ANALYSIS OF SHADING IN THE PRESELECTION PROCESS OF LANDS FOR THE CONSTRUCTION OF PHOTOVOLTAIC PARKS

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Abstract: *Through this paper, we aim to showcase the ways in which we can harness elevation models for studying shading within the GIS environment. This goal is tied to the project in which my colleague, George Emanuel Voicu, and I have participated, a project involving the acquisition of topographic data and spatial analyses to highlight shading studies – crucial aspects in selecting the most suitable areas for constructing a photovoltaic park. The initial phase involves gathering precise topographic and geospatial information, including climate data and celestial positioning. These acquired data are then integrated into Geographic Information Systems (GIS) to provide a comprehensive view of the terrain and environmental factors that could influence shading. The subsequent step involves using advanced simulation and modeling technologies to analyze the behavior of solar radiation under various conditions and at different time intervals. This stage is pivotal in generating accurate shading models that delineate critical areas with shading potential and their effects on solar panels.*

Keywords: *DEM; TIN; Sun Shadow Volume; azimuth; vertical angle; multipatch; sustainable energy; photovoltaic parks*

1. Introduction

In our current era, where the concern for utilizing renewable and sustainable resources is increasingly pressing, solar energy emerges as a key solution to meet our electricity needs. In this context, the development and implementation of photovoltaic parks represent a fundamental direction towards generating green energy. However, the success and efficiency of a photovoltaic park heavily rely on the ability to properly plan and manage shading that can affect energy production. The generation of shading models for these designated spaces meant for photovoltaic parks becomes an essential aspect in the process of design and implementation. By analyzing and comprehending how shadows cast by various obstacles - such as buildings, trees, or other surrounding structures - can impact the exposure of solar panels to sunlight, we can optimize their positioning to maximize the capture of solar energy and, consequently, electricity production.

2. The acquisition, integration and modeling of data in the GIS environment

In this stage, topographic data was collected in the researched areas (Blaj and Aiud), consisting of leveling points intended to complement the three-dimensional panel alongside raster elevation structures (Digital Elevation Model - SRTM) obtained through remote sensing. These models were reprojected into the STEREOGRAPHIC 1970 system.

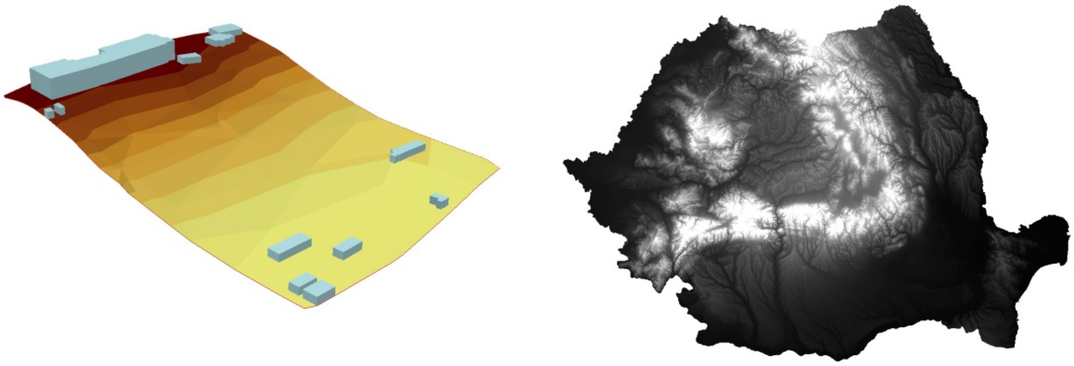

Fig. 1 Sources of altimetric data used in the study of shading

Topographic observations carried out in the field using GNSS (Global Navigation Satellite System) and electro-optical equipment (total station) led to the generation of raw ASCII files that were processed analytically and graphically, so that the newly obtained files could be suitable for importing into the GIS environment. Alongside the sources obtained from topographic measurements, an important role was played by the Digital Elevation Model (DEM) in extracting contourable points, based on which irregular networks of triangles (TIN) were generated. These models are significant in interpreting geomorphological aspects and in developing shading models. A Triangular Irregular Network (TIN) model is a three-dimensional representation of terrain or a surface created by triangulating a set of leveled points. It is composed of a network of triangles, where each triangle is defined by three adjacent control points, allowing for a more detailed and accurate representation of the terrain shape than other surface models such as raster models or models that only represent contour lines (isohypses). The TIN model can have a variable resolution, meaning the triangle shape largely depends on the density and distribution of control points. This enables focusing on details where necessary, saving storage and processing resources.

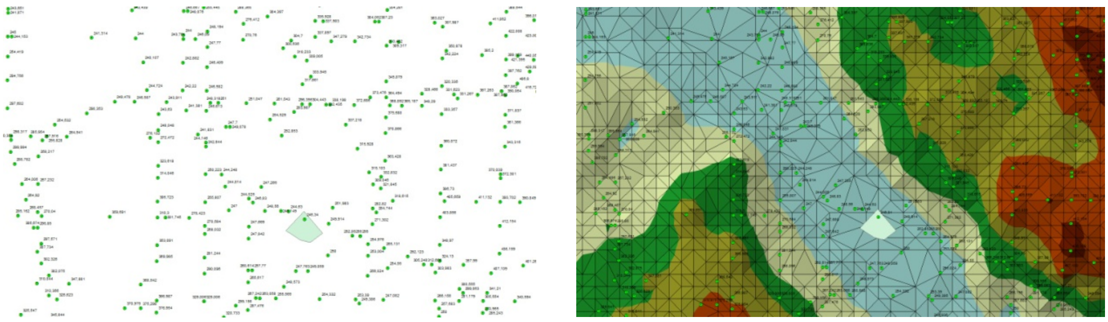

Fig. 2 Developing TIN from the extractable contour points obtained from Romania's DEM

For the two areas of interest, Blaj and Aiud, hypsometric coverage models were developed to capture the configuration of elevated marginal relief units. Integrating the area of interest along with the surrounding region allows for a detailed and precise analysis of solar shadows in the specific area. By considering the local altitude and topography, an accurate estimation of how the shadow is cast on the rugged terrain and existing objects in that area can be obtained. Furthermore, specific relationships and tendencies regarding the projection of solar shadows in that area can be identified, along with potential issues or opportunities related to the placement and optimization of solar resource utilization in that zone.

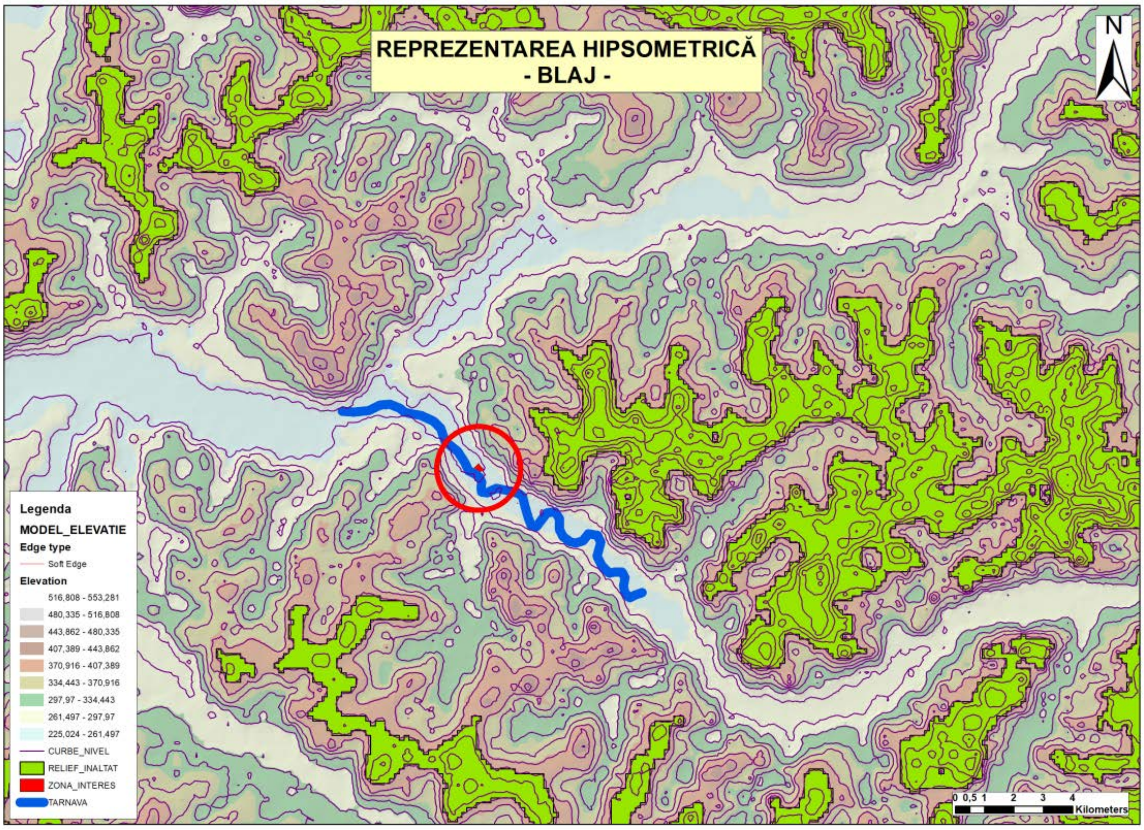

Fig. 3 Hypsometric representation – Blaj area

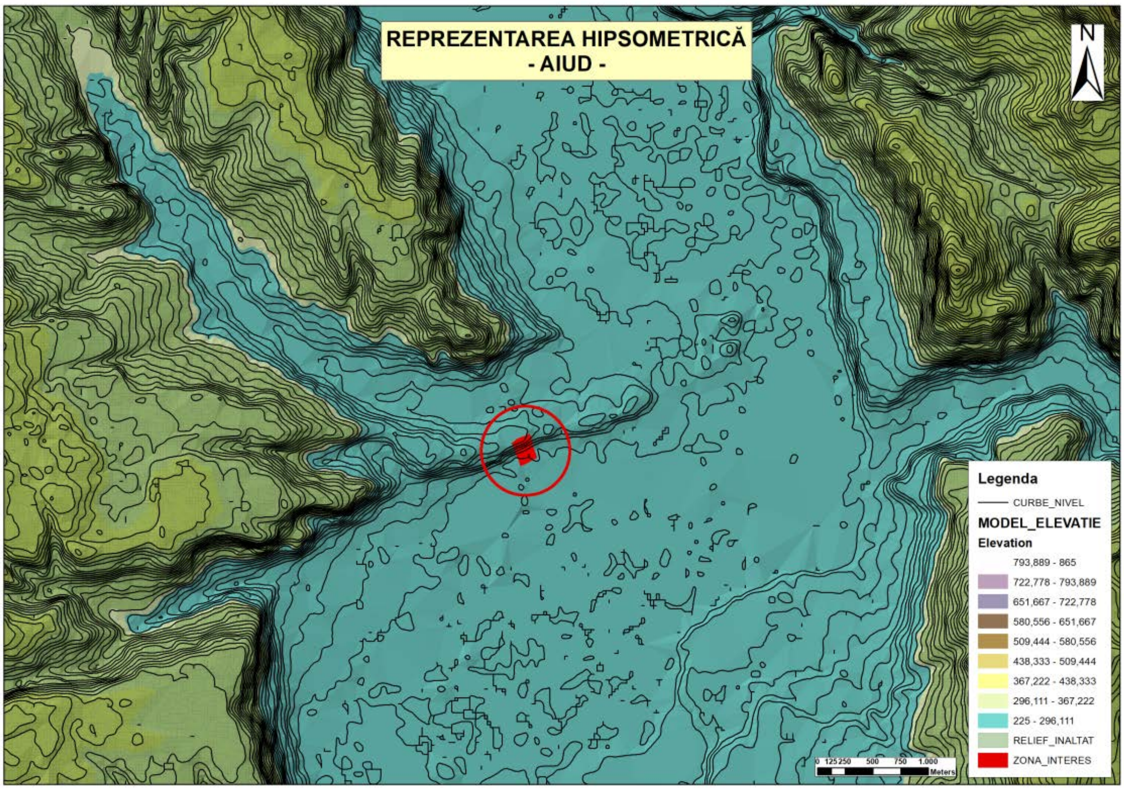

Fig. 4 Hypsometric representation – Aiud area

3. Development of shading models

For shading modeling, we concluded that the most suitable geoprocessing solution from the range of spatial analysis operations is the 'Sun Shadow Volume.' Within ESRI's 'Sun Shadow Volume' model, a series of mathematical parameters are calculated to determine the geometry of shadows based on location and the angle of observation.

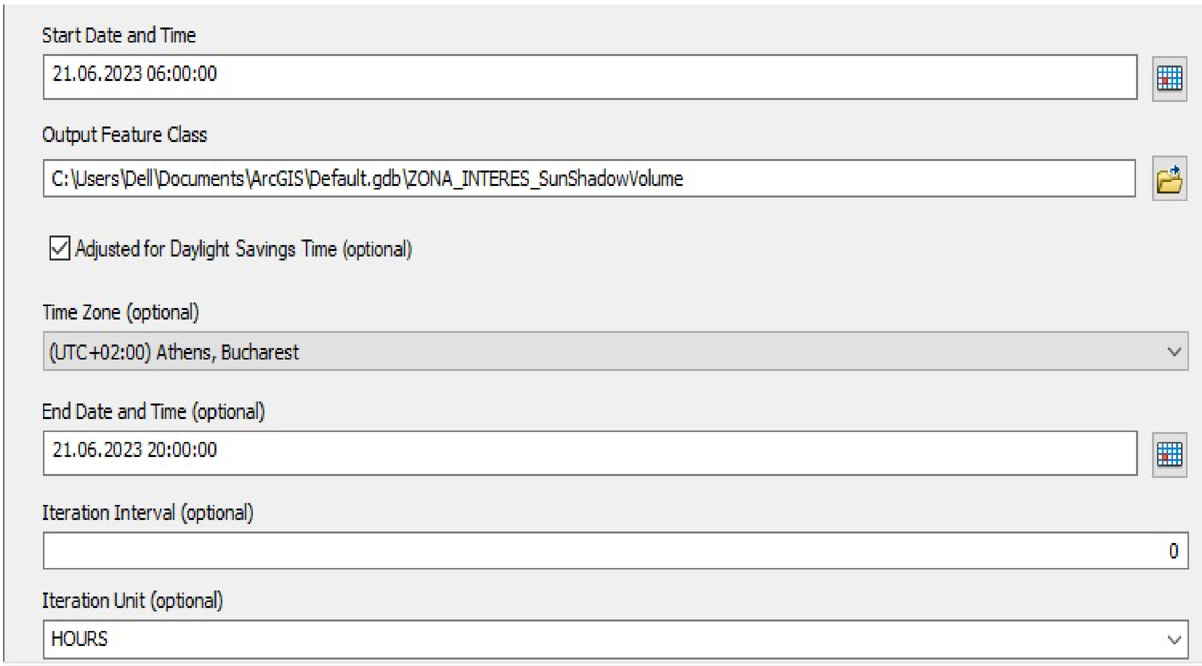

Fig. 5 The execution launch of the 'Sun Shadow Volume' function

Modeling shadows at sunrise and sunset can be achieved by providing a single set of parameters for 'Start Date and Time' and 'End Date and Time.' Shadow volumes will not be generated if the sun is not visible at a specific date and time or if the relative position of the sun is at the zenith (90 degrees) concerning the input objects (in this case, the peripheral area with elevated relief and the area of interest as the central perspective, both datasets being superimposed over the elevation model, with the altimetric component being common). In the absence of a digital terrain model, the surfaces entered into the shading indicator calculation process are required to be extruded with specified altimetry factors within their descriptive component (associated attribute table). If vector elements are already altimetrically linked to a digital terrain model (DTM), then additional extrusion to obtain the shading model is unnecessary.

The 'Sun Shadow Volume' technique is based on the concept of extruding shadows into three-dimensional space to obtain the shadow volume. This volume is then utilized to determine shaded areas and the degree of darkness based on location and the angle of observation.

Shadows are modeled as closed multipatches (three-dimensional geometric representations of object surfaces, formed from collections of facets, edges, and vertices) created by extruding input objects in the direction of sunlight. Light rays are considered parallel directed along the calculated direction for the relative position of the Sun. Each shadow volume starts and ends within a vertical plane perpendicular to the horizontal projection of the solar rays.

The following attribute fields have been applied to the objects generated within the shading model: SOURCE - The name of the object class generating the shadow volume;

SOURCE_ID - The unique ID of the object generating the shadow volume; DATE_TIME - The date and local time used to calculate the position of the Sun; AZIMUTH - The angle in degrees between the actual north (geographic in this case) and the perpendicular projection of the relative position of the Sun to the mathematical horizon of the Earth. Values range from 0 to 360 degrees; VERT_ANGLE - The angle in degrees between the mathematical horizon of the Earth and the relative position of the Sun, where the horizon is defined by the value of 0 degrees, and 90 degrees represents the vertical direction (maximum - to the zenith).

Typically, each shadow volume will appear to encircle or tightly project from the object from which it originates. If a shadow cannot be generated in this manner, it will be created from the outer extension limit of the object. When at least one shadow is created in this way, an additional field called HUGS_FEATR is included.

4. Results and discussions

The two locations, Blaj and Aiud, were analyzed in terms of developing shading models at the moments of June 21, 2023, and December 21, 2023. In the cartographic representations, in addition to the content elements, defining elements (explanatory legend, graphic scale) were depicted, aiming to complement the spatial information in a descriptive manner.

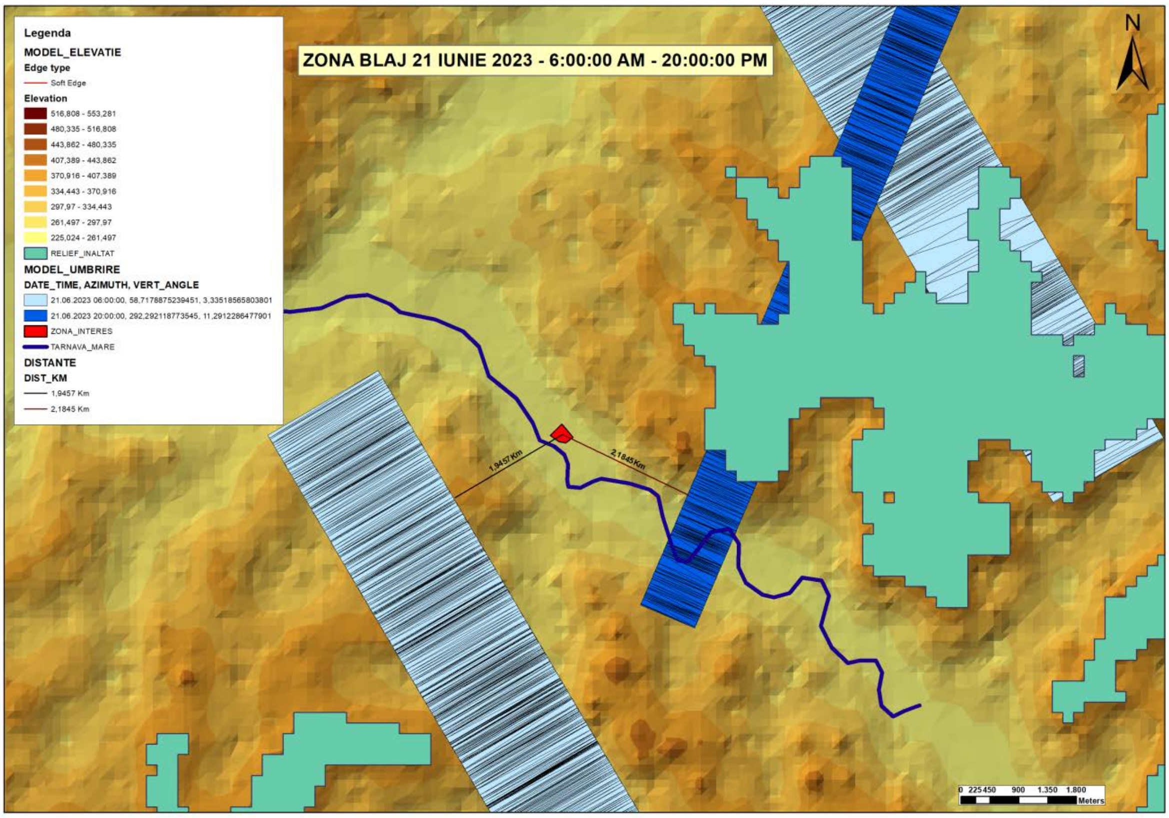

Fig. 6 Shading Representation – Blaj, June 21, 2023

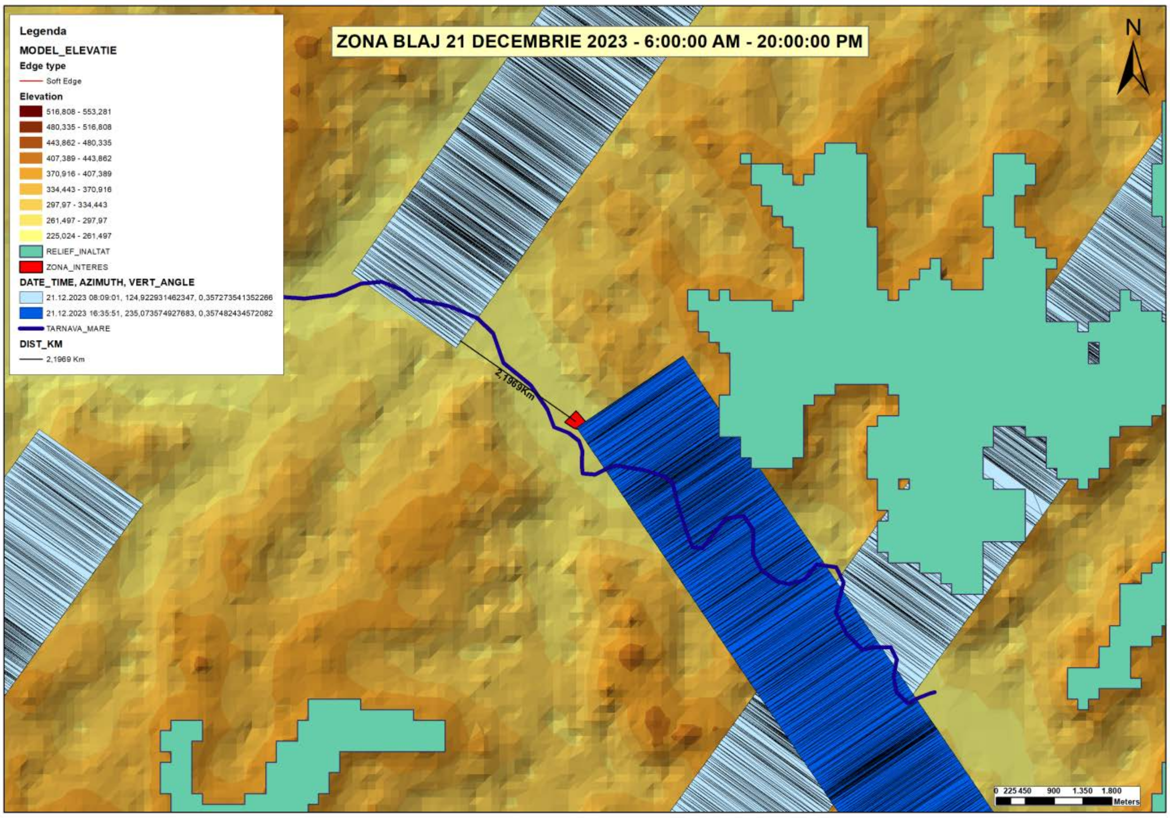

Fig. 7 Shading Representation – Blaj, December 21, 2023

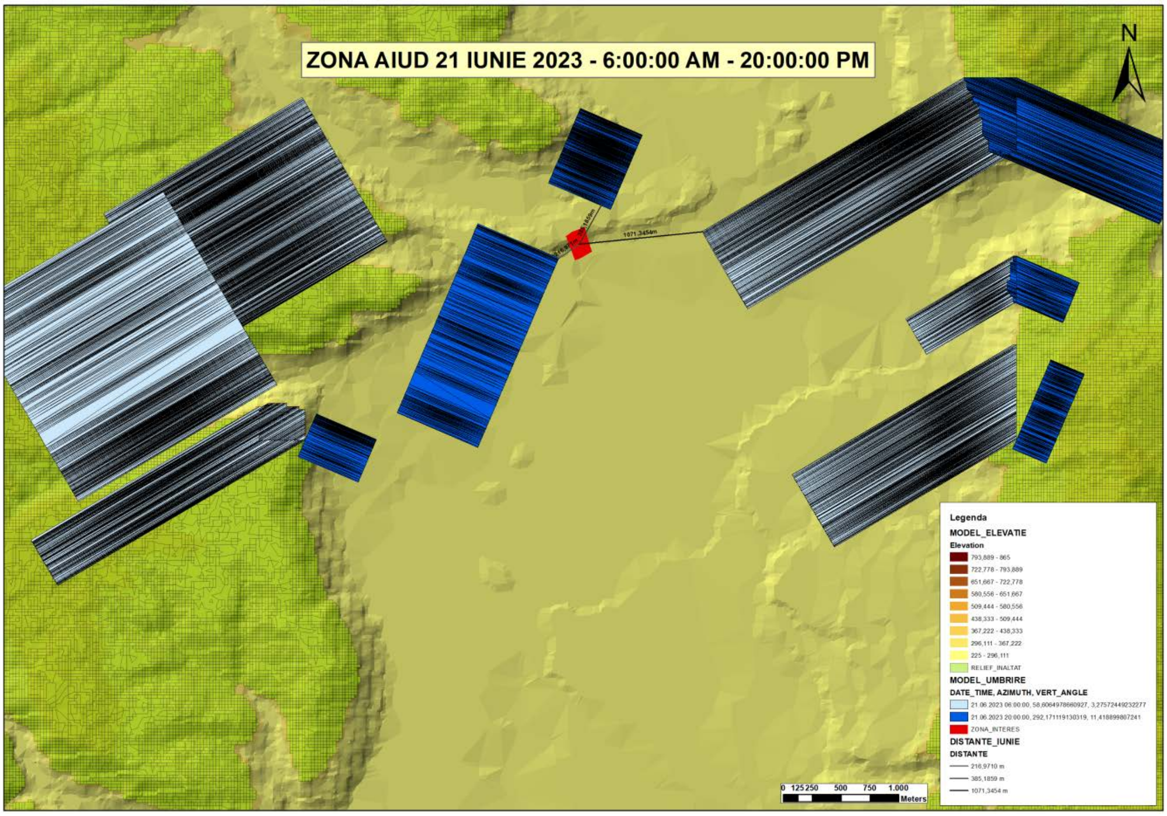

Fig. 8 Shading Representation – Aiud, June 21, 2023

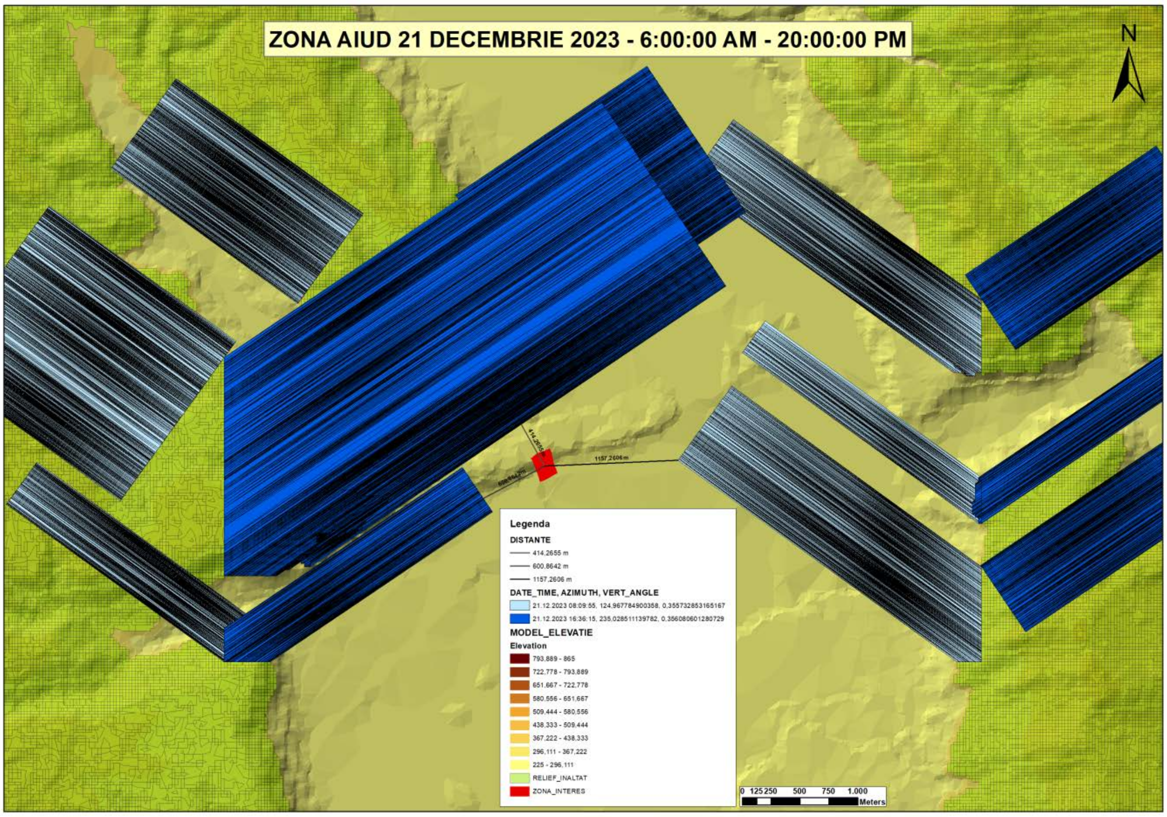

Fig. 9 Shading Representation – Aiud, December 21, 2023

The analysis of shading models in the localities of Blaj and Aiud on June 21 and December 21 highlighted significant variations in the shadow distribution during different times of the year. On June 21, the summer solstice, areas with reduced shading and increased exposure to solar radiation were identified in specific regions, reflecting a higher solar angle and an extended duration of daylight. In contrast, on December 21, the winter solstice, more pronounced shadows and reduced sun exposure were observed due to a lower solar angle and shorter daylight hours. These findings have significant implications in the efficient design and placement of solar panels in photovoltaic parks, emphasizing the need for adaptable planning to seasonal changes to maximize solar energy production and optimize photovoltaic system performance based on specific shading variations during different seasons.

5. Conclusions

Building upon the undertaken efforts, it becomes possible to identify and assess optimal solutions for the placement and orientation of solar panels, thus minimizing the negative effects of shading and maximizing the energy efficiency of the photovoltaic park. Integrating this data into the solar park infrastructure design process leads to the practical implementation of an optimized system, resilient to shading and capable of providing sustainable and efficient electrical energy. In conclusion, these materialized stages represent essential steps in the design and implementation of photovoltaic parks, facilitating strategic planning and optimizing their performance to meet the increasing demand for green and sustainable energy.

6. References

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