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GEOREFERENCING METHODS FOR ANALOGUE MAP INTEGRATION INTO GIS

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Abstract

The integration of analogue maps into Geographic Information Systems (GIS) is a key process for updating and using historical cartographic archives. This study presents the theoretical framework of digitization and georeferencing, outlining the main methods employed depending on the information contained in the analogue source. Furthermore, it examines the practical challenges encountered, such as inconsistencies between map sheets created by different cartographers, discrepancies between historical and current administrative boundaries, difficulties in identifying tics (control points), and the reduced legibility of graphic elements. The applied examples illustrate how these limitations influence the georeferencing and digitization workflow, emphasizing the need for a methodical approach and critical interpretation of data. The findings highlight the importance of adapting GIS procedures to the variability and quality of analogue sources in order to produce reliable and coherent cartographic outputs.

Key words:Geographic Information Systems, georeferencing, control points, analogue maps

INTRODUCTION

Geographic Information Systems (GIS) are essential tools for analyzing, managing, and spatially representing geographic data (Haidu&Haidu, 1998; Donisă, 1999). One of the fundamental functions of GIS is digitization, the process through which analogue information, stored on physical media (such as topographic, cadastral, or soil maps), is transformed into digital format (Hill, 2006).

Research in fields related to natural sciences, especially those studying climate change, relies on the collection, exploitation, and reuse of observational data, particularly over long periods of time. Much of the necessary data, especially from the pre-digital era, is no longer accessible to studies, either because it is in paper format or because it can no longer be read, being stored on damaged or obsolete media and thus not reusable (Arrouays et al., 2017). The term legacy data is used for existing soil information collected in previous projects or contracts, or soil mapping studies, or which can be identified/read from existing soil maps. Therefore, existing (old or legacy) data on soil heritage must be saved, compiled, and processed into a common set of relevant, coherent, and geographically consistent data with useful soil properties.

The georeferencing process enables the integration, updating, and analysis of data within a digital environment, facilitating a better understanding of spatial phenomena and supporting the development of geographic databases (SSDS, 2017). Through digitization, the graphic elements of a map - such as administrative boundaries, hydrographic networks, or soil units - are converted into vector data, allowing for their analysis, editing, and correlation with other datasets. Digitization plays an essential role in creating and updating GIS databases, ensuring coherent integration of various types of information (administrative, natural resources, i.e. soil) into a unified system. In this way, spatial data becomes easy to manage, analyze, and visualize, providing real support for territorial planning and management processes, as well as for research, monitoring, and decision-making activities based on accurate geospatial information.

Typically, maps stored in archives on paper (in analogue format) do not contain geographic coordinates and do not reference a topographic grid, making precise georeferencing impossible (Hill, 2006; Hackeloeer et al., 2013).

MATERIALS AND METHODS

To put the previously presented concepts into practice, the georeferencing process of analogue maps is carried out using two main methods, depending on the input information they contain:

- an image with geographic coordinates printed in the corners of the map (usually sheet maps)
- an image that does not have geographic coordinates

For each case, the necessary steps for proper georeferencing are described. It has to be noticed that the projection is Stereo70, the usual projection of Romania.

Method for georeferencing an image that has geographic coordinates printed in the corners of the map

- Using Stereo 70 coordinates of the control points, obtained using the NEGO program and the indicative name of map sheet, which are then entered as control points during the georeferencing process – either graphically or by completing the transformation table manually.
- Using the visual boundary of the map sheet in shapefile format. In this approach, the boundary of the map sheet (in shapefile format) is displayed in the GIS environment, and the scanned image is translated and adjusted within these limits.

This method allows for quick and coherent alignment of the image to the coordinate system of the reference map.

Method for georeferencing an image that does not have tics (control points), but represents an area with well-defined boundaries (e.g., an administrative unit)

This method applies to cartographic images that lack geographic coordinates but depict a geographic area (such as an Administrative Territorial Unit - UAT) whose boundaries are known and available in digital format (shapefile).

For UATs, the official boundaries can be obtained from the ANCPI website, in the Stereo 70 projection (double-stereo projection). In practice, two situations may arise:

- the boundary of the area has the same shape on both the scanned map and the georeferenced digital layer (Figure 1). In this case, georeferencing is performed using the GIS georeferencing module, with at least four tics distributed uniformly across the image. It is recommended to choose points located in areas where the boundary shows clear directional changes (corners, distinct intersections) to ensure optimal precision.

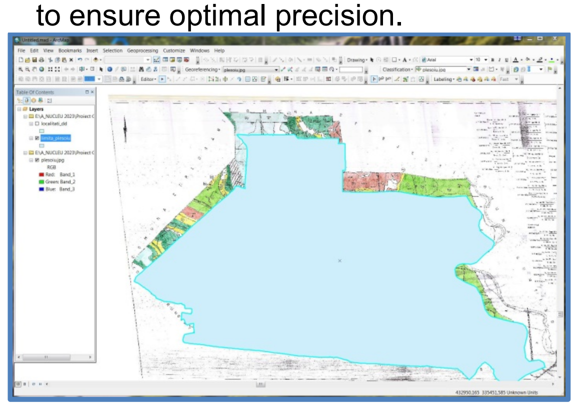

Figure 1. Georeferencing using UAT boundaries

- the boundary of the area does not perfectly match between the scanned map and the digital layer. In this case, a larger number of tics must be used, identified either in the field or by visually matching characteristic elements of the terrain or infrastructure. These may include confluence points of watercourses, intersections of roads or railways, or common points along locality boundaries (Figure 2).

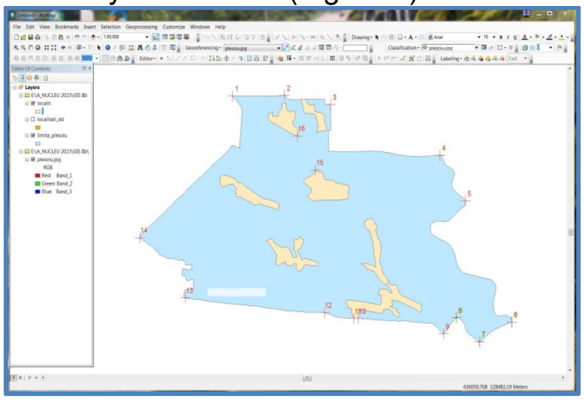

Figure 2. Georeferencing using localities limits

Increasing the number of control points improves the precision of the georeferencing process, reduces deformation errors, and ensures better alignment of the image within the reference coordinate system. After presenting the theoretical framework of digitization and georeferencing, it is necessary to illustrate how these concepts are applied in practice. While the first part of the paper explains the principles, definitions, and available methods, the following section provides a concrete, step-by-step example of a georeferencing procedure. This example demonstrates clearly and practically how the theoretical aspects translate into a real workflow within a GIS environment.

RESULTS AND DISCUSSIONS

Method for georeferencing an image that does not have geographic coordinates

Usually, the maps from BDUST do not contain geographic coordinates and are not referenced to the framework of a UAT, which makes perfect georeferencing impossible. Georeferencing can be performed based on the boundary of the administrative unit (UAT), using at least four tics (control points). This requires identifying at least four tics located on the UAT boundary that can serve as links between the coordinates of the scanned map and the coordinates of the UAT boundary. The UAT boundary has defined coordinates in the Double-Stereo projection, while the scanned image only has coordinates relative to the screen or the edges of the paper sheet.

1.Import the scanned topographic trapezoid into ArcMap using the Add Data button in the menu bar. Navigate to the directory containing the trapezoids to be georeferenced, select the desired file, and click Add.
2. From the Georeferencing toolbar, select the Add Control Points tool.
3. In the Georeferencing toolbar, turn off the Auto Adjust and Update Display options.
4. Select control point 1, located at one of the trapezoid's corners. Before doing so, use the Zoom In tool from the menu bar to choose an appropriate zoom level.
5. Enter the X and Y coordinates for each corner of the trapezoid, starting with the upper-left corner and continuing clockwise (points 1, 2, 3, 4). Note that in the transformation window, the fields are reversed: the first column corresponds to Y, and the second to X. To add a point accurately, zoom in on corner no. 1, position the cursor precisely at the intersection forming the corner, right-click, andwithout moving the mouse -left-click.
6. Right-click on Input X, Y and enter the corresponding coordinate values.
7.After entering each corner's coordinates, click the Full Extent button in the menu bar to view the entire trapezoid. Repeat this process until all four corners have been completed.
8.Once all four coordinate pairs have been entered, the trapezoid will be displayed correctly according to the assigned coordinates.
9. From the Georeferencing toolbar, click Rectify.
10.A georeferenced image is now generated, and the digitizing process can begin.

CONCLUSIONS

The difficulties encountered during the georeferencing and digitization of analogue maps stem primarily from the intrinsic limitations of historical cartographic maps. In several cases, the map of an administrative unit (UAT) is composed of two or more sheets produced in different periods or by different cartographers. In these cases, inconsistencies inevitably arise in mapping style, drawing accuracy, and the uniformity of graphic elements. These discrepancies become apparent in the GIS environment as misalignments, scale variations, missing internal areas, or noticeable mismatches between map fragments representing the same territorial unit. Another major issue concerns the mismatch between the historical UAT boundaries and the updated administrative limits. The original map, developed 10–20 years ago, reflects the territorial configuration of that period, whereas today's official datasets are precise, digitally processed, and regularly updated. This temporal gap generates significant challenges in identifying tics (control points), especially for UATs with irregular shapes, numerous curves, or areas where administrative boundaries have undergone multiple changes. Compounding these issues is the reduced legibility of map annotations – parcel numbers, soil units (US), land-use categories – which are often faded, overlapping, or incomplete. The excessive fragmentation of certain land-use units and the lack of clearly defined boundaries further complicate the digitization process. Additionally, infrastructural elements such as drainage or irrigation channels can be difficult to distinguish from roads, as graphical symbols are not always distinct, and the absence of detailed map legends makes interpretation ambiguous. These challenges do not reflect user error but are structural limitations of the analogue source material, commonly encountered in GIS integration and processing of historical maps. Their correct identification indicates a professional approach and a solid understanding of cartographic and geospatial processes.

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