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Implementation of a GIS for the Conservation of Irrigation Canals: Using ArcGIS and Python for Automation

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ABSTRACT

This study aims to automate a geographic information system (GIS) for the conservation of irrigation canals in Casaorcco, Ayacucho - Peru. The research focuses on identifying and measuring channels of different orders using specific identification tokens. A Python script was developed to optimize data processing in ArcGIS. The results showed that the study area contains first, second, and third-order channels in various conditions. The Python script significantly accelerated data processing, improving decision-making for the conservation of irrigation canals. This study demonstrates the feasibility of automating ArcGIS GIS for more effective management of irrigation canals in Casaorcco, enhancing the conservation and maintenance of water infrastructure in the region. The implications of these findings suggest that the methodology can be applied to other regions and types of infrastructure, promoting more efficient and sustainable water resource management.

1. INTRODUCTION

The geographic information systems (GIS) have become fundamental tools in the field of engineering for the management and analysis of spatial data [1]. Their capability to integrate, store, analyze, and visualize geospatial data enables users to gain a deeper understanding of the environment they work in study conducted by Calvo Rey [2]. The reason behind their use lies in the necessity to handle the complexity of spatial data. Facilitating the collection, management, and analysis of relevant geospatial data allows for more informed and efficient decision-making [3].

The conservation of irrigation channels is an essential practice in civil engineering, aiming to maintain the functionality and efficiency of irrigation structures used to distribute water to agricultural areas [4]. Channel conservation is crucial because these systems are vital for agriculture, providing a constant water supply to crops [5]. Deterioration of channels can lead to water loss, reduced agricultural productivity, and environmental issues such as soil erosion [6]. Channel conservation must ensure a reliable water supply to farmers and promote agricultural sustainability [7]. Hence, continuous evaluation of channel conditions through recurrent inventories is important [8].

The inventory and assessment process involve gathering detailed data on the conditions of existing irrigation channels, including their location, dimensions, water transport capacity, structural conditions, and any operational or deterioration issues [9]. Inventorying and assessing irrigation channels are fundamental steps in the conservation and efficient management of water resources. Conducting a comprehensive inventory of existing channels and evaluating their conservation status are essential actions to identify potential problems and establish maintenance priorities. The reason for carrying out this process lies in the need to understand the existing infrastructure and its current condition. To identify critical areas requiring immediate intervention, optimize resource usage, and ensure efficient and sustainable water supply for agriculture, the use of ARCGIS becomes an integrative tool in this process.

ArcGIS is a leading platform in the field of GIS, widely used in civil engineering due to its versatility and advanced spatial analysis capabilities [10]. The primary reason for its adoption is its robustness and extensive set of tools that enable the creation, management, and analysis of geospatial data efficiently and accurately [11]. It is applied to facilitate the visualization, analysis, and communication of spatial data related to the conservation of irrigation channels, assisting civil engineers in making informed decisions and implementing maintenance and conservation measures effectively. Therefore, the use of programming languages is fundamental [12].

Python has become a popular programming language in civil engineering due to its ease of use and a wide range of specialized libraries for data analysis and application development [13]. The reason for its adoption lies in its ability to automate repetitive tasks, perform advanced data analysis, and develop custom tools to meet project-specific needs [14]. To streamline processes, improve efficiency, and develop customized solutions contributing to the conservation and efficient management of irrigation channels through task automation and data analysis.

On the other hand, implementing a tool for monitoring the condition of channels leads to efficient management of irrigation channels, involving the implementation of practices and technologies to optimize water use, minimize losses from evaporation, infiltration, or leaks, and ensure adequate supply to agricultural areas. Efficient management of irrigation channels is crucial to ensure water availability and quality for agriculture, especially in regions with limited water resources or subject to droughts [8]. Additionally, it contributes to maximizing agricultural productivity, reducing operating costs, and minimizing the environmental impact associated with excessive or inefficient water use, which is possible through the integration of programming languages and GIS [15].

Integrating geographic information systems (GIS) with Python involves combining spatial analysis and programming tools to automate tasks, develop custom algorithms, and improve efficiency in water resources management. This is achieved by using scripts, which are computer programs written in Python, to manipulate geospatial data and perform advanced analysis [16].

It is worth noting that the integration of GIS and Python has proven to be effective in other fields, as highlighted by the study by Derbal et al. [17] in which geometric modeling was applied using digital cartography and stereography to improve technical efficiency and economic viability in mining operations.

The integration of geographic information systems (GIS) with Python involves combining spatial analysis tools and programming to automate tasks, develop custom algorithms, and enhance efficiency in water resource management. This is achieved using scripts, which are computer programs written in Python, to manipulate geospatial data and perform advanced analysis [18].

By integrating GIS and Python through the development of custom scripts, repetitive tasks can be automated, advanced spatial analysis can be performed, and predictive models can be developed for efficient management of irrigation channels. Scripts can be used to process remote sensing data, calculate hydrological parameters, identify risk areas, and generate reports automatically, streamlining workflow and facilitating data-driven decision-making. The integration of GIS and Python using scripts contributes to improving operational efficiency and sustainability of irrigation systems, ensuring adequate water supply for agriculture, and reducing the environmental impact associated with inefficient use of water resources [19].

In this scenario, the implementation of a GIS system for monitoring and conserving irrigation channels becomes an interesting field of study with great potential, as there are no precedents for creating a tool that provides this opportunity. There are research studies in other fields of study such as the one presented by Favretto et al. [14], which focuses on the development of algorithms to automate mapping of the Frontal Area Index (FAI) and the Thermal Potential Index (TPI) using GIS, specifically through ArcGIS Pro and Python. The algorithms facilitate the assessment of urban thermal and morphological conditions, contributing to the field of urban climatology and urban planning. They were implemented as independent Python script tools in ArcGIS Pro, demonstrating their applicability in a case study in São Paulo, Brazil.

On the other hand, there is the study by Julca and Espinoza [20], which addresses the development of computational tools to generate heat maps that visualize the impact of mining activities on biodiversity, specifically on the bird community, during the mine closure process. Using the Python programming language and ArcGIS software, these maps allow for analysis and development of strategies for species conservation and habitat in areas affected by mining. A case study on the species Sicalis olivascens in Peru is presented, demonstrating the utility of these tools in the assessment and monitoring of biodiversity.

Reviewing the case of the Casaorcco town in Ayacucho - Peru, regarding its irrigation channels, these are presented in a state of regular and poor conservation, so the application of a geographic information system for channel conservation is imperative to monitor and take improvement actions at the appropriate times. Based on this previous information, we conducted a study based on the management of irrigation channel infrastructure.

The objective of the research is to propose an automation tool for a geographic information system for the conservation of irrigation channels in the Casaorcco town, Carmen Alto district, Huamanga, Ayacucho. With the proposal, it is possible to identify the conservation status in real-time through data collection and processing in ARCGIS, which will allow acting appropriately to ensure the conditions of the irrigation channels.

In this context, we will explore in detail how to execute the inventory and evaluation involving gathering detailed data on the conditions of existing irrigation channels, such as location, dimensions, structural conditions, and any operational or deterioration issues. This research focuses on the integration of a GIS and Python through the development of custom scripts, to automate repetitive tasks, perform advanced spatial analysis, and develop predictive models for efficient management of irrigation channels.

2. MATERIALS AND METHODS

The implementation of a geographic information system (GIS) for the conservation of irrigation channels is an innovative approach that integrates advanced technologies such as ArcGIS and Python to automate processes and optimize the management of hydraulic infrastructures. In this section, we will detail the methodology used to carry out the implementation of this system, focusing on the configuration of ArcGIS, the development of Python scripts, and their integration for automating tasks related to the conservation of irrigation channels. Specific steps will be described for data collection, analysis of relevant variables, programming algorithms, and report generation.

For the development of this research, it is important to create a folder on "Disco local C," named "Datos" as seen in Figure 1, and within it, we will have the following: "Resultados" folder, Coordinates in CSV format (Coordenadas), Control points, Excel file "Tabla_matriz", Image of the study area.

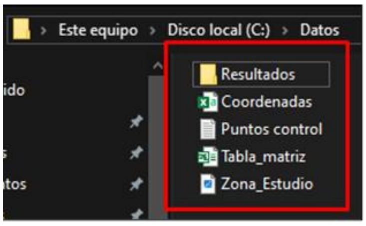

Figure 1. “Datos” folder

"Resultados" folder: A folder named "Resultados" is created, where all ArcGIS files will be created in Shapefile and TIFF formats.

Coordinates in CSV format: This is a CSV (Comma-Separated Values) file containing east and north coordinates in UTM (Universal Transverse Mercator Coordinate System) and their sample code as shown in Table 1.

Table 1. Coordinates in CSV format

Sample	East	North
S_1		
S_2		
S_3		

Control points: These coordinates will geo-reference the study area's image, as shown in Table 2.

Table 2. Control points

Control Points	East	North
Point 1		
Point 2		
Point 3		

Matrix table: In the Excel file named "Tabla_matriz," all data obtained during the inventory of the channels are compiled. This file consists of two significant sheets:

"Eval_Patol" and "General." In the "Eval_Patol" sheet, the results of the Evaluation Forms are recorded, describing the condition of the sample units (No Present "NP", Slight "L", Moderate "M", Severe "S"), as detailed in Table 3.

Table 3. Matrix table - sheet Eval_Patol

Sample	FS	GR	FR	ER	SD
S_1					
S_2					
S_3					

On the other hand, the "General" sheet (Table 4) contains a comprehensive summary of the collected data, including the sample number, the type of channel (1st, 2nd, or 3rd order), the initial and final progressive (Pro_In, Pro_Fn), the length of the sample (DIST), as well as the canal condition expressed both descriptively (Cond_D) where the following values are established: Excellent = 1, Good = 2, Poor = 3, and Very Poor = 4 and the numerical form (Cond_N). The latter is related to the results of the evaluation form, where the following values are established: No Present (Excellent), Slight (Good), Moderate (Poor), and Severe (Very Poor). Additionally, specific conditions of fissures (FS), cracks (GR), fragmentation (FR), erosion (ER), sediment (SD), as well as EAST (Start_X) and NORTH (Start_Y) coordinates are recorded.

Study area image: This is the image of the study area in JPG format, obtained from Google Earth, to enhance the visualization of the irrigation channels.

Table 4. Matrix table - Sheet general

Sample	Type of Channel	Pro_In	Pro_Fn	DIST	Cond_D	Cond_N	FS	GR	FR	ER	SD	Start_X	Start_Y
S_1													
S_2													
S_3													

2.1 Inventory and evaluation of irrigation channels

This section details the methodology for the inventory and evaluation of irrigation channels, covering data collection, variable selection, analysis methods, and result interpretation. The aim is to provide a solid foundation for informed decision-making in hydraulic infrastructure management.

Data collection uses two main instruments: the Evaluation Form (Table 5) and the Inspection Form (Table 6). The inventory process involves visiting the study area and collecting data with a GPS device, a 50-meter tape measure, and the Inspection Form.

Table 5. Evaluation form

Evaluation Form										
	Sample unit						Severity level (N.S)			
Progressive							Not present	NP		AREA
Author							Slight	L		
Length							Moderate	M		
Date							Severe	S		
	Right lateral			Canal bed			Left lateral			
Type of pathology	Area	m^2		Area	m^2		Area	m^2		Severity level of pathology
	Area with pathology (m^2)	%	N.S.	Area with pathology (m^2)	%	N.S.	Area with pathology (m^2)	%	N.S.	
Fissure										
Crack										
Fracturing										
Erosion										
Sedimentation										

Table 6. Inspection form

Inspection Form for Sample Units							
Sample							
Author							
Progressive							
Date							
Type of pathology		Right lateral	Canal bed	Left lateral	Severity level Slight	Moderate	Severe
Fissure	Longitudinal Transversal				Width of opening less than 1 mm	Width of opening between 1 and 2 mm	Width of opening greater than 2 mm
Crack	Longitudinal Transversal				Width of opening between 2 and 3 mm	Width of opening between 3 and 4 mm	Width of opening greater than 4 mm
Fracturing	Longitudinal Transversal				No separation	Blocks separated from 3 to 10 mm	Separation > 10 mm, concrete removal
Erosion	Longitudinal Transversal				Material loss < (e/12) mm	Material loss between (e/12) < (e/6) mm	Material loss > (e/6) mm
Sedimentation	Longitudinal Transversal				Base layer less than 1 cm	Base layer between 1 and 5 cm	Base layer greater than 5 cm

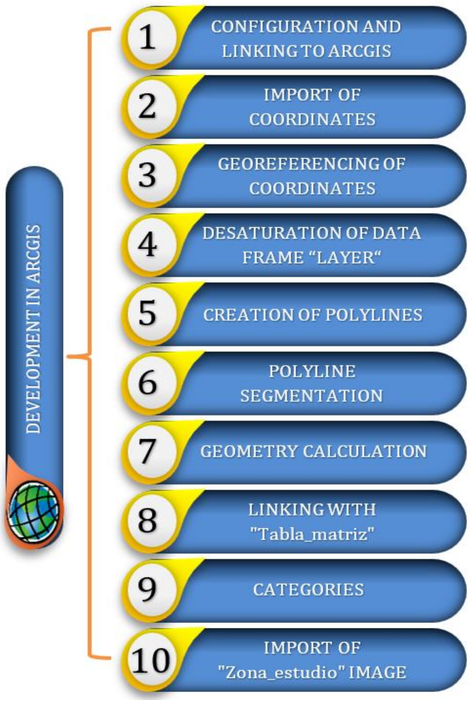

Figure 2. Steps for development in ArcGIS

2.2 Development in ArcGIS

The project in the ArcGIS software begins with the preparation of files and folders stored in the "Datos" folder. The results of the irrigation channel inventory are processed using the evaluation form (Table 6) and recorded in the Excel file named "Tabla_matriz," specifically in the "Eval_Patol" sheet (Table 3). Subsequently, these results are converted into their corresponding numerical form called "Cond_N." For this purpose, all available data in Table 4 are used. The procedure is divided into 10 steps, as illustrated in Figure 2. The results obtained from these 10 steps are reflected in the "Resultados" folder, as shown in Figure 1. This systematized process ensures proper organization and processing of data, allowing for efficient project management from its inception to the generation of results.

2.2.1 Configuration and linking in ArcGIS

The process begins with the initial setup in ArcGIS and the subsequent saving of the file in the "Resultados" folder. The corresponding coordinate system for the study area will be established, which in this case is zone 18S, therefore the "WGS 1984 UTM Zone 18S" system will be used. The file will be saved in "mxd" format, which is the standard ArcGIS format, and will be located in the "C:/Data/Resultados" folder with the name "Desarrollo.mxd".

Next, the "Datos" folder will be linked using the "Connect to Folder" tool in ArcGIS.

2.2.2 Import of coordinates

The second step involves importing the "Coordenadas.csv" file. To do this, simply drag the file into the ArcGIS table of contents. It is important to note that the format of "Coordenadas.csv" is as follows: the columns represent "Sample", "EAST", and "NORTH", respectively. By performing this action, a visualization layer will be automatically generated in ArcGIS with the imported file data.

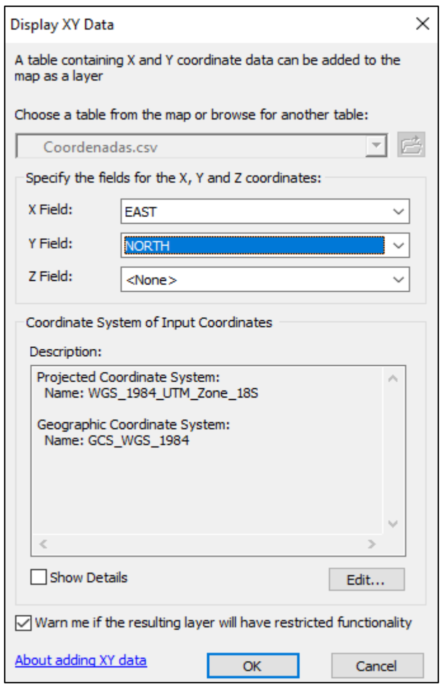

Figure 3. Display XY data

2.2.3 Georeferencing of coordinates

After importing the "Coordenadas.csv" file, we will use the

"Display XY Data" tool to georeference the coordinates. In the "X Field" section, corresponding to the X-axis coordinates, we will select the "EAST" field. For the "Y Field" field, we will choose the "NORTH" field. It is essential to verify that the coordinate system is correctly configured, ensuring that it matches the coordinate system of the study area. This check is performed in the tool's dialog box and can be visually confirmed in Figure 3.

After using the "Display XY Data" tool, a point layer will have been created in ArcGIS, with attributes from the "Coordenadas.csv" file. To ensure error-free work, it is essential to export the "Coordenadas.csv Events" layer to a point Shapefile (shp).

To perform this export, we will use the "Export Data" tool. It is important to verify that the output folder is correct, in this case, the "Resultados" folder. Additionally, we will assign the name "Coordenadas_shp" to the exported file and ensure that the file type is selected as "shapefile". This way, we will obtain a Shapefile containing the georeferenced points with the attributes from the original file.

2.2.4 Desaturation of data frame "Layers"

Once the Shapefile (shp) of coordinates has been created in the results folder, to avoid cluttering the Data Frame, we will use the "Remove" tool to delete the visualization layers created earlier. Subsequently, we will import the "Coordenadas_shp" Shapefile into the project.

It is important to mention that desaturation of the Data Frame will be performed several times throughout the research process to improve readability and focus on relevant data. This step will be repeated as needed to facilitate analysis and interpretation of the results obtained.

2.2.5 Creation of polylines

The next step involves creating a polyline using all the points from the "Coordenadas_shp" file. To do this, we will use the "Point to Line" tool, available in "ArcToolbox/Data Management Tools/Features/Point to Line".

In the "Input Features" section, we will select the "Coordenadas_shp" file. For the "Output Feature Class" option, specifying the output folder and file name, we will choose the "Resultados" folder "C:/Datos/Resultados" and assign the name "PL_Coordenadas", which will be saved as a shp file.

The parts that need to be modified in the "Points to Line" tool to perform this operation are highlighted in Figure 4.

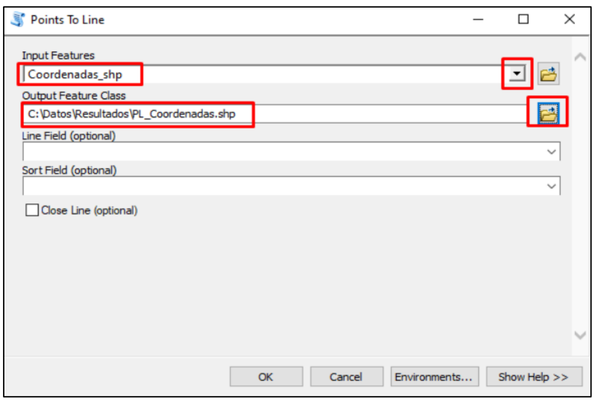

Figure 4. Points to line

2.2.6 Polyline segments

Once we have obtained the new shp file "PL_Coordenadas," which represents a single polyline without attributes, as shown in Figure 5, we will proceed to use the "Split Line at Point" tool (Figure 6), available in "ArcToolbox/Data Management Tools/Features/Split Line at Point."

This tool fragments the polyline based on the points from the "Coordenadas_shp" file, generating polyline segments that represent the field samples taken. For the tool to function correctly, both "PL_Coordenadas" and "Coordenadas_shp" need to be in the ArcGIS Data Frame.

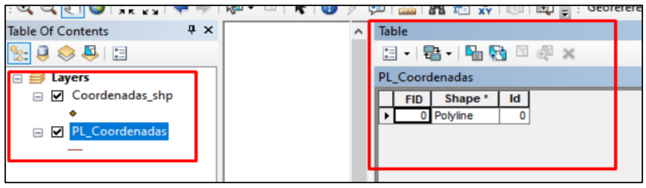

Figure 5. PL_Coordenadas without attributes

The configuration of the files in the tool will follow as highlighted in Figure 6, considering the output folder and assigning the name "seg_shp." To improve accuracy in the cutting process, a value of 0.001 will be set for the "Search Radius" parameter.

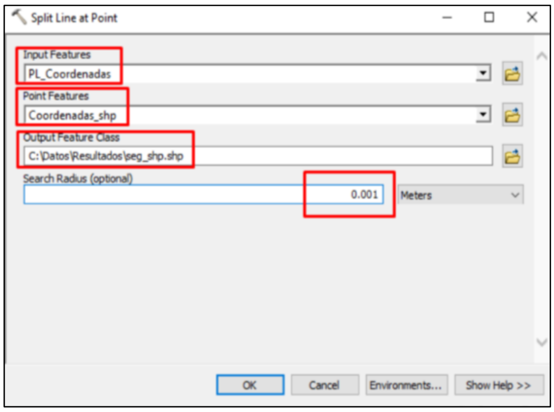

Figure 6. Split line at point

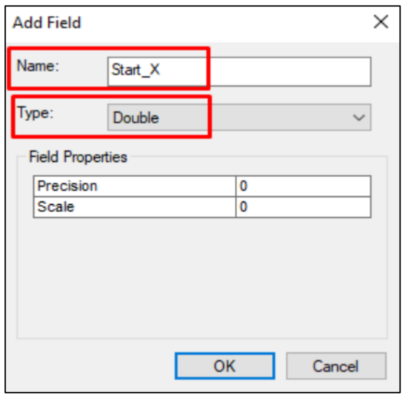

Figure 7. Add field

After using the aforementioned tool, the shapefile "seg_shp" generates 163 polylines, which represent the field-evaluated samples. In order to add the attributes available in the Excel file "Tabla_matriz", it is necessary for the shapefile to have similar fields.

Therefore, we will proceed to use the "Add Field" tool (Figure 7), which allows adding fields to the attribute table. In this case, we will add fields for the initial coordinates of each segment. We will label the X coordinate as "Start_X" and the Y coordinate as "Start_Y". These fields will be of type "Double", as they will represent numerical coordinates.

2.2.7 Geometry calculation

Then, to populate the coordinates in the attribute table, we will use "Calculate Geometry", and the property will be chosen for both X and Y, providing the coordinates to each polyline as shown in Figure 8.

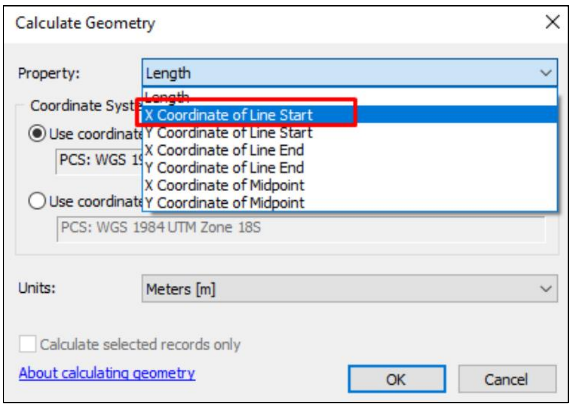

Figure 8. Calculate geometry

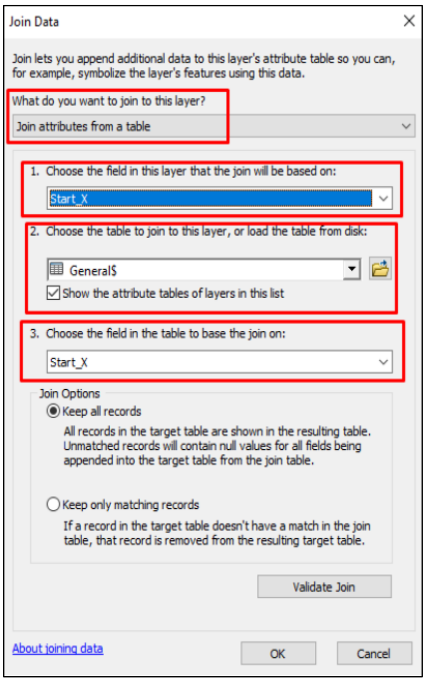

Figure 9. Join data

2.2.8 Linking with "Tabla_matriz"

To maintain proper order, we will once again use the "Remove" tool to delete all files except the "seg_shp" shapefile. Now that this file already contains the initial coordinates of each segment, we can establish a link with the attributes of the Excel file "Tabla_matriz", which must be saved in "Excel 97-2003 Workbook" format to be compatible with ArcGIS.

We will bring the "Tabla_matriz" file into the ArcGIS Data Frame, specifically selecting the sheet named "General". We will use the "Join Data" tool to add attributes to the "seg_shp" shapefile, as shown in the highlighted part of Figure 9. This way, we will link the attribute information from the Excel file to the polylines in the shapefile.

2.2.9 Categories

Once we have obtained the attributes for each sample, we proceed to categorize and format them for visualization. To do this, we access the layer properties and go to the "Symbology" tab. Then, we select "Categories" and "Unique Values". In this section, we choose the field to evaluate, which in this case will be "Cond_N", and add all available values. Subsequently, we select the desired color ramp to represent the different categories of values. This configuration is highlighted in Figure 10. This way, we achieve a clear and effective visual representation of the data according to its classification.

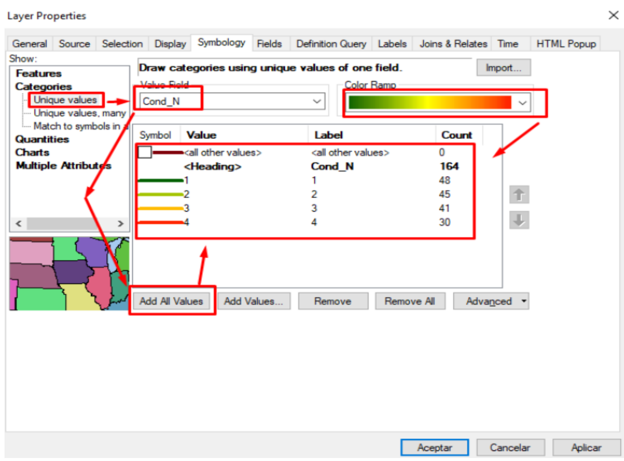

Figure 10. Categories of layers

2.2.10 Importar imagen “Zona_Estudio”

To import the image generated with Google Earth, "Zona_Estudio," we proceed similarly to how it was done previously. However, since it is not georeferenced, it may not display correctly in the Data Frame. To address this, we will use the "Zoom to Layer" tool to focus on the imported image.

Then, we will proceed to georeference the image using control points and the "Add Control Points" tool. We will start by clicking on control point 1 "Ctr 1" and then right-click to display a menu. We will select "Input X and Y" to manually enter the control point coordinates, as shown in Figure 11. It is recommended to perform georeferencing using at least four control points to mitigate GPS error and achieve greater precision in georeferencing.

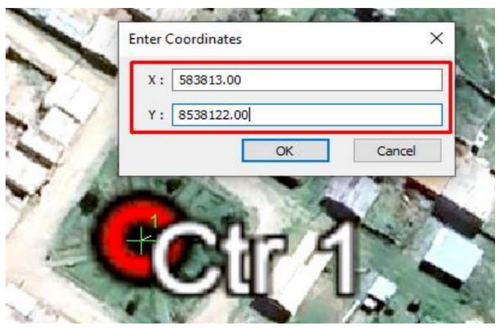

Figure 11. Control points

Once georeferenced, we save it using "Update Georeferencing" and export it using "Export Data" as a "TIFF" file, named "Zona_Estudio.tif".

2.3 Python script

The automation and geospatial analysis process was carried out using a Python script that integrates the "arcpy" ArcGIS library and "pandas" for data manipulation. Each step of the code used is described in detail below:

Definition of coding and libraries. The script begins by setting the file encoding to UTF-8 to handle special characters and accents in the text. Next, the "arcpy" libraries are imported to work with geospatial data and "pandas" for data manipulation.

Definition of the main function. A function called "process" is defined that contains the main flow of the script, allowing the reuse and organization of the code.

Creating an XY event layer. The first step within the "process" function is to convert a CSV file containing coordinates into an XY event layer in ArcGIS. The "EAST" and "NORTH" columns are specified as the X and Y coordinates respectively, and the UTM zone 18S coordinate system is defined using the EPSG code "32718".

Conversion to shapefile. The XY event layer is then converted to a shapefile, which is saved in the "Results" folder.

Generation of lines from points. Lines are created from the points in the previously generated shapefile, resulting in a new shapefile of lines.

Line segmentation at intersection points. The generated lines are divided into segments at the points of intersection with the original points, and the result is saved in a new shapefile. The segmentation precision is specified as "0.001 Meters".

Layer Management in ArcGIS. References are obtained to the current map document ("mxd") and to the data layers (Coordenadas_csv, PL_Corrdenadas, Coordenadas_shp). These references allow manipulation of layers within the ArcGIS environment.

Elimination of intermediate layers. To keep the work environment clean and organized, the intermediate layers of the ArcGIS Data Frame are removed. This ensures that only the necessary layers remain visible and manageable in the project.

Configuration of the work environment. The working directory is defined as the path of the segmented shapefile and overwriting of existing files is allowed. This ensures that the results are saved in the correct location and that any existing files are replaced if necessary.

Adding fields to the attribute table. Several fields are added to the attribute table of the segmented shapefile to store additional information, such as start coordinates (Start_X, Start_Y), sample, properties, and conditions.

Initial Coordinates Update. The values of the "Start_X" and "Start_Y" fields are updated with the initial coordinates of each polyline in the shapefile. This allows you to link the attributes of the shapefile with those of the Excel file.

Reading data from Excel. Reads the Excel file "Table_matrix.xls" using the "pandas" library and stores it in a DataFrame. This allows data to be managed in a structured and efficient way.

Creation of a data dictionary. It iterates over each row of the DataFrame and creates a dictionary where the keys are the values of "Start_X" and the values are a set of corresponding attributes. This makes it easier to compare and verify data.

Update attributes in the shapefile. Using an update cursor, the fields of the segmented shapefile are looped and updated with the values from the dictionary based on "Start_X". This transfers the attribute contents in the Excel to the shapefile.

Export of the Updated Shapefile. Finally, the updated Shapefile is exported as a new Shapefile in the Results folder, consolidating all changes made.

```
-*- coding: utf-8 -*-
import arcpy
import pandas as pd

def proceso():
    arcpy.MakeXYEventLayer_management("C:/
Datos/Coordenadas.csv","ESTE","NORTE","Coorden
adas_csv",32718)

arcpy.FeatureClassToFeatureClass_conversion( "Coor
denadas_csv","C:\Datos\Resultados","Coordenadas_s
hp")

arcpy.PointsToLine_management( "Coordenadas_shp
",r'C:/Datos/Resultados/PL_Corrdenadas')

arcpy.SplitLineAtPoint_management( "PL_Corrdenad
as", "Coordenadas_shp","C:\Datos
/Resultados\seg_shp.shp",'0.001 Meters')
    mxd = arcpy.mapping.MapDocument("current")
    df = arcpy.mapping.ListDataFrames(mxd,
"Layers")[0]
    cordcsv = arcpy.mapping.ListLayers(mxd,
"Coordenadas_csv")[0]
    PL_cord = arcpy.mapping.ListLayers(mxd,
"PL_Corrdenadas")[0]
    cordshp = arcpy.mapping.ListLayers(mxd,
"Coordenadas_shp")[0]

    arcpy.mapping.RemoveLayer(df,cordcsv)
    arcpy.mapping.RemoveLayer(df,PL_cord)
    arcpy.mapping.RemoveLayer(df,cordshp)

    shapefile_path = r'C:\Datos\Resultados
\seg_shp.shp'
    arcpy.env.workspace = shapefile_path
    arcpy.env.overwriteOutput = True

shapefile_path = r'C:\Datos\Resultados \seg_shp.shp'
    excel_path = r'C:\Datos\Tabla_matriz.xls'

    df_excel = pd.read_excel(excel_path,
sheet_name='General')

    excel_data_dict = {}
    for index, row in df_excel.iterrows():
        start_x_value = row['Start_X']
        attributes = {
            'Muestra': row['Muestra'],
            'Pro_In': row['Pro_In'],
            'Pro_Fn': row['Pro_Fn'],
            'Cond_D': row['Cond_D'],
            'Cond_N': row['Cond_N'],
            'FS': row['FS'],
            'GR': row['GR'],
            'FR': row['FR'],
            'ER': row['ER'],
            'SD': row['SD'],
        }
        excel_data_dict[start_x_value] = attributes
```

3. RESULTS

3.1 Inventory and evaluation of irrigation channels

Within the framework of the irrigation channel inventory conducted in the Casaorcco – Carmen Alto – Huamanga – Ayacucho region, the length of three different categories of channels was identified, as detailed in Table 7. Additionally, a comprehensive evaluation of the second-order channel was carried out, obtaining results on the conditions of said channel in 15-meter sections, as well as the quantity of samples evaluated, as presented in Table 8.

Table 7. General inventory of channels in the study area

Type	Length	Material
First Order	1,455 m	Concrete
Second Order	2,461 m	Concrete
Third Order	1,888 m	Earth

Table 8. Second-order channel evaluation

Condition	Samples	Percentage
Excellent	48	29%
Good	45	28%
Poor	41	25%
Very Poor	30	18%
TOTAL	164	100%

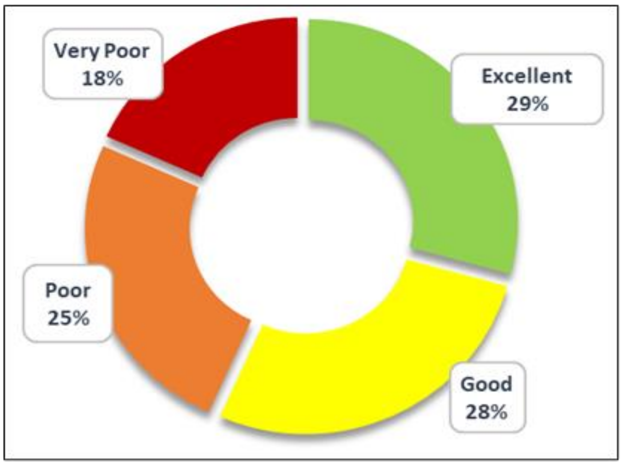

Figure 12. Evaluation results

According to Figure 12, the distribution of conditions (29% Excellent, 28% Good, 25% Poor, 18% Very Poor) indicates a general condition of deterioration in the second order channel, with more than 43% of the samples evaluated in Poor or Very Poor conditions. This suggests the need for maintenance or rehabilitation interventions.

3.2 ArcGIS development

Following the segmentation of the sections based on their condition, we have the opportunity to analyze each stratum separately. This allows for a more detailed visualization of the samples, as well as a more precise understanding of their distribution in each condition category. Furthermore, this methodology facilitates the possibility of individually examining each sample, detailing its characteristics and the results of its evaluation, providing a more comprehensive understanding of the quality and condition of the channels under study. In Figure 13, a pattern is observed where the sections with very poor severity levels are predominantly found in areas close to residential zones, highlighting the influence of human activity on the deterioration of the channels. This pattern is also reflected in other sections of the canal, indicating a widespread trend of deterioration in areas with higher residential presence.

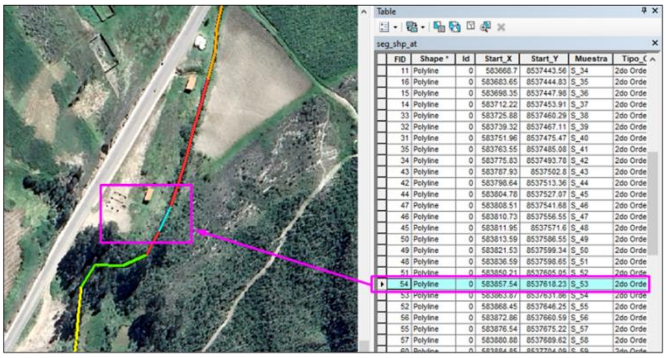

Figure 13. Result per sample unit

3.3 Python script development

The process of developing and executing the Python script, compared to operations performed in ArcGIS, revealed a significant reduction in processing time. While in ArcGIS, ten different steps were carried out, from initial setup to importing images of the study area, the Python script effectively replaced steps 2 through 8. In detail, the Python script facilitated the import of coordinates from external files, their georeferencing, the creation and segmentation of polylines, as well as the calculation of the corresponding geometry. Additionally, it automated the linking of tables, eliminating the need for manual intervention. These processes were carried out using specialized libraries and tools, such as Pandas and ArcPy, according to the specific requirements of each step. Below is the source code resulting from the conducted research, which can be applied to all projects of the same nature or modified as required.

This approach proved to be highly efficient, reducing processing time by an impressive 70%, as shown in Figure 14.

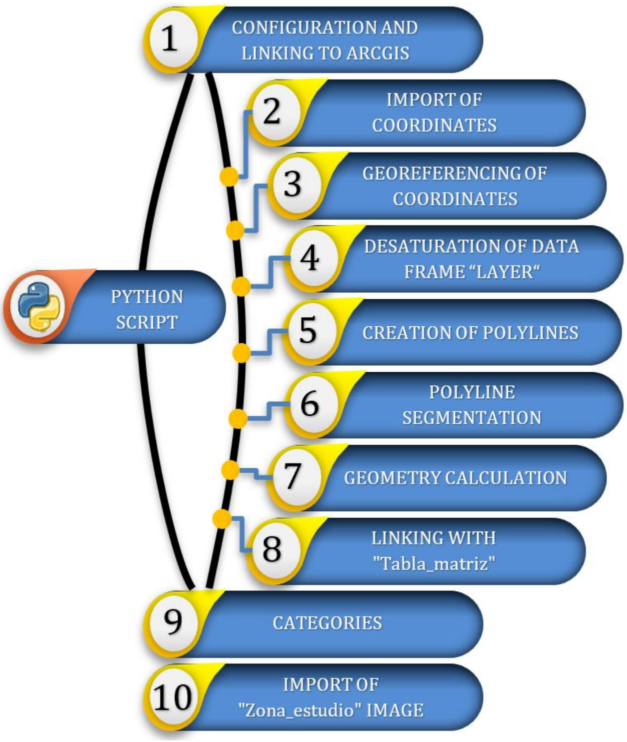

Figure 14. Development in ArcGIS vs. Python

This level of improvement in operational efficiency not only highlights the effectiveness of the method employed but also underscores its relevance in the context of hydraulic project management. The ability to significantly reduce processing time not only optimizes available resources but also streamlines the decision-making process, which is crucial in environments where the management and conservation of hydraulic infrastructure demand agile and precise responses.

The results obtained in this research have significant implications for irrigation management and sustainable agriculture. The precise identification and evaluation of the condition of irrigation channels enable more efficient management, prioritizing areas that require immediate attention and optimizing the use of available resources. The significant reduction in processing time through the use of Python not only speeds up decision-making but also allows for a quicker response to identified issues, which is crucial in environments where the conservation of water infrastructure is essential for agricultural productivity. These findings underscore the need to integrate advanced technologies in water resource management to improve operational efficiency and ensure a sustainable water supply. Additionally, the results have broader implications for water resource management, suggesting that automation and advanced analysis can be applied to other irrigation systems and types of water infrastructure, promoting more sustainable and resilient practices. This study also highlights the importance of updating current policies and practices to incorporate technologies that enable more proactive and efficient water resource management, aligning with sustainable development goals in the agricultural sector.

Comparing our findings with previous studies, it is observed that the automated approach presented in this study aligns with the results of Derbal et al. [17], who also found significant improvements in operational efficiency through GIS automation. However, our study differs in its specific application to the conservation of irrigation canals, which has not been widely explored in the literature.

This study contributes to the existing body of knowledge by demonstrating the feasibility and effectiveness of integrating GIS and Python in irrigation canal management and conservation. The findings suggest that the methodology can be applied in other regions and types of infrastructure, promoting more efficient and sustainable management of water resources.

4. CONCLUSIONS

The automation of a geographic information system (GIS) plays a crucial role in improving the conservation of irrigation channels in the Casaorcco community. The evaluation reveals the diversity of channel conditions, highlighting the need for efficient management to ensure their optimal functioning. Different orders of channels were precisely identified, providing a clear view of the water infrastructure. The detailed assessment revealed valuable data on channel quality, enabling the prioritization of areas requiring immediate attention and the planning of long-term conservation actions.

The use of ArcGIS software has revolutionized the understanding and management of water infrastructure. This technological tool has facilitated the mapping, analysis, and understanding of the irrigation system, enhancing decision-making and the efficiency of conservation work. The introduction of a Python script designed to accelerate data processing in ArcGIS has been fundamental in the pursuit of efficiency and sustainability. This script has significantly reduced processing time, enabling quicker and more effective decisions regarding the conservation of irrigation channels.

This study underscores the importance of automation in managing water infrastructure, demonstrating how the integration of GIS and Python can optimize the conservation of irrigation channels. The employed methodology not only improves operational efficiency but also provides a robust tool for informed decision-making. However, the study presents certain limitations. The accuracy of the data largely depends on the precision of the GPS and the quality of the in situ collected data. Additionally, the developed methodology was applied in a specific region, so its applicability in other regions with different geographical and climatic characteristics needs to be validated.

For future research, it is recommended to explore the scalability of the methodology to other regions and types of water infrastructure. It would be valuable to investigate how this tool can be adapted for managing other infrastructures, such as sewer systems or stormwater drainage. Additionally, further research could integrate additional technologies, such as IoT sensors for real-time data collection, to further enhance the system's accuracy and efficiency. The developed methodology has high scalability potential and can be applied in various regions with minimal adjustments. The flexibility of the Python script allows its adaptation to different contexts, facilitating its use in conserving various infrastructures. Implementing this methodology in other areas could provide significant benefits, optimizing the management and conservation of water resources globally.

To strengthen future research and applications, it is recommended to validate the methodology in different geographical and climatic contexts, integrate emerging technologies like IoT sensors to improve data collection, develop additional modules in the script to extend its functionality to other types of infrastructure, and promote collaboration between academic institutions and government entities for continuous implementation and improvement of the methodology. In summary, this study highlights the relevance of automation in the conservation of irrigation channels and provides a solid foundation for future research and applications in water infrastructure management.

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NOMENCLATURE

NP	No present, dimensionless
L	Slight, dimensionless
M	Moderate, dimensionless
S	Severe, dimensionless
Pro_In	Initial progressive, m
Pro_Fn	Final progressive, m
DIST	Length of the sample, m
Cond_D	Descriptive channel condition, dimensionless
Cond_N	Numeric channel condition, dimensionless
FS	Fissure, mm
GR	Crack, mm, cm
FR	Fracturing, mm, cm
ER	Erosion, mm
SD	Sedimentation, cm
NS	Severity level, dimensionless