

Generation of heat maps for the preservation of biological diversity up to mine closure by computer programming

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Abstract

Mine Closure is a legal instrument that guarantees the prevention, minimization, control of risks and effects on health, safety of people, environment, surroundings, property that could be generated during the completion of mining operations.

The description of the biological environment is part of the content of the Mine Closure Plan and includes the characterization and dynamics of the flora and fauna, based on biological diversity indexes such as abundance, distribution, conservation status, according to the national list of endangered species and degree of endemism. Additionally, the characterization of fragile ecosystems, Natural Areas, Buffer Zones, landscape units and elements that could threaten the conservation of ecosystems. It is of utmost importance to integrate biological information due to the intrinsic value of biological diversity, ecological, genetic, social, economic, scientific, educational, cultural, recreational and aesthetic values of biological diversity.

These indices measure the impact before, during and after the cessation of mining operations, numerically; however, this data does not allow us to visually observe the impact on flora and fauna communities. Therefore, there is a need to generate tools that optimize the evaluation of the impact on the biological environment and thus generate strategies that allow its conservation.

The objective of this project is the development of computer tools that allow visualizing the impact that mining activities have had on the flora and fauna communities, from the construction phase to the moment of its closure.

Programming in Python language in conjunction with ArcGIS software makes it possible to generate "heat maps" in an instantaneous, versatile and adaptable way for the analysis of flora and fauna communities. Through the tool, the user will be able to enter information and maintain an updated database, obtained from biological monitoring of flora or fauna, generating visual representations and values. In order to analyze any disturbance in the species and their ecosystems, with the purpose of implementing timely strategies to minimize their affectation and guarantee the conservation of the species to the communities or parts of interest.

Keywords: Restoration, Biodiversity, Computer Programming, Python, ArcGIS

1 Introduction

Mine closure is a legal process that aims to prevent and control the negative health, safety and environmental impacts generated at the end of mining operations. The Mine Closure Plan includes a description of the biological environment, including the characterization and dynamics of flora and fauna, as well as biodiversity indices, such as the abundance, distribution and conservation status of endangered and endemic species. The identification of fragile ecosystems, Natural Areas, Buffer Zones and other elements that may threaten the conservation of ecosystems is also considered. It is essential to integrate biological information due to the intrinsic value and multiple benefits that biological diversity provides.

Although these indices provide numerical measurements of the impact of mining operations on biodiversity, they do not allow a clear visualization of the impact on flora and fauna communities. Therefore, the need

arises to develop tools that optimize the visual assessment of the impact on the biological environment and allow the generation of effective strategies for its conservation.

The objective of this project is to develop software tools using the Python programming language and ArcGIS software to visualize the impact of mining activities on flora and fauna communities from the construction phase to mine closure. These tools are based on the generation of instant, versatile and adaptable "heat maps" for the analysis of flora and fauna communities. Users will be able to enter information and maintain an updated database of biological monitoring data, which will generate visual representations and statistical values. This will allow the analysis of disturbances in species and their ecosystems, and take timely measures to minimize their impact and ensure the conservation of species in the communities of interest.

2 Methodology

The project was carried out to evaluate the impact of mining activities of the Lincuna Mining Unit on the populations of the Greenish Chirigüe (*Sicalis olivascens*), a bird endemic to the region of Huancavelica, Peru. The study was conducted during the period from the Dry Season (July-November 2021) to the Wet Season (December-March 2023).

2.1 Mining unit

The Lincuna Mining Unit is a mining operation located in the Ancash region of central Peru. It is engaged in the extraction and processing of minerals, especially zinc and lead, which are metals of great industrial importance.

Lincuna is a subway mine that exploits mineral deposits in the Huancapeti area. This area, located in the province of Huancavelica in the central highlands of Peru, is known for its wealth of mineral resources and has been the subject of several mining operations over the years. The Lincuna Mining Unit is part of the Peruvian mining industry and contributes significantly to the country's economy. The extraction of zinc and lead at this mine is essential for the production of metals used in various sectors, such as construction, automobile manufacturing and the electronics industry.

2.2 Avifauna monitoring

2.2.1 *Unlimited point count method.*

2.2.2 *Quantitative assessment*

The avifauna assessment was carried out using the unrestricted point count method. Limited to distance, this method consisted of the observer remaining at a fixed point and taking note of all birds sighted and heard in a given time, using unbounded distances with a variable radius (MINAM, 2015a).

This method is the most widely used in the evaluation of birds for environmental studies, because it allows us to calculate abundances in areas with different types of habitats and to identify the population the population status of the birds recorded.

It is also specified that, as part of the species identification, the scientific and common names were those proposed by the SACC (South American Classification Committee) (Remsen et al., 2019), which is the official governing body in charge of standardizing the nomenclature and ordering used for the birds of South America; Likewise, we used the field guide Birds of Peru by Plenge.

At the beginning of each counting point (CP), a wait of three (03) to five (05) minutes was considered in order to minimize the disturbance generated by the minutes in order to minimize the disturbance generated by the evaluator, then the visual/auditory sampling time was ten minutes. the visual/auditory sampling time was ten minutes, and these would have a distance of 200 m. a distance of 200 m; a total of 20 counting points

were carried out per evaluation station. counting points were performed per evaluation station. The evaluation of the counting points was carried out in the early morning (6:30 - 11:30) and afternoon (15:00 - 18:00), coinciding with the hours of greatest bird activity. the hours of greatest bird activity. Binoculars were used to visualize the species. Vortex 8 x 42.

It should be noted that no individuals were captured for any reason, all individuals were recorded visually with the Vortex 8 x 42 binoculars.

individuals were recorded visually with the method described above.

2.2.3 *Opportunistic observations*

These observations are those that were made without any order, time, distance or any other type of parameter. other type of parameter. For the study, records were made during other activities other than the evaluation activities (such as travel), during which time qualitative information on the presence/absence of species was recorded using qualitative information on the presence/absence of species was recorded through indirect methods (songs, tracks, shelters, nests, nests, feces, scavenging, feathers and/or carcasses), which allowed the detection of less conspicuous species. less conspicuous species.

2.2.4 *Frequency*

The frequency of monitoring and reporting was semiannual. The parameters to be evaluated were: Species Richness, Abundance, Shannon Wiener Diversity Index, Simpson's Index, Equity Index, Conservation Categories and Endemism.

2.3 Fauna species: *Sicalis olivascens*

The species *Sicalis olivascens* is a small bird that inhabits the region of Huancavelica, Peru. This species belongs to the Tyrannidae family and measures approximately 10 centimeters in length. Its plumage is predominantly olive green above and greenish yellow below. It has a slightly crested crown and a distinctive white eye ring, with a short black bill.

The Greenish Chirigüe is found mainly in montane forests and areas of dense vegetation in Huancavelica. It prefers mountain habitats with shrubby vegetation, cloud forests and forest edges. It feeds mainly on insects, which it captures in flight or searches through vegetation.

This species plays an important role in the Huancavelica ecosystem as part of the local avifauna. It contributes to the control of insect populations in its habitat, which helps maintain the ecological balance. In addition, the Green Chirigüe acts as an indicator of the health of the ecosystem, reflecting the quality of the forests and the availability of food resources. Therefore, its conservation and protection are essential to maintain biodiversity and environmental balance in Huancavelica.

2.4 Tool

The tool developed is based on the use of ArcGIS software and the Python programming language, taking advantage of the integrated ArcGIS interface. ArcGIS is a versatile tool that allows generating thematic maps, analyzing geographic information and performing geostatistical analysis. Python is a high-level programming language used to develop applications in various fields.

The tool allows information to be entered into an Excel-type database and the study area to be defined using shapefile files. The database contains information on biological monitoring, including the species, monitoring stations, UTM geographic coordinates and the number of times the monitoring was recorded. The internal code of the tool uses the statistical technique of Kriging interpolation to generate a spatial representation of the analyzed species, which facilitates the analysis of the disturbance caused by mining activities on the species and its environment.

2.5 The database

The Excel-type document is made up of the inventory of records of the species *Sicalis olivascens* from the dry season (DS) of 2021 (July-November) to the wet season (WS) of 2023 (December-March). In this database the species are entered with their respective year of identification and the monitoring stations declared by the Lincuna Mining Unit, as shown below:

Table 1 Presence of *Sicalis Olivascents* during biology monitoring

SAMPLE	XCOORD	YCOORD	<i>Sicalis olivascens</i> (DS_2021)	<i>Sicalis olivascens</i> (WS_2022)	<i>Sicalis olivascens</i> (DS_2022)	<i>Sicalis olivascens</i> (WS_2023)
AV-2	222282	8922826	0	0	1	0
AV-3	223406	8921977	1	0	2	0
AV-5	220482	8919818	7	5	3	0
AV-7	223497	8922039	25	0	15	0
AV-10	222577	8919760	3	0	2	0
AV-11	222640	8919238	0	0	0	1
AV-12	220037	8921344	0	0	0	0
AV-15	215480	8918181	3	0	5	1

3 Results

This section will present the results obtained with the generated tool.

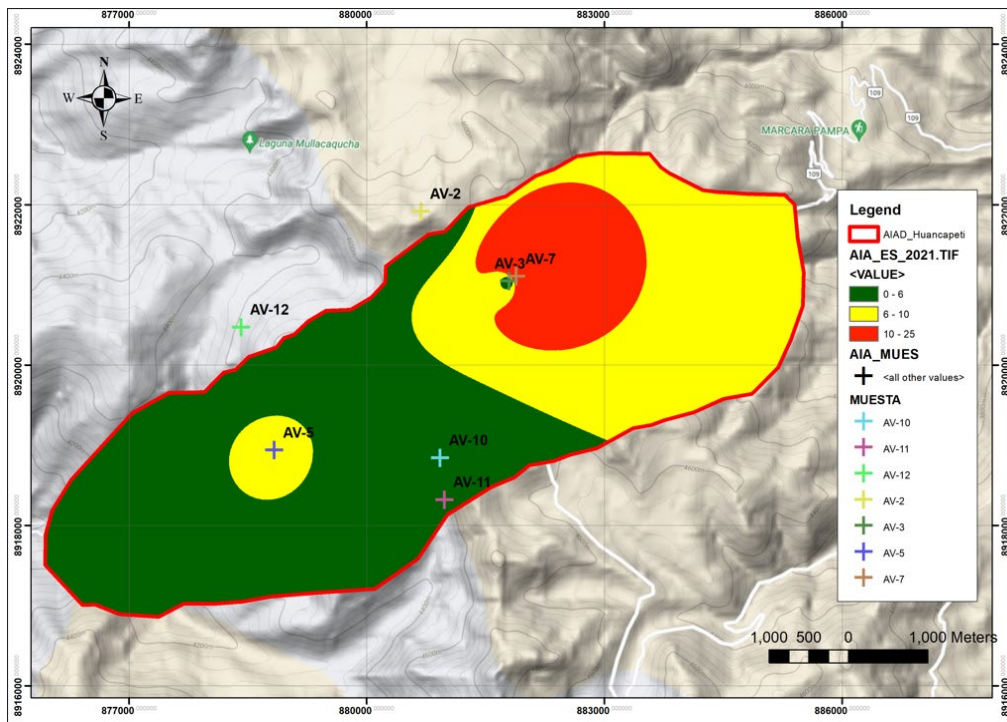


Figure 1 Presence of *Sialis Olivascents* during biology monitoring, during dry season 2021

During the dry season of 2021, it is observed that the species has a greater presence (10-25) in the area near the biological monitoring stations AV-3 and AV-7. Likewise, it is observed that the species is present but reduced, ranging from 0-6.

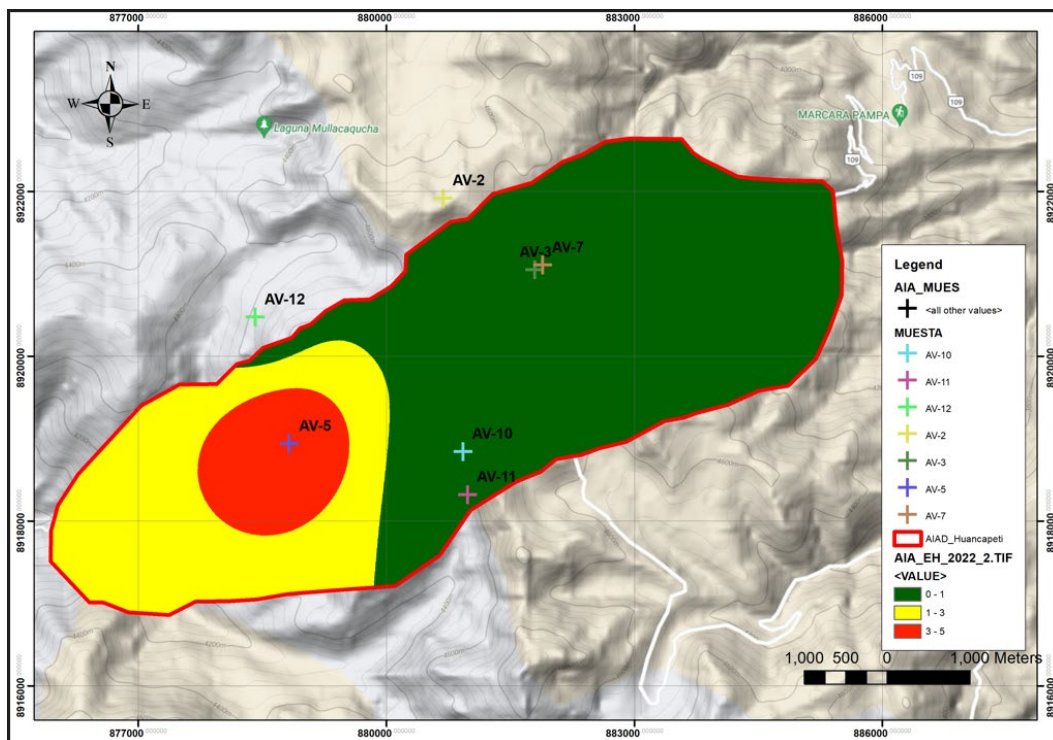


Figure 2 Presence of *Sialis Olivascents* during biology monitoring, during wet season 2022

During the wet season of 2022, a greater presence of the species (3-5) is observed in the area near the biological monitoring station AV-5. However, an almost null presence is recorded at stations AV-3 and AV-7 (0-1).

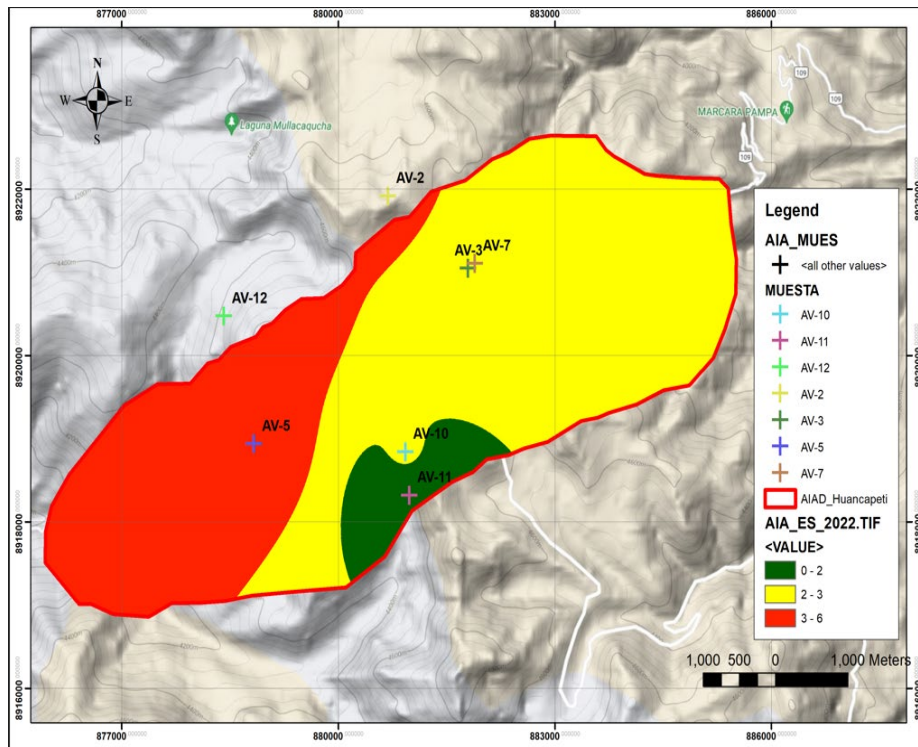


Figure 3 Presence of *Sicalis Olivascents* during biology monitoring, during dry season 2022

During the dry season of 2022, a greater presence of the species (3-6) is observed in the area near biological monitoring station AV-5. A partial presence is also recorded at stations AV-3 and AV-7 (2-3).

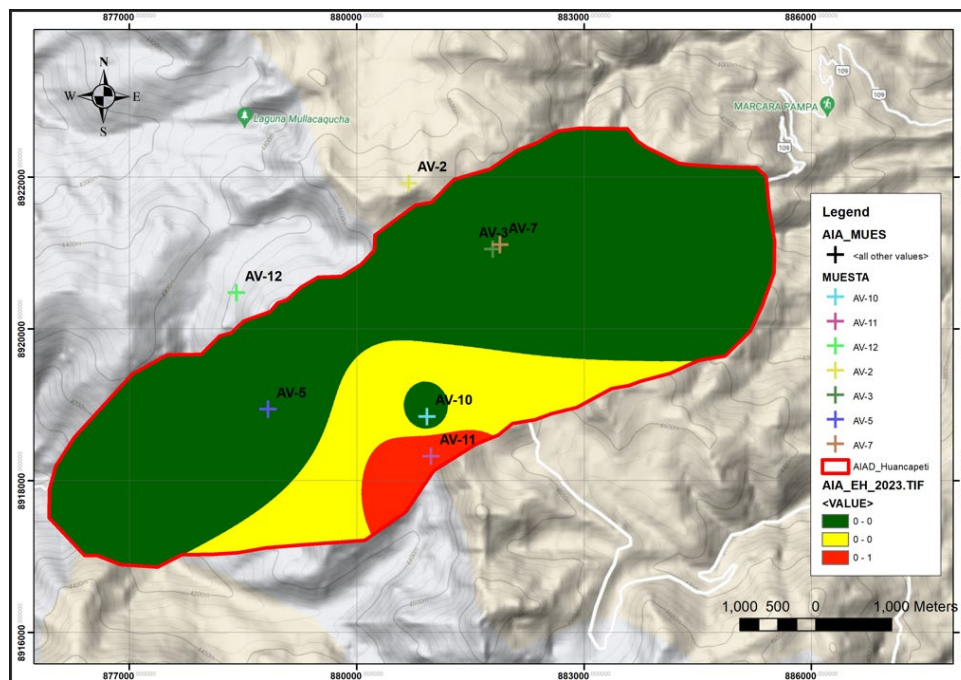


Figure 4 Presence of *Sicalis Olivascents* during biology monitoring, during wet season 2023

During the wet season of 2023, it was observed that the species presented mostly almost no presence in the entire study area.

4 Conclusions

The development of computer tools using Python and ArcGIS has proven to be effective in visualizing the impact of mining activities on flora and fauna communities during the mine closure process.

The heat maps generated from the tool allow a clear visual representation of the impact on flora and fauna communities, thus facilitating analysis and decision making for the conservation of species at risk.

The case study of *Sicalis olivascens* in the Huancavelica region has demonstrated the importance of using tools such as this one to assess and monitor biodiversity in areas affected by mining activities.

The tool developed offers the possibility of entering and maintaining an updated biological monitoring database, which facilitates follow-up and analysis over time.

The application of the Kriging interpolation technique in the generation of the heat maps has allowed a more accurate spatial representation of the distribution of the species studied and their relationship with mining activities

5 Recommendations

It is advisable to continue monitoring the species and generating heat maps over a longer period to obtain a more complete perspective of its distribution and possible fluctuations over time.

The tool developed can be applied to other species and areas affected by mining activities, which would allow a comparative analysis and a broader evaluation of the impacts on biological diversity.

The implementation of conservation strategies based on the results obtained through the tool is suggested, such as the protection of key areas for the species studied and the implementation of mitigation measures to minimize the impact of mining activities.

It is important to continue promoting awareness of the importance of biodiversity conservation and the development of tools and strategies that allow for sustainable management of natural resources in the mining context.

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