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"Visibility" at Italian natural parks: preliminary data from the first-ever pilot project by ENEA and CUFAA

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ABSTRACT "Visibility" is meant as the greatest distance at which an observer can see a distant object in contrast with the horizon and, when referred to a landscape, it depends on the optical characteristics of the atmosphere, somehow linked to the presence of air pollutants.Visibility can hence become a useful indicator of air quality and the project Visibility, representing the first case of visibility monitoring in Europe, aims to apply this approach within the Italian National Parks as natural areas with a significant fruition vocation. The goal is to test the U.S. National Park Service protocol I.M.PRO.V.E. (Interagency Monitoring of PROtected Visual Environment) for the quantification of a coefficient that describes the light extinction (B_{ext}) as a function of different chemical-physical parameters associated with molecules dispersed in the air, and the Circeo National Park (LT) was selected for the "pilot" action, with the positioning of the measuring instruments for atmospheric pollution evaluation at the Lago dei Monaci site. 24-hours samplings were performed in spring-summer 2021 and winter 2021/2022, to measure the air concentration of $PM_{2.5}$ and PM_{10} particulate matter, sulfates and nitrates, elemental carbon and organic carbon, metals and trace elements and the gaseous species nitrogen dioxide, with the consequential calculation of the B_{ext}. The visual detection of the degree of air transparency was performed by a panoramic camera pointed in the direction of the "landmark" Monte Circeo, taken as a reference for the definition of long-distance visibility.

KEY WORDS Atmospheric visibility; Air pollutants; Particulate matter; Light extinction; IMPROVE algorithm.

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THE PROJECT "VISIBILITY"

"Visibility" is meant as the greatest distance at which an observer can see a distant object in contrast with the horizon and, when referred to a landscape, it depends on the optical characteristics of the atmosphere, which are also linked to the presence of gaseous or particulate pollutants that contribute to generating haze that obstructs clear vision.

Visibility is therefore a useful indicator of air quality in natural areas with a significant naturalistic, ecological or attractiveness vocation such as the National Parks. In these areas the possibility of enjoying a clear panorama immersed in a natural landscape represents a precious recreational value, a *de facto* ecosystem service. The Italian Constitution itself (Article 9) and several Italian laws point at preserving the nature and the landscape.

OBJECTIVE. The goal is to employ the U.S. National Park Service protocol I.M.PRO.V.E. (Interagency Monitoring of PROtected Visual Environment) based on the algorithm developed by Malm et al. (1994) for the quantification of the coefficient B_{ext} - light extinction, equation (a) - as a function of different chemical-physical parameters associated with compounds in the particulate and gaseous phase of both anthropic and natural origin.

$$B_{ext} \approx 2.2 * fS (RH) * [Small\ Ammonium\ Sulfate] + 4.8 * fL (RH) * [Large\ Ammonium\ Sulfate] + 2.4 * fS (RH) * [Small\ Ammonium\ Nitrate] + 5.1 * fL (RH) * [Large\ Ammonium\ Nitrate] * 2.8 * [Small\ Organic\ Mass] + 6.1 * [Large\ Organic\ Mass] + 10 * [Elemental\ Carbon] + 1 * [Fine\ Soil] + 1.7 * fSS (RH) * [Sea\ Salt] + 0.6 * [Coarse\ Mass] + Rayleigh\ Scattering\ (Site\ Specific) + 0.33 * [NO2\ (ppb)]$$ (a)

THE PILOT SITE. The first site study to apply the Visibility approach in Europe is the Circeo National Park (Latina, Italy). The measuring instruments are located near the Lago dei Monaci site. The identified site is far from local sources of pollutant emissions, is characterized by good local ventilation and faces a site of high naturalistic interest, namely the Circeo promontory.

THE VISIBILITY SAMPLING CABINET. The cabinet developed for Visibility is equipped with two FAI Hydra dual-channel samplers for atmospheric particulate matter sampling, an analyser

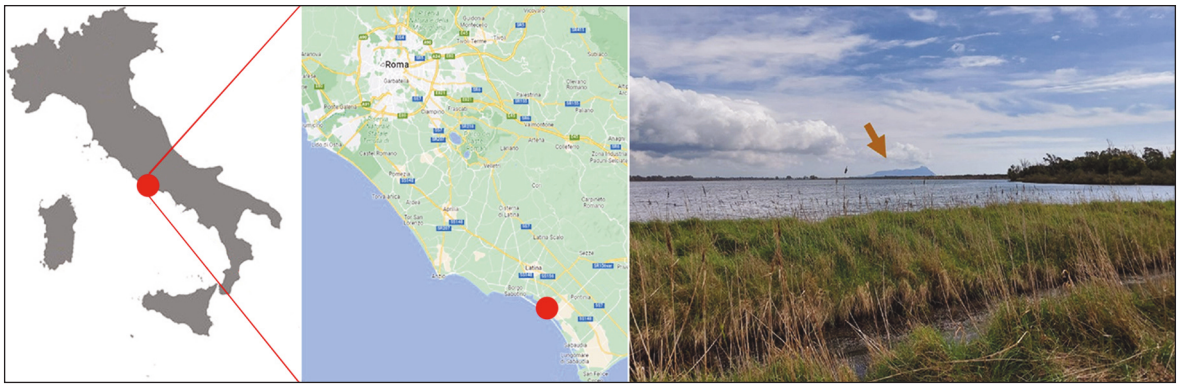

Figure 1. Sampling site near the Lago dei Monaci and view of the Circeo promontory from the sampling area (distance ≈ 20Km). Brown arrows: the Monte Circeo, focus point of the photocamera).

Figure 2. The Visibility cabinet near the Lago dei Monaci, drone view and focus on the sampling lines for particulate matter and the meteorological measurements.

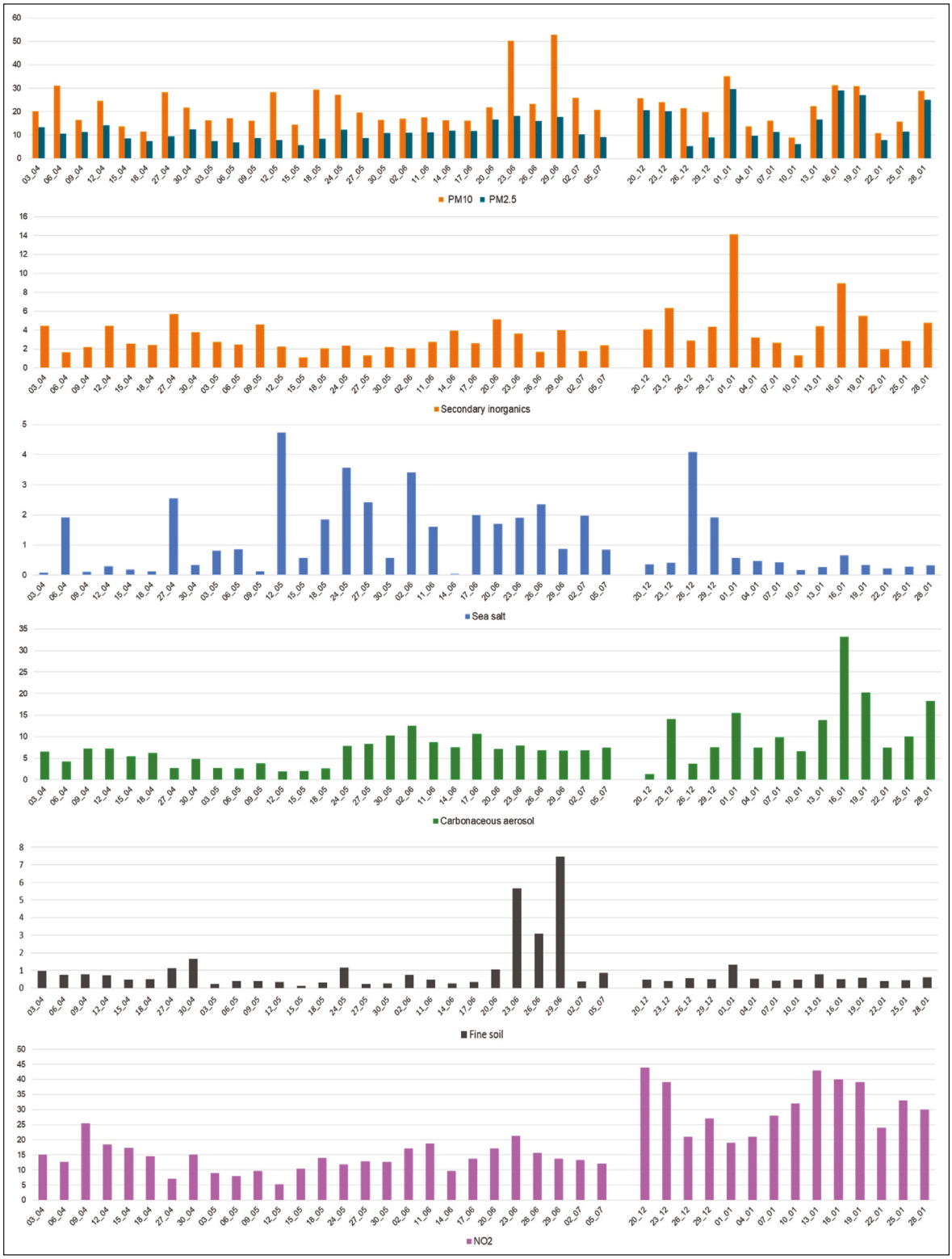

Figure 3. Daily measures of the different sources affecting air quality characterized according to the equation (a). The chemical species underlying this sources were used to determine the B_{ext} parameter. The daily value were used to calculate the B_{ext} parameter during each day and to correlate the obtained value to actual pictures giving evidence of the real possibility to distinguish the Circeo promontory (examples in Fig. 4).

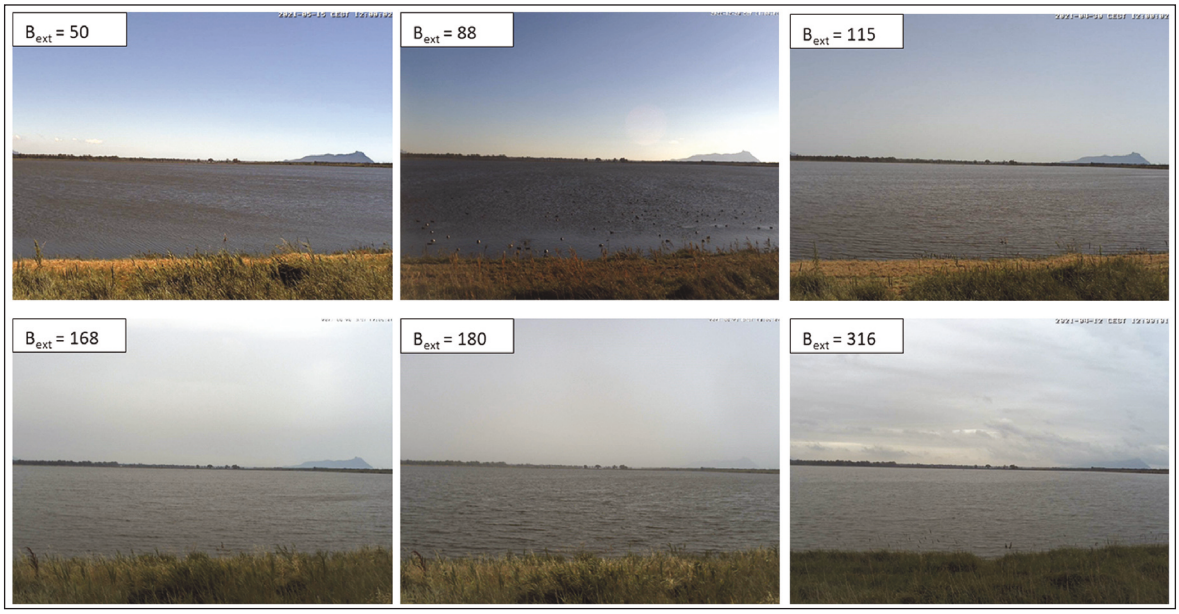

Figure 4. Preliminary results from the Visibility approach. Low value of the B_{ext} coefficient are related to good visibility while high values correlate to scarce or reduced visibility of the Circeo promontory.

for NO_X, a camera for image acquisition (pointed towards Monte Circeo, necessary for the definition of long-distance optical visibility) and a weather station for the collection of local meteorological data (in particular, relative humidity is one of the factors required for calculating the visibility coefficient).

EXPERIMENTAL MEASURES. During spring-summer 2021 and winter 2021/2022, 24-hours samples were collected, with a frequency of one every three days. The following chemical species and components were characterized and quantified (μg/m^3) according to equation (a): PM_{10}, $PM_{2.5}$, water soluble Anions and Cations (Sulfates, Nitrates and Ammonium for Secondary inorganics pollutants, and Chloride to calculate the Marine – Sea salt spray aerosol concentration), Elemental and Organic Carbon (Tracer of organic emissions from both natural sources or anthropogenic sources such as combustion), Metals and trace elements (Al, Ti, Si, Ca and Fe, necessary for calculating Fine soil particles component) and NO_2 (concentration quantified in ppb with a dedicated monitor).

THE "VISIBILITY INDEX". A first visibility index (B_{ext}) was calculated (according to equation (a)) and preliminary results show that an increasing B_{ext} effectively corresponds to a decreasing optical visibility at long distance. The parameters that seem to contribute the most to reduce the visibility and hence to the increase of B_{ext} are the Secondary Inorganic species (Ammonium Sulfate and Ammonium Nitrate) closely linked to atmospheric humidity.

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