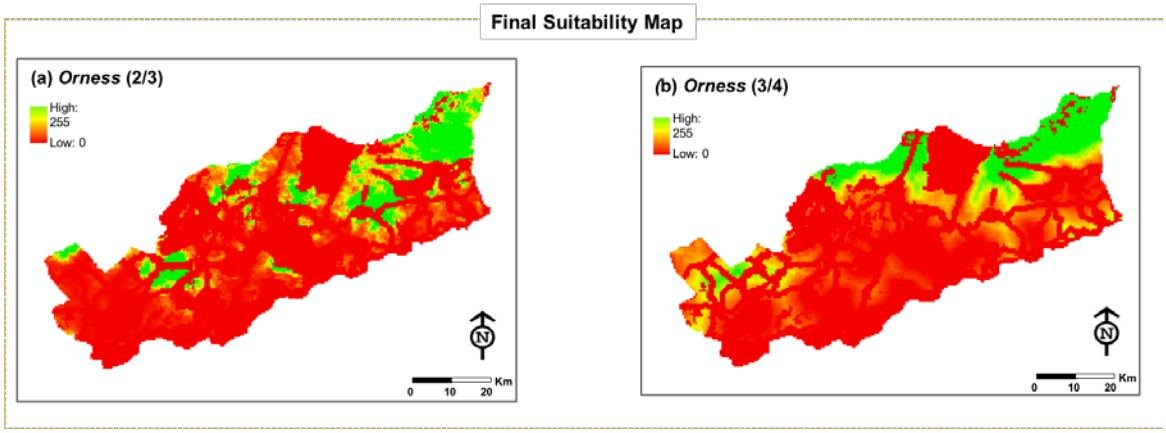

Fig. 4. Possible composite suitability map based on 2/3 and 3/4 sensitivity analysis derived by three criteria groups

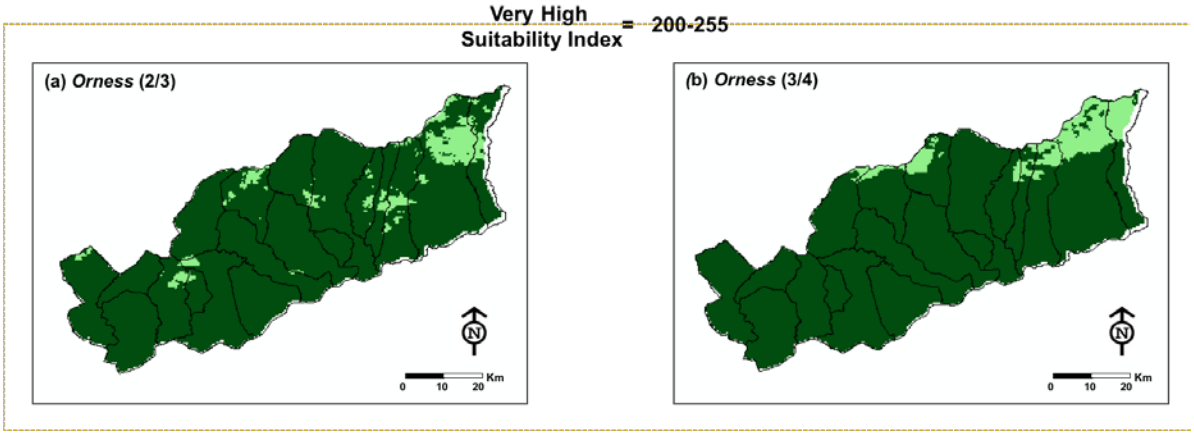

Fig. 5. Each highest suitability map presenting each municipality

Concerning the final suitability map for housings planning and development in Spanish rural region on ecotourism, from the suitable to unsuitable areas, they were identified as the suitability index 0–255, that is, the higher the score, the more suitable the area. The OWA method was applied to resolve its criteria problems. The maps in following figures present the process to decide the land priority to gratify the research objective. Therefore, the final suitability maps are created by gathering, using the same practice based on the intermediate results. Particularly, constraints (exclusionary criteria) always remain as Boolean masks and they are not related in any weight assignment manner as shown in Fig. 2.

The intermediate maps of suitability that outcome from these three evaluated groups were used like the weighting functions, 0.667 (2/3) and 0.750 (3/4) on the scale of 'orness' and 'maximum entropy' as described in Fig. 3a to 3c. The four ordered weights were allocated by way of the same manner of the intermediate results: 1st position is 0.500, 2nd position is 0.333, and 3rd position is 0.167 (2/3 'orness' weights); 1st position is 0.0514, 2nd position is 0.305 and 3rd position is 0.181 (2/3 'maximum entropy' weights); 1st position is 0.611, 2nd position is 0.278 and 3rd position is 0.111 (3/4 'orness' weights); 1st position is 0.616, 2nd position is 0.268 and 3rd position is 0.116 (3/4 'maximum entropy' weights). The assigned ordered weights present a low risk level. Aggregation is skewed into the criterion of the highest suitability value. The possible grouping settings were demonstrated as using three major criteria, which were united with six constraint criteria and twelve sub-criteria (refer to Fig. 4). The OWA methods were nominated as the correct approach to solve the multiple criteria problems of the rural housing siting on ecotourism. For instance, alternative (a) uses 2/3 'orness'; alternative (b) uses 3/4 'orness' following tourism resource parameters, environmental criteria and social-economic measures. It

describes the categorized areas in percentage: the best area of alternative (a) is 7.00% with high membership values 200 to 255; alternative (b) allocates the most suitable areas 7.99% with high membership values of 200 to 255. In the municipalities' context, the results illustrate how much percentage area was assigned to each area (refer to Fig. 5). Among 19 municipalities in La Vera (case study area), Villanueva de la Vera in the Fig. 1 has the highest suitability scale for the assessment of both alternatives.

The results of the combination process are noteworthy to point out that various spatial patterns, produced by the weights allocated to the criteria, the tourism resource, environmental and social-economic objectives excepted six constraints and to indicate that the presented methodology is able to reveal the most suitable areas for rural housings into its landscape towards ecotourism, as well as to give an initial ranking of the suitable areas. Thus, it is fairly simple to search different spatial planning scenarios, as far as an ecotourism approach is anticipated, or a more sensitive environmental alternative is intended. Based on the estimated study area of 888 km2, suitable location and/or locations must be at least the study area size using a post combination constraint if only one rural housing is to serve the entire study area.

This is necessary to be designated in a fixed quantity of top-ranked sites, which fits to the fifth suitability category, that is, 200 to 255 index value, corresponding to the required area. Accordingly, integrated multi-criteria spatial decision model according to the methodology projected in this article with developments can be very valuable in the final decision-makings.

V. Conclusions

This paper presents the spatial and sustainable operational method, in order to identify suitable sites for sustainable rural housings in Spanish region under ecotourism, measuring regional geographical characteristics. The main advantages of this approach are to selecting criteria and to weighting them by local residents and decision-makers. This has flexibility and ability to integrate with the GIS framework, the six constraints and twelve criteria (total eighteen criteria) clustered into four groups, namely constraints, tourism resource, environmental and social-economic group. Three intermediate maps of suitability were made that were combined to make the composite final suitability map. The MCDA and the AHP were used first and were then offered a quite unbiased weights assignment procedure. The method projected was used to select the coefficients of criteria weight, or importance of each criterion, and the OWA with the sensitivity analysis ('orness' and 'maximum entropy') were applied to summarize the criteria weight and the suitability spots classification for rural housings planning of the case study area.

The final analysis results present that the proposed model has high suitability and reliability. The application of operational model for sustainable and resilient housings planning potentials evaluation has identified as positive and justified based on the criteria adopted. Also, it positively differentiated the parts of space highly suitable for sustainable and resilient housings planning. Sensitivity analysis by altering the group weight coefficients revealed a high degree stability of the model. However, the siting process, with the proposed methodology outlined in the present study, could be very useful for multiple participants, especially residents' attitude, related siting of human activities related with rural housing planning. Therefore, the proposed planning and development method and the results can be used for policy and decision making procedure of sustainable and resilient housing planning at all government levels and also private sectors. Moreover, this approach can extend to similar geographical conditions and situations for verifying suitable housings planning suitability.

Since new rural housings planning and development depend on public opinion forces and regional planning policies in accordance with scientific and logical analysis, we postulate that this methodology holds important potential to encourage the complexity of decision-making in real world applications. Hence, the presented methodology and analyses here can be customized to other regions and countries requiring more integrated and efficient planning and development for the management of sustainable and resilient works towards ecotourism. The evaluation results also deliver a new empirical approach to assessing existing environment and infrastructure and to forecasting their future improvements. Precisely, this model analysis suggests a method to the sustainable and resilient assessment management considered regional geographical characteristics with the main aim of rising the life quality and satisfaction for residents, visitors and tourists.

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