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1. Introduction

The use of geographic information in decision-making is a fundamental for everyday life that often goes unnoticed. From selecting the most efficient route to work, to finding the address of a store via a smartphone, people constantly make decisions based on the analysis of geographic information, often without realizing it.

Geographic Information Systems (GIS) are valuable tools that allow for analyzing spatial data more efficiently and accurately. Using GIS, it is possible to visualize geographic data, identify patterns and trends, and make informed decisions in various contexts, including urban planning, natural resource management, traffic management, and much more. In summary, GIS is an essential tool for improving the efficiency and accuracy of decision-making based on geographic information.

According to López Trigal (2015), a GIS is an integrated system composed of hardware, software, data, and users that allows for capture, storage, manage and analyze digital information, besides the creation of graphics and maps, including the representation of alphanumeric data. Burrough (1986) defines GIS as a computerized model of geographic reality, designed to meet specific information needs, allowing for the creation, sharing, and application of useful information based on data and maps.

For many decades, GIS has been used in issues related to land and natural resource management, environment, military coordination, and in contexts related to Earth sciences, such as geography and geology. Recently, its potential use has also been explored in unprecedented fields as in Human and Social Sciences research (Del Bosque, Fernández Freire, Martín-Forero Morente, & Pérez Asensio, 2012).

ArcGIS Pro is ESRI's flagship application, encompassing classic desktop GIS functionality. ArcGIS Pro includes a set of tools that enable the visualization and management of geographic information, and has an extensible architecture, involving new functionalities. These extensions include the Spatial Analyst, 3D Analyst, and the well-known Geostatistical Analyst.

The objective of this technical manual is to introduce basic GIS concepts through the exploration of case studies that cover the entire map creation process. Although ArcGIS Pro has a wealth of tools, it is important to note that not all of them can be covered exhaustively. Instead, the purpose of this document is to help users become familiar with the general operation of the program and to motivate them to continue learning independently.

As the manual progresses, it is expected that users will acquire and improve skills, analyzing geographic information more efficiently to create high-quality maps. This document is a useful tool for those interested in developing their GIS skills and for those who wish to enhance their existing abilities.

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Without further delay, the ArcGIS Pro Manual is presented, with the expectation that it will be highly beneficial to the reader.

This manual was developed using ArcGIS Pro 3.3/3.4. Some parts were optimized with ChatGPT. The exercises are available at https://github.com/franzpc/arcpro_en

2. Geographic Terms

Geographic information in digital formats needs the standardization of criteria and the inclusion of minimum parameters to ensure its quality. This standardization enables interoperability among users, optimizing the use and exchange of information. It also facilitates the reuse and democratization of this information (SENPLADES, 2013).

Below is a glossary of the most relevant geographic terms that will be utilized throughout this document:

- **Band:** Each section of the electromagnetic spectrum classifies radiation into different wavelengths, which are captured by sensors. Radiation data is typically organized as raster files and contains numerical values collected for each defined band (Moreno, 2008).
- **Cartographic projection:** This geometric operation enables the representation of the curved surface of the Earth (three-dimensional) to a flat surface (two-dimensional). This procedure transforms the real angular coordinates of geographic objects into planar

coordinates, thus enabling their cartographic representation in two dimensions (Lopez L., 2015).

- **Coordinate:** The value of a position on the Earth's surface defines the location of any point on it, allowing for the determination of the distance between any two points. Imaginary lines, perpendicular to each other and called parallels and meridians, are used to obtain these values. Their intersection defines the position of a point in the coordinate system (López L., 2015).
- **Datum:** A parameter or set of parameters that defines position (A.282). Different coordinate systems vary in their origin, scale, and orientation [ISO 19111:2007].
- **Digital Elevation Model (DEM):** A digital elevation model, or DEM, represents the height of the terrain above sea level in a particular area. It is a numerical data structure that depicts the spatial distribution of the land surface's altitude (Mancebo et al., 2008).
- **Ellipsoid:** A surface formed by rotation around a principal axis, as the movement of the Earth. Note: The international definition specifies that ellipsoids are always oblong, meaning the axis of rotation is always the minor axis [ISO 19111:2007].
- **Geopositioning**: The measurement of an object's geographic position using a Global Positioning System (GPS) [ISO/TS 19130:2010].
- **Georeferencing**: The operation of assigning geographic coordinates to any information (usually a layer) that lacks in it. It is commonly applied to represent accurately the position of Earth images or associated events [Moreno, 2008].
- **Image**: A raster-type layer, whose attribute values are distributed in grids, representing a physical parameter in numerical form [ISO 19115-2:2009].
- **Latitude**, represented by the symbol (φ): Latitude is the angle measured from the Earth´s center between the Equator and a specific point on an ellipsoid. Circles of equal latitude form complete circles around the Earth's surface. Latitude is measured from the Equator (0°) to the poles (90°), with positive values in the Northern Hemisphere (0° to 90°) and negative values in the Southern Hemisphere (0° to -90°) (Del Bosque et al., 2012).
- **Layer**: A basic unit of geographic information according to a map in raster (grids) or vector (points, lines, or polygons) format from a server [ISO 19128:2005]. Conceptually, a layer is a portion of geographic space in a specific area, equivalent to an element of the map legend, like temperature or atmospheric pressure [SENPLADES, 2013].
- **Legend**: The application of a classification to a specific area (A.52) using a defined mapping scale and a specific dataset [ISO 19144-1:2009].
- **Longitude,** represented by the symbol (λ): Longitude is the angle measured from the Earth´s center between the zero meridian and a specified point on an ellipsoid. Points

on the Earth's surface with equal longitude form semicircles from the North Pole to the South Pole, crossing the parallels of each latitude perpendicularly (Del Bosque et al. 2012). The zero meridian passes through Greenwich, United Kingdom (0°), from which the longitude is measured up to 180° westward (positive) and eastward (negative).

- **Remote Sensing**: Broadly defined, remote sensing is the acquisition of information about an object from a distance, without physical contact between the object and the observing system, such as radar or satellite images (Sobrino, 2000).
- **Scale**: The relationship between the magnitudes of elements represented on a map compared to their real values. This involves the reduction of the real-world elements to significantly smaller maps or documents. Scale representation on a map can be graphical or numerical [López L., 2015].
- **Slope**: The ratio of change in elevation relative to distance or the length of the curve [ISO 19133:2005].
- **Vertical Datum**: A parameter defining the height or depth of a point above or below sea level. Note: Geodetic heights are related to a three-dimensional ellipsoidal coordinate system referenced to a geodetic datum [ISO 19111:2007].

3. Data Models

It might seem obvious, but before working with GIS data, it is essential that these data are in a digital format. Almost all features found on the Earth's surface can be encoded for computer processing. Depending on the type of information, one may choose a specific data model or another option.

What is less obvious is the method of representing the real world in a digital medium (ESRI, 2010). Despite the diversity of geographic information, there are two basic models for simplifying and modeling space within a computer system: (i) the vector model, which uses points, lines, or polygons, and is typically employed for discrete geographic phenomena (such as roads, urban areas, vegetation cover, etc.); and (ii) the raster model, which utilizes grids or pixels, and is generally used for continuous phenomena (like temperature and precipitation). Both models are complementary and coexist within GIS, as they are suitable for studying specific types of information (Del Bosque et al., 2012).

3.1. Vector Model

The vector data model operates on the principle that the Earth's surface consists of discrete objects, such as trees, rivers, and lagoons (ESRI, 2010). Unlike models that use basic units