Using Geographic Information Systems in Visual and Aesthetic Analysis: the case study of a golf course in Algarve

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Abstract: Adequate information about the existing landscape and about the nature of places that it is desirable to create and to experiment, can no longer be the result of superficial approaches based exclusively on designers and planners' ideas. Even if, planning and monitoring programs frequently use remote sensing data, focusing on changes in land cover and land use in relation to values such as biodiversity, land capability and recreation, they often neglect landscape aesthetics and culture. Aesthetics, a concept developed by the western civilization, has been a subject of debate for philosophers and artists, from the time of the ancient Greece, and more recently for architects, urban and environmental managers and even policy makers. In the present study a quantitative landscape assessment method was used in order to estimate visual impact, landscape quality, landscape fragility and visual absorption capability of a planned golf course which will be implemented in a forest landscape in the Algarve. The Study area is an enclosed, meadow, riverside landscape in Loulé, Portugal. Numerical values were used to assign factors such slope, vegetation observation distance, visual magnitude and human activities in order to analyze, evaluate and characterize the landscape. Geographic Information Systems (GIS) were used in order to understand and manage the visual resources and to mitigate the visual impacts that may arrise from the implemetation of the proposed golf course development.

Keywords: Geographic information system, aesthetics, landscape quality, landscape fragility, visual absorption capability, visual impact, landscape assessment.

1 Introduction

Increased demand for diverse and quality recreation opportunities has placed pressure on the natural resources and its management. For this reason in the last decades, visual and aesthetical researches frequently focused upon special modelling tools and techniques to reproduce the three-dimensional environmental qualities [1, 4, 5, 12, 14, 15, 17, 23].

This fact coupled with the current common way of perceiving landscape as something separate from us, with several functions for society and individuals – instead of something that changes automatically according to cultural, economical and social changes – enhances the necessity of developing new holistic approaches [16, 19, 20, 21, 22] and methodologies that effectively apply sustainable principles to landscape monitoring, planning and management.

Golf course development - one of the fastest growing tourist activities – is one of the main responsible for the significant changes that have occurred in the Mediterranean landscape during the last decades. In 2004, 31 golf courses exist in Algarve and another 25 are under construction or planned [18]. Nowadays more than 40 golf courses are active.

This fact increases the need to develop strategies able to predict not only the visual impact [24] and aesthetic change introduced by this activity, but also the capacity of the former cultural landscape [3, 8, 10, 11, 27, 28] to absorb change.

The present study will address these questions by using methodologies and techniques able to estimate quantitatively the visual impact promoted by the land use change and to analyse landscape quality, landscape fragility and visual absorption capability caused by the construction of a golf course.

2 Material and Methods

A geographic information system has been used not only to produce and analyse cartography, but also to improve the capacity to understand and manage natural and visual resources.

In order to increase the quality of the analysis and to visualize the proposed changes new technologies – similar to the ones found in a flight simulator – were developed and used.

The study area was an enclosed forest-rough system between Querença and Tôr (Figure 1).

Figure 1- 3D Model of study area

Numerical values were used to assign factors such as physiography, slope, vegetation, observation distance, visual magnitude and human activities in order to analyze, evaluate and characterize the landscape.

A decision support system was developed to predict and help mitigate the visual impacts of the proposed development.

The study area was then divided in five landscape unities and constituent elements like the scattered change and roads of circulation: agricultural, forest, meadow, river and the urban zone. The most frequently used surrounding roads were selected as "key viewpoints".

To perform the analysis fifty five "viewsheds" were calculated taking into consideration the selected key-points. However, in the present paper there will only be analysed an observation point and a track.

Visual simulation in 3D was elaborated with the help of ArcGIS 9.0 - 3D Analyst - and fly-over digital video was made to visualize the future development projects on the study area (Figure 2). Three dimensional imaging for characterization of environmental sites is beneficial in perceiving the whole picture and in making better and quicker decisions because of the higher capacity in visualization. The development of 3D geographic information system could help to understand the problems and to minimize visual and other negative impacts of golf course development projects in the Mediterranean rural landscape.

Figure 2- The proposed development golf Master-plan superimposed on the aerial photograph of the study area.

3 The role of aesthetics in sustainable landscape development

It is widely acknowledged that future land use planning have to be in consultation with a global design agenda for climatic stability, sustainable food sources, renewable natural resources and protection of the globe's inhabitants [6]. However, the role that aesthetical and visual analysis can play in the development of new landscapes is not well developed.

Aesthetic influences upon land use change include the landscape of the locality, traditional influences in landscape design, and various theoretical approaches [26]. Aesthetic values are inherent in things. Things emanate from them, somewhat as odours do from food or from flowers. And like tangible perfumes they determinate our sensitive or emotional reaction. Aesthetic impacts influence us at all moments.

Consciously, or in most cases subconsciously, they provoke friendly or hostile reactions. They escape from our rationalistic strong-holds, directly back to our emotions and therefore out of our control [26]. This means that aesthetic values are no simple trimmings but indeed have their roots in the depth of the soul. Their impact on man's decisions reach even into the most practical problems, into the shaping of things of daily use and above all, of our human environment and landscape is certainly one of them.

4 Visual Impact Assessment

The evaluation of visual impacts on a certain landscape is accomplished by the support of three elemental quantitative proceedings, which were Landscape Quality, Landscape Fragility and Visual Absorption Capability.

The quantification/classification of the scenic significance of a landscape has always a subjective nature, inherent to the kind of interpretation of the territory that is made by the observer [6, 15]. However, it is relatively consensual that its significance is as much superior as longer is the diversity and contrast of present situations, and greater is the harmony between space utilization and the biophysical support that it's underlying to it. Beyond the scenic significance of a landscape, it is of extremely relevance the quantification of the visual absorption capability. The visual impact of any infrastructure implementation in a given landscape is greater as the visual fragility is bigger and the visual absorption capability is lower.

4.1 Landscape Units

Subsequently and referring to the present study, it was made a holistic territory analysis. This study was made through a synthetic and ecological landscape analysis, contemplating the meaning of Landscape Units, in order to understand and

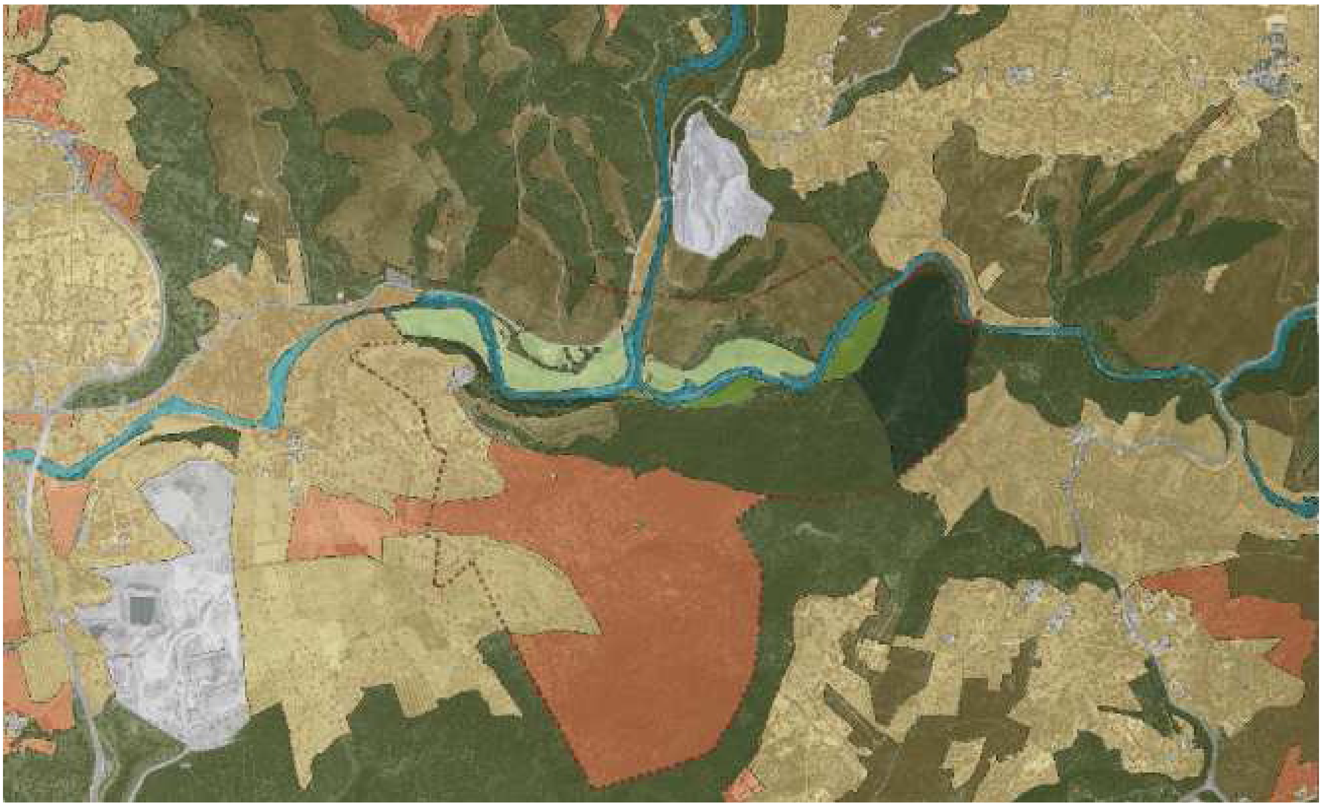

Figure 3- Landscape Units Plan.

interpret the interrelations between the different resources parametrically analysed, consummated previously at the biophysical characterization.

The territory was divided in Landscape Units, (Figure 3) and these were defined according to predetermined standards, which were based on the knowledge and recognition of the morphological, climacteric and geologic characteristics, which represent a vast sequence of situations and outcome from the integrant diversity of the (Agro-Forest System) in which "Quinta da Ombria" is inserted.

The landscape units definition was based in homogeneity criteria having in account the use of the space, vegetation type, slope, water availability, among others, in order that each Sub-Unit distinguishes from the others [13]. The Sub-Units where closely connected to the current Use of Soil.

Five landscape units had been defined (Agriculture, Forest, Meadow, Riparian Gallery, and Urban area). For these Landscape Units, ten Landscape Sub-units had been defined (Abandoned Agriculture, Intensive Agricultural, Quercinea Forest, Covered Trees, Weeds, Xerophilic Meadow, Hydrophilic Meadow, Riverside, Industrial zone and Urban). Roads and dispersed constructions were classified as landscape elements.

4.2 Landscape Visual Quality

It is understood for the term of Visual Quality of a Landscape "*the capacity degree that this possess not to be modified or to be destroyed or in other way the capacity that this has so that its essence and its current structure if conserve*" [2].

The Visual Quality of the analysed landscape was calculated for each Sub-Landscape Unit (Table 1) on the basis of the attributed classifications by the application of the quality model and taking into account the following parameters:

- Unevenness – difference between the maximum and minimum quote of each Landscape Sub-Unit;
- Form Complexity – landscape structural complexity;
- Formation Diversity – number of vegetation forms;
- Visual Quality of formations – closely linked to the formations visual quality;
- Water presence – presence or absence of water bodies;
- Roads and Ways Density – occupation density of the Landscape Sub-Unit for Roads or ways;
- Habitation Density – occupation density of the Landscape built Sub-unit by buildings.

4.3 Landscape Visual Fragility

The Visual Fragility, is defined as "the sensibility degree of landscape to the transformation, in result of a use alteration that is verified in this landscape, thus it is the expression of the deterioration degree that the landscapes experience before the incidence of determined activities" [2].

The Landscape Visual Fragility was calculated for each Landscape Sub-Unit (Table 2) based on the classifications developed by Ayala et al. (2003) and taking into consideration the following parameters:

- Vegetation and Soil Use – explain the capacity that the soil use has to occult determined alteration;

Table 1-Visual quality of landscape units at the study area.

Landscape units		**Area (ha)**	**%**	**Quality**	**Class**
Agriculture	**Extensive**	270	34,44	1,82	mod
	Intensive	50	6,37	2,04	mod
Forest	**Low Dens.**	290	36,98	2,94	high
	Quercine	32	2,81	3,63	v.high
Meadow	**Xerophilic**	32	4,08	1,86	mod
	Hydrofilic	10	1,27	1,95	mod
Riparian		38	4,84	2,42	mod
Mineral extraction		40	5,10	1,40	low
Residential and road network		32	4,08	1,45	low

Table 2-Visual fragility of landscape units at the golf study area.

Landscape Units		**Area(ha)**	**%**	**Fragility**	**Class**
Agriculture	**Extensive**	270	34,44	2,48	mod
	Intensive	50	6,37	2,41	mod
Forest	**Low dens.**	290	36,98	2,78	high
	Quercinea	22	2,81	2,49	mod
Meadow	**Xerophilic**	32	4,08	2,19	mod
	Hydrophilic	10	1,27	1,93	mod
Riparian		38	4,84	2,45	mod
Mineral extraction		40	5,10	3,05	high
Residential and road network		32	4,08	1,05	low

- Slope - translates the inclination percentage between two points in the territory and is linked to the exposition of determined alteration of the current use of the territory to the observer;
- Morphology - closely linked to topographical position occupied in the Landscape Unit;
- Form and Size of "viewshead" – closely linked to the form that the viewshead occupies in the territory;
- Viewshead complexity – closely linked to the forms diversity of the viewshead;
- Distance (from the road network and from the urban areas) – closely linked to the proximity of the determined Landscape Unit to roads, ways or residential areas.

4.4 Visual Absorption Capability

The Visual Absorption Capability (VAC) corresponds to the greater or minor aptitude that a landscape has to integrate definitive alterations or modifications, without diminishing its visual qualities.

To define the visual resources six factors were considered [7]. The first three are directly related with the landscape, while the last translates the physical and secular relation between observer and landscape: Shape (mass or object aspect); Spatial definition (enclosure, orientation creation); Light incidence; Distance (foreground, middleground, background); Observation position (higher, equal or lower); Sequence and visual disposition of the landscape scenarios.

To calculate Visual Absorption Capability, the most frequently used surrounding roads were selected as "key viewpoints". From the fifty five "viewsheds" calculated – in order to exemplify the proposed process – we selected two of the most representative ones to be analysed in this paper: observation point P10 (located at a hill top in the study landscape) and observation track T8 (located in the road that follows to Querença and is already inside the intervention area) (Figure 4).

Figure 4- Key viewpoints and track used for the visual impact study.

Table 3- Visual Absorption Capability measured at the most important points and tracks of study area.

			Point	Track
	Variable	Mark	P10	T8
Observer position (degree)	+5 till + 10	1	1	5
	+2 till + 5	2		
	+/-2	3		
	-2 till -5	4		
	-5 till-10	5		
Observer distance (meters)	0-400	1	3	5
	400-800	2		
	800-1600	3		
	1600-3200	4		
	+3200	5		
Visualization time (seconds)	>30	1	1	1
	10-30	2		
	5-10	3		
	3-5	4		
	0-3	5		
Landscape type	Characteristic	1	4	3
	Focal	2		
	Enclosed	3		
	Panoramic	4		
	Other	5		
Gradient	>45	1	5	4
	30-45	2		
	20-30	3		
	10-20	4		
	0-10	5		
		Total	14	15
		VAC	Mod	Mod

Table 3 demonstrates the results of the Visual Absorption Capability evaluation for the point and track studied according to criteria used from the Forest Service's of the USA [9].

4.5 Visual Impact Identification

From the Viewshed of the observation point P10 located at the golf course of Quinta da Ombria (Figures 5, 6 and 7) it is possible to visualize half of the intervention area. This visualization is done in two distinct directions. To the North side one can observe a great part of the Riparian and Meadow zones where a great part of the golf course will be implemented. To the South side one can observe the site where the tourist village of family housing will be located. The visible zone for South of the intervention area corresponds to the forest zone only. This Observation Point is associated with a skyline inside of the intervention area. This point can still be characterized as possessing a great high complexity viewshead.

From this Observation Point it can be verified that the sensible visible areas correspond essentially to the zone of family housing and to the zone of housing grouped in urban complex. The moderate Visual Absorption Capability, previously determined for this Observation Point may inform that visual impact is lower.

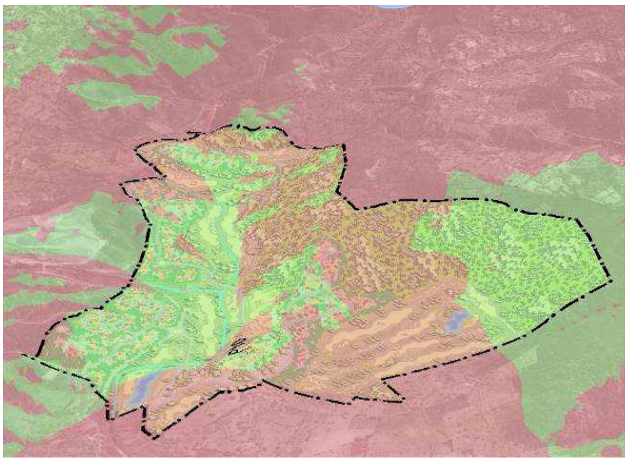

Figure 5- 3D simulation of observation point nr.10.

Figures 6 and 7- panoramic views of the site where point nr. 10 is located.

Figure 8- panoramic view obtained from track nr. 8.

Throughout the observation track T8 (Figures 8 and 9) located in the road that follows to Querença, within the limit of the intervention area, it is possible to visualize approximately half of the intervention area, as such it is considered a great and average complexity viewshead. Although this track is also relatively long it doesn't present a visualization of the intervention area in all its extension, being the visualization relatively conditioned by the existing vegetation which sometimes constitutes a visual barrier.

This Observation track is considered with Average Visual Absorption Capability, which means that any alteration contemplated for the vision would have one considerably attenuated visual impact in the landscape.

Thus, it was considered that the visual impact induced by the presented golf development proposal for Quinta da Ombria is insignificant from this observation point, once the largest part of the visualized area corresponds to the forest zone which will not be changed according to the golf course project.

However, from the studied observation track, proposed urban elements, such as family housing, are visible causing a higher visual impact.

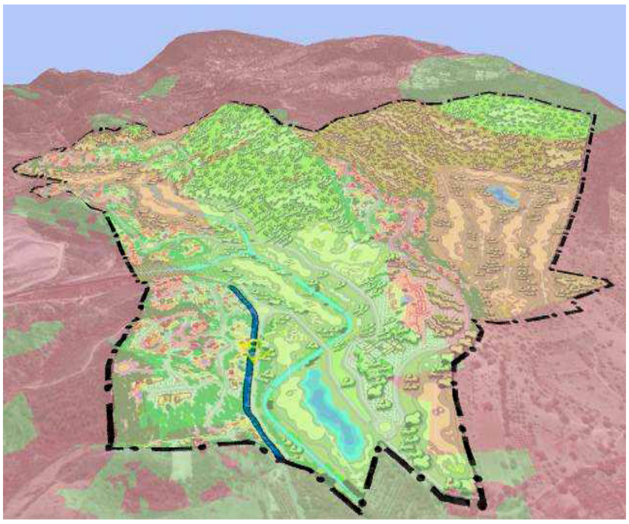

Figure 9- 3D simulation of track nr. 8 (top image) and panoramic view obtained from the same track (bottom image).

4.6 Mitigating visual impacts

In order to mitigate the negative visual impacts of the urbanization zones we suggest the utilization of construction materials which textures and colours match the existing landscape patterns. This will enhance the integration of the proposed development with the surrounding landscape. To recoup buildings and surrounding zone was advised to reuse materials from the old structures and in particular the materials of the demolished structures, preserving the ones with historical meaning. Whenever the visual exposition was high, it was considered the implantation of landscape visual barriers to block intrusions of the project. Those barriers can be simple alignments of trees along the streets but with care to not look artificial.

A decision matrix (table 4) was presented for identification of visual impacts for the golf proposal. Through this matrix it was possible to suggest alterations in the original proposal. The mitigation measures turn possible to take decisions to minimize negative visual intrusion of the proposal presented for the study area. Several important aspects should be taken into consideration. The use and protection of the existing vegetation with high ecological value, and the use of scale, form, color and construction tones were considered.

Table 4- Visual Impact Mitigation Decision Matrix

Decision Parameters	Points and lines of observation	
	P10	T8
Existent Visual Recourses	1	2
Visual Impact category	B	B
Mitigation Possibility	N	S
Recommended Decision	II	III

Existent Visual Recourses
1-High
2-Moderate
3-Low

Mitigation Possibility
Y-Yes
N-No

Impact Category
A-Potential Significance
B-Possible Significance
C-Without Significance

Recommended Decision
I.Change or abandon propose
II.Complete study with monitoring
III.Complete Study.

The provision of green belts in golf course surroundings should include different situations of grass, gardening, trees and flowers having in account different tonalities, sizes and dispersion. For the places with heavy construction or infrastructures, the choice of coloration was essential to make it compatible with the involving landscape.

5 Discussion and Conclusions

Most of the 143 ha of the area affected by the golf course of Quinta da Ombria present a middle visual quality, moderate visual fragility and intermediate visual absorption capability. Forest landscape unit had the most elevated visual potentiality as from the point of view of the visual quality as the visual fragility. The agriculture landscape unit presents the lowest visual potential regarding visual fragility. Meadow presents generally a middle visual potential whereas the sub-unit of the industrial landscape unit presents the lowest visual potential.

The aesthetic study helped to assess adverse impacts of golf course and to suggest mitigation measures and rehabilitation design alternatives. The golf project could be used to reclaim the nearby abandoned mineral extraction sites. Computer simulations such as photomontages and digital flyover videos helped in three dimensional imaging and characterization of the landscape [25].

The presented landscape evaluation method could help planners, and other professionals involved in the design of sustainable landscapes with aesthetic and social value. It also could enrich the decision-making process and help governmental officials to take the appropriate decisions: accept, reject or suggest aesthetical modifications in any proposed golf course project.

The incorporation of aesthetic concepts may help to minimize visual impact of golf courses or other development projects in Mediterranean landscapes, mainly in a period when government has an important role to play in the matters of providing aesthetic welfare and avoiding conflicts between public and golf courses.

To conclude we may say that with the increased ability to disturb and affect large portions of the landscape, private and public concern with the necessity to develop scientific frameworks and methods to assist in landscape analysis and development is increasing. In order to achieve sustainability, development projects should reinforce landscape character taking into consideration the aesthetics and spirit of the place, integrating the pre-existence in the new landscape.

Future evolution of the present study is to integrate the expert/design approach with the perception-based assessment methods.

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