VISIBILITY ANALYSIS IN WETLAND PROTECTION PROCESSES

Vito Martelliano, Nicoletta Denaro

Abstract: Wetlands are 'areas of high naturalness' essential for the survival of a large number of animal and plant species. The preservation of the biological diversity of wetlands is implemented through various protection regimes, such as parks, reserves, SCIs, SPAs and Ramsar sites.
However, in some cases, protection initiatives are insufficient in reducing anthropogenic pressures on wetlands threatened by the widespread urbanization and anthropization of the landscape, also their presence effectively affects, from a perceptive point of view, the landscape of wetlands.
The introduction of the perception analysis in wetland conservation processes could guarantee the integral protection of landscape. The visibility analysis method is based on the visual perception: intervisibility maps are created using GIS tools that measure how much a portion of land is visible from previously identified points, thus highlighting visual existing interactions between wetlands and the surrounding. The maps of the most visually exposed areas could be additional tools to protect wetland landscape, anticipating potential impacts on it. The proposed methodology has been applied to the case study of the southeastern Sicilian wetlands.

Keywords: landscape analysis, visibility analysis, GIS tools, wetlands protection

Vito Martelliano, University of Catania, Italy, vito.martelliano@unict.it, 0000-0002-2465-6499
Nicoletta Denaro, University of Catania, Italy, nicoletta.denaro@phd.unict.it, 0009-0006-9735-0518

Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)

Vito Martelliano, Nicoletta Denaro, *Visibility analysis in wetland protection processes*, pp. 409-419, © 2024

1. Introduction

The protection of the landscape heritage is implemented through the affixing of restrictions, the establishment of areas destined for protection and conservation of a natural, historic-cultural or archaeological context as well as the approval of landscape plans that, through a holistic approach, systemize the whole protection measures and regulations present in a territory.

In this context, the protection of a single asset, be it historical or natural, focuses more on the conservation of its physical integrity and less on the safeguarding of its relations with its context, i.e. with its users, uses, the elements of the landscape, the culture of the territory and society. Protection instruments aim to define more or less vast perimeters within which measures can be envisaged to protect the asset from the risks of improper and harmful uses. Often, an enclosure drawn on paper does not correspond to the signs of the territory demarcating instead a sharp transition from inside, where protection rules apply, and outside where they do not. To mitigate this transition, buffer zones characterized by an intermediate protection regime are introduced in order to produce a gradual transition between protected and unprotected areas. Nevertheless, the perceptive relations established by the protected property with the landscape context definitively escape the logic of enclosures. The gaze goes well beyond the constraining perimeters and unites the destiny of vast territories in an indissoluble bond [1].

The spread of GIS (Geographic Information System) tools, the creation of specific algorithms and the availability of increasingly accurate digital terrain models (DTM, DEM, DSM) has improved in recent decades thus refining the use of visibility analysis in the territorial and landscape field, and thus making it an essential tool for assessing the environmental impact of human interventions and, more generally, the identification of policies to protect the landscape heritage [1]. The result is the overcoming of the protection of the panorama in favour of a more general protection of perceptive relations and the identification of perceptive basins that constitute the reference areas for the definition of adequate safeguard measures.

The application of visibility analysis is widely used in the landscape field for the determination of the value of viewpoints and scenic routes [4]; on the contrary it is rarely used in highly natural systems. In natural areas, in fact, the study of physical and eco-systemic factors prevails over the perceptive one so that the resulting analytic-knowledge framework is only partially able to direct protection policies.

This paper aims to explore the concept of visibility in the context of wetland conservation, by analyzing the potential and limitations of this approach, and also by providing an example of its practical application in the context of south-eastern Sicily. Through the analysis of the proposed case study, we intend to demonstrate the importance of visibility consideration in the planning and sustainable management of wetlands in order to ensure the conservation of these precious ecosystems for the future generations.

2. Materials and methods

2.1 Wetland: values and threats

In comparison with other types of ecosystems, wetlands cover a relatively small area, approximately 6 % of the entire Earth's surface [10]. However, they represent some of the most important types of ecosystems in the world [5]: they are characterised by a very rich biodiversity, about the 40% of the world's species of plants and animals completely dependent on them [6], for that reason their conservation becomes a fundamental factor to guarantee biodiversity richness.

The life of many species of birds depends on wetland's network, especially during annual migrations: waterbirds rely on wetlands areas, they play a fundamental role in guaranteeing biological processes like breeding, wintering, and stop-hover [11].

Due to human activities, and also for natural effects, the total wetland surface in the world has been decreasing and the remaining has been deteriorating in quality to different degrees [2]. Over the last decades interest in wetland has increased and protection initiatives too, but widespread urbanisation, climate and land-use changes still threaten worldwide wetland habitat and waterbird species.

2.2. The wetlands of South-Eastern Sicily

Most of wetlands in Sicily are located on the slopes of the Iblei Mountains, along the coast of South-Eastern Sicily in the territories of Syracuse and Ragusa and involve four municipalities: Noto, Pachino, Portopalo di Capo Passero and Ispica (Figure 1).

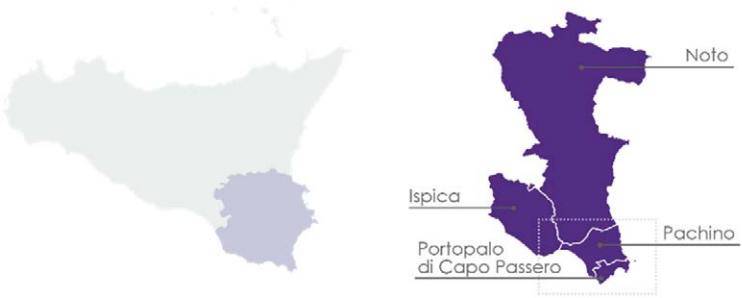

Figure 1 – Geographical location.

The system of wetlands (Figure 2) hosts a huge number of animal and plant species and plays a strategic function especially by serving as stopover stations during the pre-post-reproductive migratory routes between Europe and Africa [3].

The current wetland system is characterised by a series of bodies of water that differ in shape, salinity gradient, extension and depth and are supplied by rainwater, sea water and partly by the aquifer [9].

The variation in the size of the bodies of water is regulated by the seasonal cycle; during summer months which are characterized by intense heat periods, most of the lake becomes considerably shrink or it completely dries up.

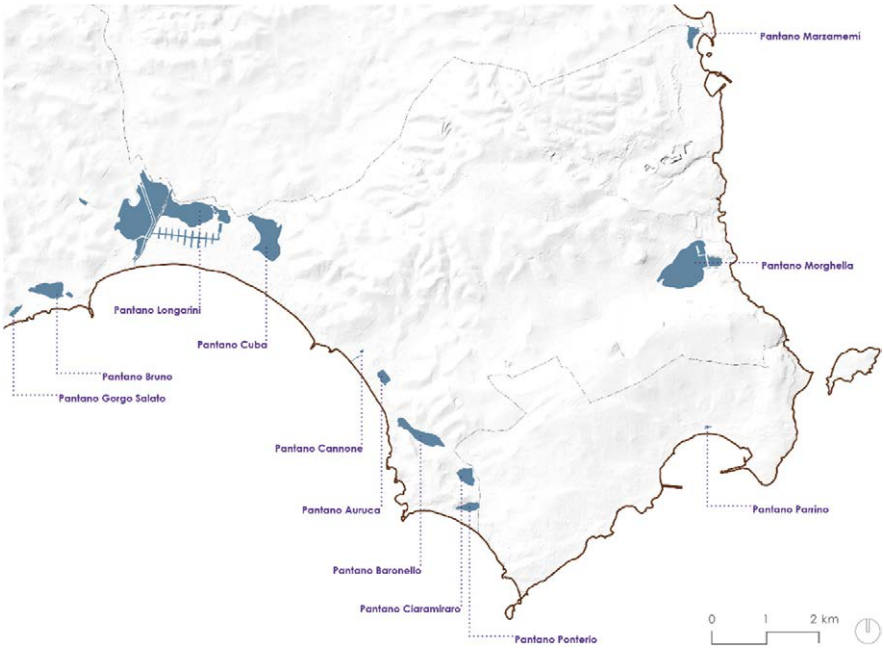

Figure 2 – South-eastern Sicily wetlands.

Since the second half of the 19th century, numerous wetland reclamation operations have reduced the wetland zones. Nevertheless, the high ecological importance of these areas continues to be seriously threatened by the anthropization of the territory. In particular, the construction along the coast and intensive greenhouse agriculture have a strong impact on wetlands.

Since the beginning of the 1970s protected horticulture has become widespread and the Sicilian South-Eastern coastal areas, due to their pedoclimatic characteristics, have been widely affected by these constructions that altered the traditional agricultural landscape thus reducing its quality [7].

Not only is the presence of greenhouses a visual detractor for the agricultural and wetlands landscape, but also it causes an effective imbalance in the natural ecosystem: reduces the lacustrine vegetation, exploits fertile soils and withdraws water for irrigation (figure 3). Pesticides and fertilisers full of nitrates, also threaten the wetlands [8], due to the permeability of the soil, pollute the water bodies thus causing an impoverishment of flora and fauna.

Finally, the plastic covers of the greenhouses creating the so-called 'lake effect', with direct impacts on the birdlife that swaps the greenhouses for water basins.

Figure 3 – Bird's-eye view of the Morghella water basin.

In order to protect current biodiversity and avoid further fragmentation, the wetlands are interested by national, regional and European protection programmes such as the Sicilian Ecological Network and the Natura 2000 Network. Yet, they have not been sufficient to prevent further anthropization and fragmentation of the landscape.

Analysis, protection and monitoring tools focus on achieving standards on wetland habitat quality thus overlooking the necessity of protecting the wetland landscape from a perceptive point of view. Uncontrolled land use of areas surrounding bodies of water modifies the entire perception of the wetland landscape by increasingly fragmenting it.

In this context, the introduction of an additional tool in the protection processes, such as the intervisibility maps, can contribute to the identification of perceived problems and help to protect the integrity of the wetland landscape.

2.3. Visibility analysis method

Thanks to the widespread use of GIS software visibility viewshed analysis have become easily accessible and workable. These methods are based on the quantification of which portions of landscapes could be seen from specific points of view, or otherwise the portion of lands whom seen specific points [1].

Usually, visibility analysis is used to calculate the portion of the landscape seen from privileged viewpoints or previously identified panoramic roads in order to monitor the impact of punctual elements such as new infrastructure or buildings on a specific observed view.

In the case of the integral landscape protection of natural elements such as wetlands, not only privileged viewpoints are selected but all potential viewpoints are identified by discretising the perimeter of water bodies into points at a constant distance of 30 m from each other (Figure 4).

Figure 4 – Outline of the wetland discretization process and definition of the maximum visual field extension.

To consider the variability in the extension of the water bodies that occurs with a reduction during the summer season, perimeters further inland than the main at a distance of 10, 20, 40 and 80 m. Other parameters concern the width and height of the visual range and the maximum depth of observation, coherently set.

The fundamental information source for processing the visibility analysis is the Digital Terrain Model (DTM), an elevation representation of the terrain using a grid of square cells; each cell contains the real correspondent height of the terrain. The resolution and accuracy of the spatial datum is variable and it characterises the quality of the visibility analysis: choosing the appropriate datum is crucial. For the visibility analysis of wetlands, a DTM was chosen that only has information on the ground surface without architectural constructs and vegetation. The use of DSM, Digital Surface Mode, was excluded because the altimetric information on the heights of buildings and vegetation in some cases distorts the results, for example vegetation is assimilated to an architectural building, without considering the transparency of the vegetated mass [1].

Furthermore, land cover may be subject to change over time, intervisibility maps using the DSM may represent a situation of transitory visibility so only the data containing the terrain information is taken as a baseline.

After processing between the extracted viewpoints and the DTM we obtain a raster file representing the associated viewshed, each pixel containing information on the number of points, so the number of times, from which that particular cell is viewed.

If we had considered only one point of view we would have obtained a binary raster (1 visible, 0 not visible), having n points, the values of the visible are sum up, in this way we can identify the most visually exposed areas (Figure 5).

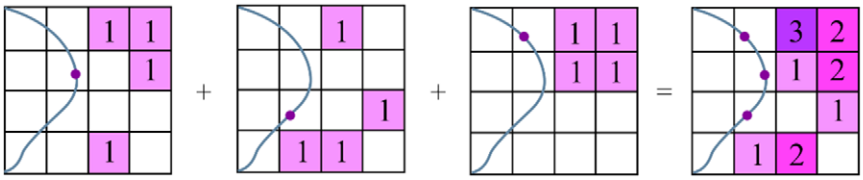

Figure 5 – Sum of viewshed considering multi points of view at the same time.

Results

The visibility analysis method was applied to the wetland of South-Eastern Sicily. First, the singular wetlands or groups of wetlands close to each other were discretized into points, which will constitute the observation points of the viewsheds (Figure 7). The inner perimeters were established at a distance of 10 m, 20 m, 40 m and 80 m from the most external one (Figure 6).

At this point, it has been defined all the parameters to simulate the perception of wetland from the surrounding: the observation point height is set at 0,5 m, the visibility radius at 5 km, that is the maximum observation distance in which contours and silhouettes can be distinguished in the landscape.

In terms of the source data 2x2 m DTM was used for this visibility analysis.

Once the data has been collected and all the required parameters have been set, the visibility analysis will be processed. The result is a single-band raster where the highest pixel value indicates the most visually exposed areas from/of wetlands (Figure 7). This process was carried out for all the observation points (in Figure 6) and at the end the pixel value where related to classes of visibility from very low visibility 1, to the very hight visibility 5. The last step that has been done was summing up all the visibility analysis in order to have a global map of visibility (Figure 8).

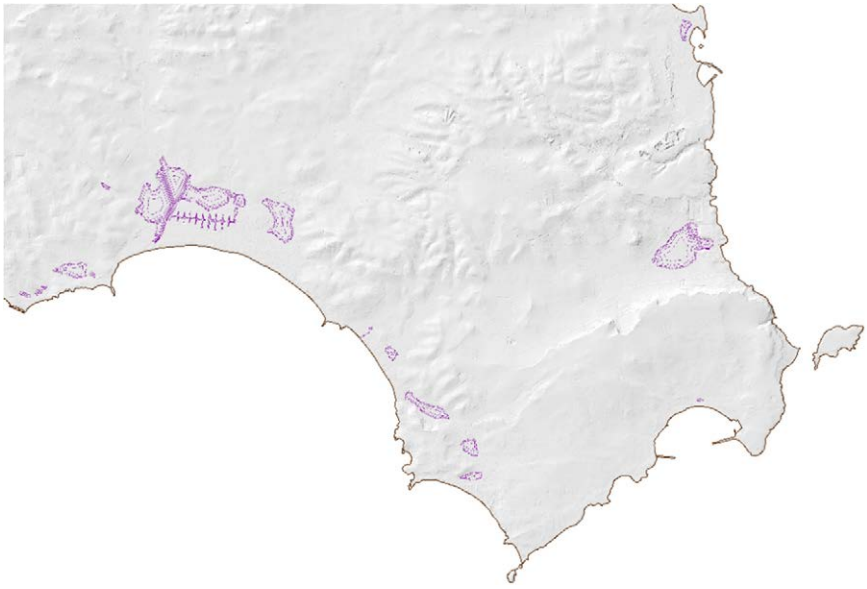

Figure 6 – Assumptions of more wetland perimeters as the seasons change.

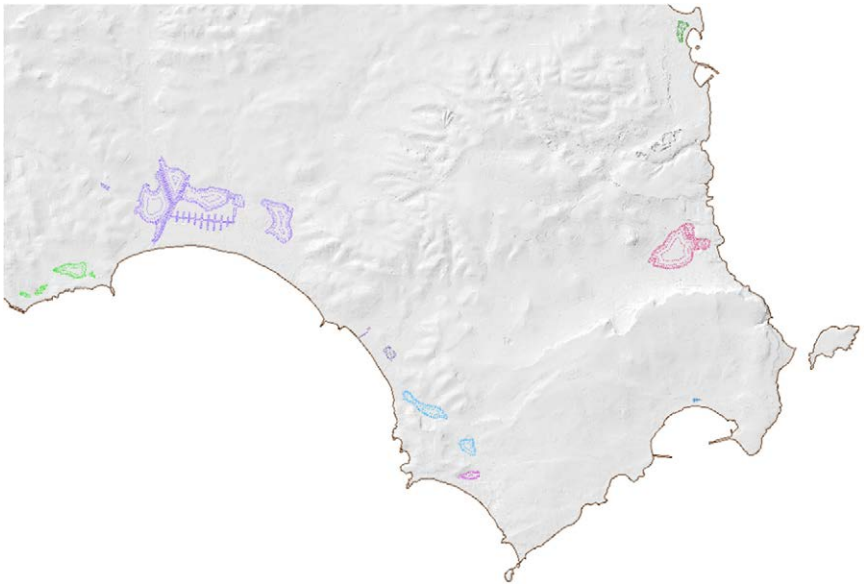

Figure 7 – Discretization of wetlands perimeters into points of observation.

Figure 8 – Map of visibility analysis for Morghella viewshed.

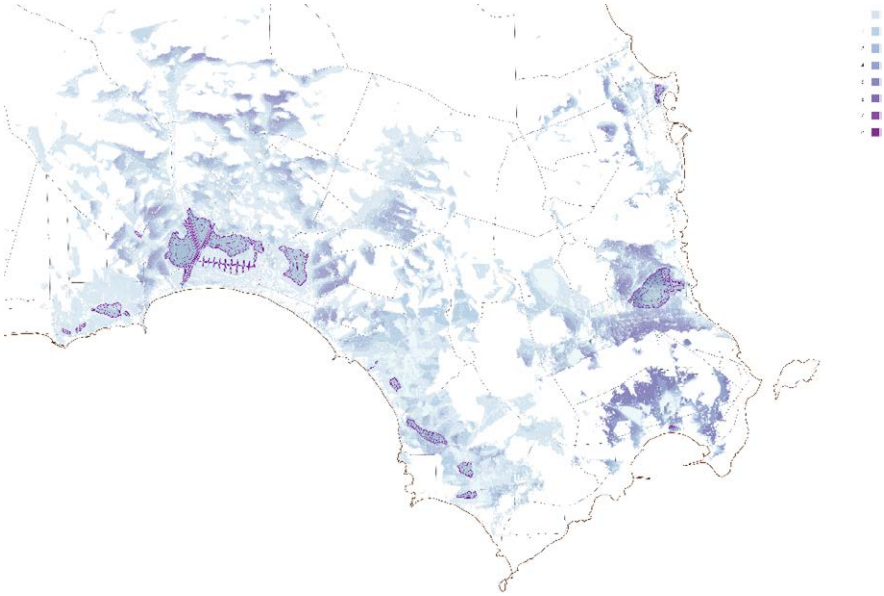

Figure 9 – Map of visibility analysis for the viewshed summed up.

Discussion

The landscape visibility analysis may be extremely useful in monitoring the effects that land use changes have on the visual perception of the wetland landscape.

The research employs a methodology for drafting an intervisibility basin for wetland complexes and, along with eco-system analysis, it proposes its use for the definition of a strategy of wetland protection. A strategy that defines wetland landscape made up of high natural value areas (i.e. wetlands and bordering areas), areas of ecosystemic interaction (i.e. areas that directly influence the ecosystemic conditions of wetlands) and areas of perceptual interaction.

The research demonstrates, then, that the wetland protection process cannot be said fully accomplished if, besides the protection of the physical and ecosystemic components, the perceptive component is not also pursued.

Visibility analysis is an effective complementary tool to safeguard wetlands and can be helpful in preserving their landscape integrity and defining more effective perimeter protection. It is even more true in the case of a complex of wetlands of territorial value whose perceptual basin is made up of all the perceptual basins of each wetland.

Conclusion

In this research, visibility analysis emerges as an innovative and interdisciplinary approach to understand and assess the visual relationships that wetlands establish with the bordering territorial context.

Through the use of GIS tools, it has been possible to integrate spatial data and perceptive analysis in order to identify areas of a highly perceptive interaction within which incoherent interventions can generate alterations in the high natural wetland ecosystem contexts.

The methodology proposed on a vast territory for the perceptual analysis of a naturalistic context made up of several wetlands allows, through the qualitative identification of the visibility basin of the wetland system, to influence decision-making processes and protection policies through the definition of a protection area not exclusively linked to ecosystem aspects.

Bibliography

[1] Cassatella C. (2014) - *Linee guida per l'analisi, la tutela e la valorizzazione degli aspetti scenico-percettivi del paesaggio*, MIBACT Direzione Regionale per i beni culturali e paesaggistici del Piemonte, Regione Piemonte, Dipartimento Interateneo di Scienze, Progetto e Politiche del Territorio (DIST), Politecnico e Università di Torino, Torino.

[2] Gardner R.C., Barchiesi S., Beltrame C., Finlayson C.M., Galewski T.; Harrison I., Paganini M., Perennou C., Pritchard D, Rosenqvist A. et al. (2015) - *State of the*

World's Wetlands and Their Services to People: A Compilation of Recent Analyses; Social Science Electronic, Gland, Switzerland.

[3] Guglielmo A., Spampinato G., Sciandrello S. et al. (2013) - *I pantani della Sicilia sud-orientale un ponte tra l'Europa e l'Africa, Conservazione della biodiversità, restauro ambientale e uso sostenibile,* pp.115-125.

[4] La Rosa, D.; Izakovi˘cová, Z. (2022) - *Visibility Analysis to Enhance Landscape Protection: A Proposal of Planning Norms and Regulations for Slovakia.,* Land, 11, 977. https://doi.org/10.3390/land11070977

[5] Ramsar (2009) - Factsheet *6: Reservoirs of biodiversity*, Gland, Switzerland, Ramsar Convention Secretariat.

[6] Ramsar (2021) - *50th Anniversary, Wetland and biodiversity Factsheet* Convention on Wetlands

[7] Regione Siciliana Assessorato dell'Economia (2016) - *6° Censimento agricoltura 2010 rapporto sui dati definitivi della Sicilia, Le statistiche sull'agricoltura siciliana: informazioni per l'analisi e le politiche - vol. 1.* Palermo

[8] [8] Regione siciliana, presidenza autorità di bacino distretto idrografico della Sicilia (2022) – *Relazione Direttiva 91/676/CEE – Aggiornamento della carta delle zone vulnerabili ai nitrati di origine agricola (ZVN) sulla base dei dati di monitoraggio 2016-2019*

[9] Regione Siciliana Assessorato Territorio e Ambiente (2009) - *Piano Stralcio di Bacino per l'Assetto Idrogeologico (P.A.I.) Relazione Bacino Idrografico del Fiume Tellaro (086) Area Territoriale tra il bacino del Fiume Tellaro e Capo Passero (085)*

[10] Schuyt, K., Brander, L., (2004) - Living *Waters Conserving the source of life. The economic values of the world's wetlands*, World Wildl. Fund, Amsterdam.

[11] Xu, T.; Weng, B.; Yan, D.; Wang, K.; Li, X.; Bi, W.; Li, M.; Cheng, X.; Liu, Y. (2019) - *Wetlands of International Importance: Status, Threats, and Future Protection*. Int. J. Environ. Res. Public Health*,* 16*,* 1818.