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Geographical contribution to International Development Cooperation: soil quality spatial analysis tools to reactivate rural economies in Sucumbíos (Ecuador)

Esperanza Sánchez-Rodríguez
esanchez@us.es 0000-0001-7446-4236
Belén García-Martínez
mbelen@us.es 0000-0002-4589-9385
Mónica Aguilar-Alba
malba@us.es 0000-0003-3386-3710

Departamento de Geografía Física y Análisis Geográfico Regional, Universidad de Sevilla.
Calle María de Padilla, s/n. 41004 Sevilla (España).

Fátima Gaibor
fatimagaibor@gmail.com 0000-0003-0307-5377
Instituto Superior Tecnológico CRECERMAS (ISTEC),
Vía Quito km 12 ½ margen derecho segunda línea, Santa Cecilia, Sucumbíos (Ecuador).

Alexandra Albán
alexandraalban@istec.edu.ec 0009-0006-6433-0377
Instituto Superior Tecnológico CRECERMAS (ISTEC).
Vía Quito km 12 ½ margen derecho, segunda línea. Santa Cecilia, Sucumbíos (Ecuador).

Enrique Vélez-García
enriquevg1999@gmail.com 0009-0009-2730-5393
Departamento de Geografía Física y Análisis Geográfico Regional, Universidad de Sevilla.
Calle María de Padilla, s/n. 41004 Sevilla (España).

Enrique Fuertes-Grábalos
enriqfuertes@gmail.com 0000-0002-7641-2664
Instituto Superior Tecnológico CRECERMAS (ISTEC).
Vía Quito km 12 ½ margen derecho, segunda línea. Santa Cecilia, Sucumbíos (Ecuador).

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The province of Sucumbíos in Ecuador is facing significant environmental degradation, primarily caused by oil extraction. Consequently, cocoa and coffee cultivated in the region have exceptionally high levels of cadmium and lead, posing challenges for their international marketability. To revive the rural economies in the area, it is crucial to assess the soil condition thoroughly. This assessment will serve as a foundation for implementing future measures to mitigate pollution and improve fertilization practices.

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Correspondencia autores: esanchez@us.es (Esperanza Sánchez-Rodríguez)

In this context, an international cooperation project emerged between the Department of Physical Geography and Regional Geographical Analysis at the University of Seville (Spain) and the Higher Technological Institute Crecermas (ISTEC) in Lago Agrio (Ecuador). The Cooperation Office of the University of Seville funded the project in 2021 through a competitive call. The project had the following objectives:

1. To design and validate in the field the data collection protocols (including soil, leaf, fruit and socio-economic data) to ensure their relevance and compatibility with the project goals.
2. To develop the structure of a Territorial Information System database that enables efficient management of field data, their integration with environmental and soil variables, statistical analysis, and cartographic production.
3. To provide training to local agents through workshops focused on spatial information utilization and management, handling of spatial data, and cartography generation, empowering them to autonomously manage and exploit the Territorial Information System.

The cooperation intervention in the Ecuadorian Amazon, aimed at diagnosing soil contamination and revitalizing rural economies in Sucumbíos province, follows a five-phase process. Each phase builds upon the previous one, providing conceptual and methodological foundations. The methodology includes:

- Phase I: Diagnosis of local agents' needs and collection of basic information; it involves conducting working meetings with professionals and technicians from ISTEC, the Provincial Government of Sucumbíos, and other local organizations such as UDAPT (Union of Affected People by Texaco Oil Company). The objective is to gain an understanding of the Amazonian context, identify the tasks to be addressed, and establish expectations for the outcomes. Two participatory workshops were organized with local agents to determine the required information for field data collection, aimed at diagnosing soil contamination, and to establish a systematic procedure for collecting data from a total of 1,500 plots.
- Phase II: Design, elaboration and validation of protocols for data collection, including soil, leaf, and fruit samples, as well as socio-economic information from the families owning each plot.
- Phase III: Modeling the database structure and designing the Territorial Information System (TIS) is the next step. Building upon the data sources identified in the previous phases, the TIS is developed using a spatial database powered by PostgreSQL with PostGIS. The design encompasses queries, cartographic representations, and spatial analysis that can be executed through the QGIS client. For the management and querying of alphanumeric data, pgAdmin 4 serves as the dedicated client. This phase also involves designing views that capture the anticipated queries to exploit the Information System effectively once it becomes operational.
- Phase IV: Training for Territorial Information System operation is vital, as local agents (Provincial Government and ISTEC) will be responsible for managing the operational TIS. To facilitate this, two training workshops were conducted during the field stay. Additionally, a virtual curse (Google Classroom) was established to host all training materials pertaining to the usage of the spatial database, management of the QGIS client, and cartographic production. These skills are essential for effectively managing and operating the TIS.
- Phase V: Implementation of monitoring mechanisms. The Department of Physical Geography and Regional Geographical Analysis (AGR) at the University of Seville intends to provide ongoing support to local agents throughout the sampling and data collection process. This assistance will be extended into the geostatistical and cartographic analysis phase for data exploitation. The results of these analyses will inform future decision-making processes, including the implementation of mitigation measures to address hydrocarbon contamination and the introduction of fertilization programs in degraded cocoa and coffee plots.

The application of this methodology has yielded the following results:

- Identification of the necessary data for diagnosing soil quality and determining the appropriate methods for data collection of soil, leaf, and fruit samples, as well as the surveys conducted with cocoa and coffee producers.
- Field design and validation of protocols for gathering the field data required, including conducting extensive interviews with plot owners and collecting soil, leaf, and fruit samples from each selected plot. These samples will undergo laboratory analysis to quantify relevant pollution parameters. In both cases, mechanisms have been devised to ensure data representativeness and adaptability to geographical characteristics and general plot typologies.
- Modeling the database and designing the Territorial Information System (TIS), incorporating both project-specific field data and environmental variables obtained from various official sources. Spatial data is transformed into spatial tables and linked topologically with other data. Each plot's field data is associated with its central coordinate, enabling spatial relationships with other variables. After modeling and testing the database structure using sample data, it is implemented in PostgreSQL. External data, such as orthophotos or images, is imported from shapefiles, and project-specific data is created as tables, populated with information from text files generated during the data collection process (surveys and laboratory analysis). The result is a database comprising over 120 tables.
- Local agents were trained for managing and utilizing the Territorial Information System through three on-site workshops: (i) Basic training on spatial data characteristics and requirements, with emphasis on handling spatial reference systems; (ii) Workshop on managing spatial databases using PostgreSQL with PostGIS, providing fundamental training for local agents on the database supporting the entire information system, using examples from the project database; (iii) Basic QGIS workshop, focusing on connecting the QGIS client to the project's database, visualizing query results via views, and generating the corresponding cartography.
- Creation of several manuals for specific tasks, available in the virtual classroom (Google Classroom). Such manuals cover topics such as data entry into the database and defining database queries.
- Design of monitoring mechanisms for the execution of the following work in Sucumbíos, to support local agents in initiating the exploitation of the database, conducting initial statistical analyses, and producing cartography through the Territorial Information System.

Upon completion of the cooperation project, local agents (the Sucumbíos Province administration and collaborating entities) will be responsible for collecting data to diagnose soil contamination and design remediation measures. After collecting data from 1500 plots and integrating it into the system, the information exploitation phase will begin. This phase will involve statistical analysis and cartographic production to propose new developments and research challenges. The Department of Physical Geography and Regional Geographical Analysis at the University of Seville plans to continue collaborating by participating in future cooperation project calls.

This intervention offers Amazonian local agents (ISTEC, Autonomous Decentralized Government of the Province of Sucumbíos, UDAPT) an analytical tool for spatial data analysis and decision-making. It helps mitigate soil contamination and enhances the productivity and commercialization of cocoa and coffee. Additionally, it facilitates the efficient transfer of territory management technologies to local technicians, reducing the time it would typically take to incorporate them into their daily work.