Assessment Tools in Landscape Environment

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Summary

The application of Image Analysis procedures to territory is not something new. Nevertheless, utilizing these techniques to detect the degree of visual intrusion of a photovoltaic plant, or any type of structure, in a landscape is certainly innovative and has yet to be applied in Italy. Under Italian legislation, the assessment of the environmental impact is usually carried out through qualitative investigations that lead to overly subjective judgments. The lack of a single standard has resulted in disputes between various authorities and developers. The methodology presented below helps to define environmental impact in an objective and quantifiable manner with the aim of providing a useful tool for decision-makers.

Keywords: landscape assessment, GIS, perceptual impact assessment

1. Introduction

The analysis and methodology which determine how any type of project is carried out generally use defined parameters, as well as standard indexes and units of measurement, which allow for an objective evaluation. For example, the analyses of the environmental components involved in completing a project take into account the maximum NOx and SOx levels permitted and the level of electromagnetic or acoustic pollution, all of which are defined by specific parameters clearly outlined by law, resulting in a defined range of sustainability. In other types of studies, such as urban, the level of urbanization is determined zone by zone and expressed in cubic meters/square meters so, like an economic feasibility study, the costs are clearly identified by a number and by a unit of measurement.

The clear unequivocal standards mentioned above, however, are largely lacking in assessments carried out to understand the impact that the construction of a new infrastructure, location or building would have on a landscape. It is extremely difficult to objectively evaluate the landscape because of the perceptual aspects which are tied to the subjective judgment of the technician as well as the complexity of the object of the technician's evaluation, the landscape itself. The landscape is a complex idea which is derived from various interrelated factors including: the morphology of the territory, type of human settlement, biodiversity, historical and cultural heritage, type of vegetation as well as other aspects which define and give value to the landscape.

Therefore, the objective of this study is to reduce the level of subjectivity in these assessments and to provide an analytic instrument supported by more appropriate indexes, including the use of numeric data, to guarantee more homogeneous guidelines which, in turn, will result in more homogeneous assessments by all the technicians involved in the evaluating and planning of prospective structures to be built in various landscapes.

2. Current assessment tools

In Italy, the evaluation of a project, and its compatibility with the landscape in which it is to be inserted, is currently based on two main standards. The first criteria involves urban and landscape instruments and requires that the structure conform with urban planning and building regulations in force at the time. The second criteria relates to architectural compatibility and is generally assessed by using viewshed analysis, photo insertion and rendering for simulation. The architects, and other technicians involved, seek to produce models which are as reliable as possible using these tools.

It has become common practice to create viewshed analysis which allow for the reproduction of an object, or structure, in a given area. These viewshed analysis enable us to calculate numeric values related to the geometry of the territory, and they give us an index of the degree of visibility of a certain object from various distances, taking into account visual barriers. Nevertheless, they don't give us any qualitative information regarding the type of landscape being evaluated, including all the factors which contribute to its value, nor do they give us any indication of the quality of the structure to be inserted in the landscape. Furthermore, the biggest drawback of these maps is that they often provide indexes of visibility which are overestimated.

In fact, the computer "sees" an object, or a portion of it, by exclusively following geometrical directions; it recognizes the xyz coordinates of the observation point and the volume of space occupied. For a person, however, the ability to see an object not only depends on the object's dimensions and any visual barriers between the object and the observer but also on the contrast in luminosity - color between the object and its immediate surroundings (relationship shape-background).

For the reasons stated above, it can be affirmed that this type of model is not completely reliable and hence, doesn't allow us to achieve the objective of assessing the visual impact of structures to be inserted in a particular landscape with the highest degree of accuracy possible.

Similarly, the model based on a photo-simulation isn't complete because it doesn't allow us to systematically assess, in numeric terms, the various components that constitute a landscape, such as orographic aspects, soil use, settlements, and cultural heritage. It does have an advantage in that it allows for the collection of qualitative information relating to the chromatic relationship between the object and surrounding area. Nevertheless, it is not a comprehensive model and hence, is not reliable for a complete assessment of all the variables which define a landscape nor can it accurately predict the impact which will result from the insertion of a new structure in this landscape. Furthermore, the results of this model are highly subject to the individual discretion of the technician interpreting the photo-simulation. They depend on the technician's abilities, education, and training and thus, can easily be contested and are not scientifically reliable.

3. Proposal of a method for analysis and evaluation

A multi-disciplinary approach, executed by a competent team of technicians, is fundamental for an optimized and comprehensive study. These technicians, each working in his or her research field, will have to be able to gather the data (indexes), both main and secondary, in the given territory to then share their findings with the other team members to establish relationships and interplay between the various indexes of the landscape being assessed.

For every index analyzed, a model will be produced that is able to reproduce attributes, which can be represented in the report and/or maps. A discussion forum will enable the technicians to decide what weight (importance) to attribute to each index in order to establish a hierarchy of the factors which characterize the territory. At this point, it is possible to create more complex models that can simulate the visibility of a building inserted in a certain location within a territory (Visual Area) and maps which show the sensibility and visual impact of the building.

The map which displays the visual impact is the final result of the first part of the study, in which all of the areas from which the proposed structure can be seen are represented. The areas represented on the map are characterized by various color tones which indicate how the degree of perceptual impact varies from one area to another; the degrees of impact are based on the analysis of the indexes of the various areas. This technique currently represents one standard of analysis used to assess the visual impact of projects being evaluated.

After numerous professional experiences, the majority of which utilized viewshed analysis, we found that the structure, once completed, did not have the same visual impact in the context of the area in which it was built as had been predicted by the simulation. In fact, the synthesis maps always showed a higher impact with respect to the reality, resulting in an overestimation of the visual impact. The problem was rooted in the modeling of the visibility maps.

As mentioned earlier, computers generate visibility maps by utilizing a model which reproduces the surface area of a territory, both natural and anthropic. It is sufficient to represent a structure with a volume and any GIS software with 3D extension will be able to produce a map with all the points from which it will be possible to see the target structure. The only customization that can be introduced into the calculation is a modification of the percentage of the entire volume which can be seen from different observation points.

Based exclusively on geometric rules, the algorithm used by the GIS software does not produce a reliable model of visibility. Theoretically, two points at an infinite distance without any obstacles placed between them (without any interruption in the imaginary line that unites them) are visible for a computer. This example, while perhaps extreme, is very useful in understanding how serious of an error can be made when utilizing visual simulations based on the algorithms standardly in use.

It is an established fact that our eyes have well-defined limitations, both geometric and in terms of luminosity. For a person, the ability to see an object mainly depends on three factors:

* Geometric visibility
* Target dimensions and/or distance of observation point from target
* Contrast in luminosity between the target and its surroundings

The geometric volume of an object and its shape is perceived only if there is a contrast in color either on the surface of the object or compared to the surrounding objects. Therefore, it is fundamental to study the contrast in luminosity between the background and the target object and relate these two factors to the distance at which the object is observed.

4. Case study

We want to demonstrate that a viewshed analysis created by only utilizing the GIS software algorithm can be correct and accurate when combined with the inter-disciplinary approach described above to reproduce a model which much more closely represents the reality of the situation.

A real study was analyzed that was widely-debated in the field of landscape evaluation. It involves a minor intervention but with a large visual impact. The area in which the structure was inserted is a town located in central Italy, which is very important both in terms of nature and landscape as well as cultural/monumental heritage. The zone is protected as a cultural heritage site at both the local and regional levels.

The project calls for the installation of a small photovoltaic plant on the roof of an agricultural building located directly behind the ancient walls which surround the town (fig.1).

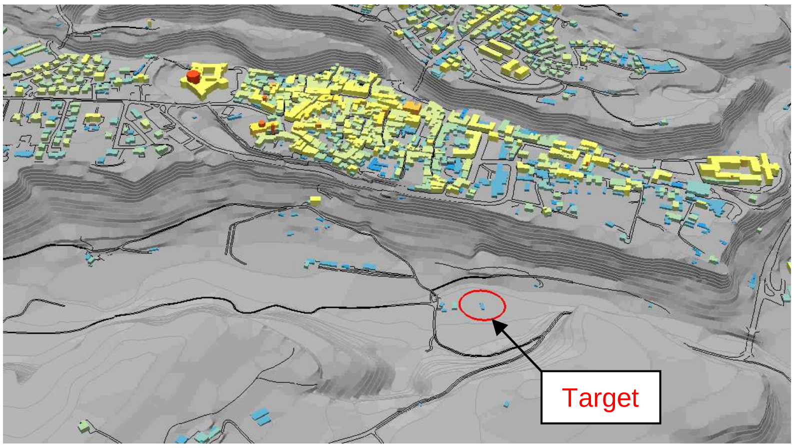

Fig.1 3D model of the territory (a) - agricultural building (b)

On the basis of the 3D model and what is known about the geometry of the building on which the photovoltaic panels would be installed, a standard viewshed analysis was created that shows (using various tones of red) the percentage of the photovoltaic roof which is visible from every observation point (fig.2)

Fig.2 standard inter-visibility map (red visibility 100% - white visibility 10%)

Since the area of the study was very small (57 Ha), it was possible to actually verify the validity of the map produced by doing an on-site audit to visually verify the model of visibility produced from 40 check points. The visual illustration showed that the visibility from the internal areas of the furthest observation points from the target was not confirmed; variations between the current and proposed state of those areas were not able to be detected.

At this point, a very detailed model of the surroundings of the agricultural building was produced to be able to define the characteristics of its luminosity and chromatic contrast, for both the current and proposed state (fig.3)

Fig.3a- 3D current and proposed state (the lines represent the chromatic sections studied)

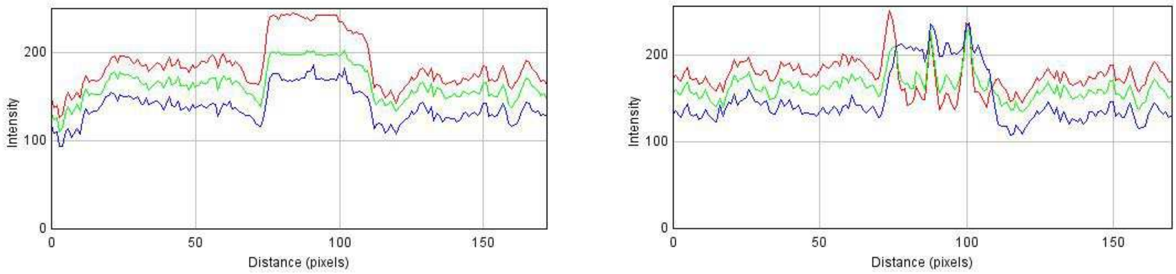

Fig.3b- values of the intensity of the RGB canals along the sections studied

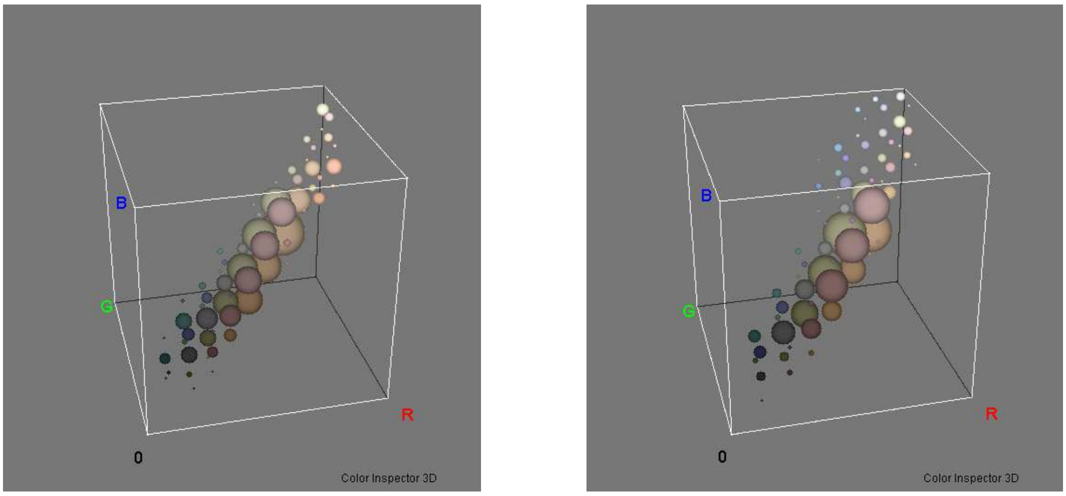

Fig.3c- study of the total variation in the RGB values

Studying the contrast in luminosity and chromaticity between the target and its surroundings allows us to ascertain the visual thresholds of the human eye and hence, to define appropriate limits of distance between observer and target. In fact, the contrast in luminosity is the key parameter that enables us to state whether an object is visible or not.

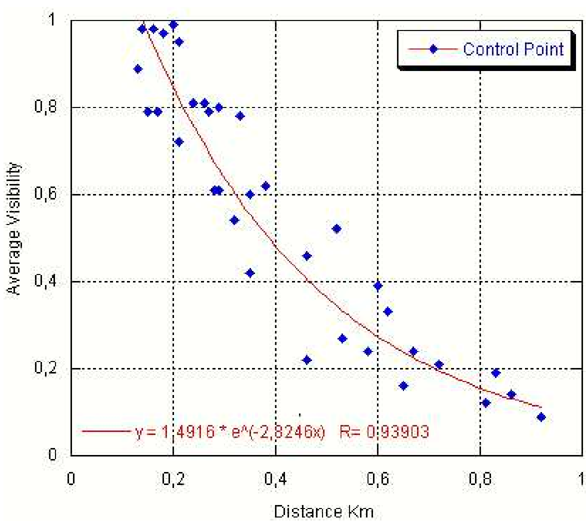

Fig.4- variation of the visibility as a function of distance

As a result of the 40 factors studied, it was possible to create a graph with a defined exponential function that reproduces the variation in visibility as a function of distance for the photovoltaic roof positioned on the building. The error with regard to the fitting was due to the different luminosity conditions in the various areas and/or to the different orientations in the visual line (fig.4)

As can be seen in fig.4, the visibility of the photovoltaic plant becomes practically zero at a distance of approximately 0.9 Km. At this point, we have to revisit the map created and shown in fig.2, inserting an exponential function (like the one shown in fig.4) in the calculation; the result obtained constitutes evidence, even if this is a brief and synthetic text, that the standard algorithms used in the most common GIS software programs overestimate the surface areas from which it is possible to see an object.

In fig. 5, the real limit of visibility of the photovoltaic plant is indicated with a blue circle.

5. Conclusions

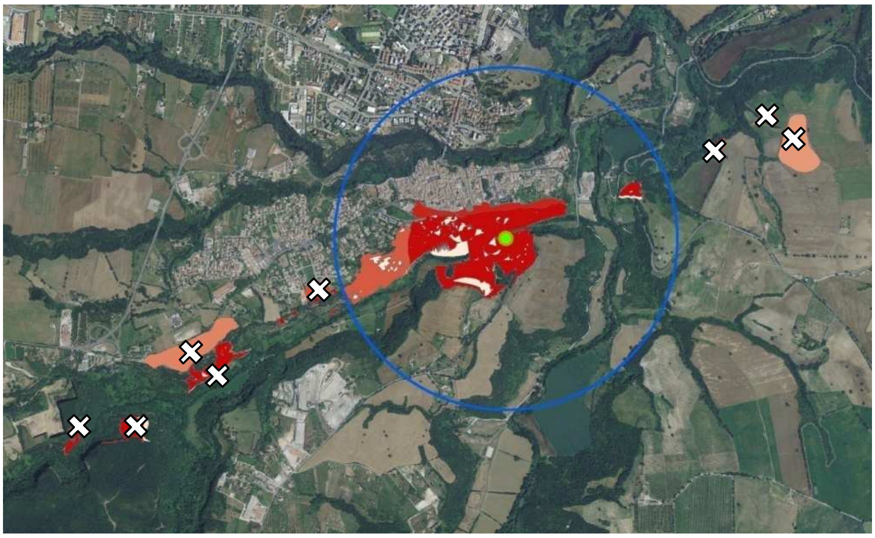

Fig.5- actual limits of visibility of the photovoltaic plant

We do not claim that this study is sufficient for the methodology proposed to become the new guidelines for these analyses. Rather, we intend this study to be a springboard from which other more in-depth and complex studies will arise with the objective of continually improving the models used.

The methodology discussed above gives us an in-depth understanding of the Visual Area at the time when the project is originally proposed as well as a clear picture of the results, in perceptual terms, after a project has been completed.

The type of analysis conducted in the case study allows for accurate planning of any interventions which might be needed to mitigate the visual impact of the structure being inserted into a landscape, hence optimizing the costs of such interventions.

Finally, it is useful to highlight that at the foundation of this study, besides the utilization of well-established methods such as GIS Spatial Analysis and Image Analysis in general, is a multi-disciplinary approach which requires specialized techniques which enable us to grasp historical, cultural and natural complexities to more accurately assess the feasibility of projects proposed in a wide range of challenging landscapes.

6. References

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