Application of Geographic Information Systems in Social Science Teacher Training: Analysis of the Evaluation of Natural, Cultural, and Landscape Heritage in Depopulated Areas

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Abstract Aware of the need for future teachers to acquire digital competencies in handling GIS as a key tool to analyze the evolution of natural, cultural, and landscape heritage, this article presents an intervention using GIS based on a comparison of aerial photographs in depopulated rural areas. The results highlight the high potential of such activities to foster students' digital and spatial competencies, document and analyze the state of heritage conservation over time, and assess potential threats through geospatial data analysis. This approach fosters meaningful learning through critical analysis, enhancing awareness and promoting an educational model that can be applied to other regions in Spain and Europe.

Resumen Conscientes de la necesidad de que los futuros docentes adquieran las competencias digitales de manejo de los SIG como herramienta clave para analizar la evolución del patrimonio natural, cultural y paisajístico, el siguiente artículo recoge una intervención con SIG basada en una comparación de fotografías aéreas en zonas rurales despobladas. Los resultados advierten del alto potencial de este tipo de actividades para fomentar las competencias digitales y espaciales del alumnado, documentar y analizar el estado de conservación del patrimonio a lo largo del tiempo y

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R. de Miguel González and P. Rivero Gracia (eds.), *Geospatial Technologies for Heritage Education*, Key Challenges in Geography,
https://doi.org/10.1007/978-3-031-96372-8_8

evaluar sus posibles amenazas desde el análisis de datos geoespaciales. De esta forma se genera un aprendizaje significativo mediante un análisis crítico que ayuda a una mayor sensibilización mediante un modelo educativo extrapolable a otras regiones de España y Europa.

Keywords Geospatial analysis · Heritage · Depopulation · Social science education · Teacher training

Palabras Clave Análisis geoespacial · Patrimonio · Despoblación · Educación en ciencias sociales · Formación del profesorado

Introduction

In recent decades, the use of Information and Communication Technologies, and more specifically Geographic Information Systems (GIS), has become established for the study of space, with a corresponding educational transposition (Boix et al. 2009). Their implementation in the classroom stems from the potential of GIS to surpass the limitations imposed by mere visual exploration, although it requires a basic level of knowledge to manage the information appropriately and maximize its utility (Boix and Olivella 2007). In particular, activities such as this one enable the analysis of changes over time in specific territories through visual comparisons that facilitate the development of geographical competencies. Within this framework, this study focuses on Spain's depopulated areas to address a heritage that tends to be largely neglected (Scazzosi 2018). As an open, negotiable, dialogical, transformative, and reflective concept, heritage (Fontal and Martínez 2017, p. 71) requires that when approaching rural spaces, the notions of debate and change must play a fundamental role (López-Estébanez et al. 2024), since these spaces are shaped by the values society assigns to them at any given time, which are subject to change (Baena Gallé 2016, p. 8).

In light of the above, we can agree that, in the educational field, GIS represents an indispensable tool for understanding and analyzing landscapes, as it integrates spatial data and attributes into a single system, allowing for the visualization and analysis of complex information in comprehensible and accessible ways (Boix and Olivella 2007; Torralba 2021). In fact, by creating thematic maps, digital terrain models, and spatial analysis, students can investigate the interactions between environmental, social, and economic factors that shape the landscape. In this way, the ability to overlay and analyze multiple layers of information within a spatial context fosters a deeper understanding of the processes affecting the environment (Mártinez and Molina 2015; Torralba 2021; De Migel et al. 2019).

Aerial photography, when used in combination with GIS, further amplifies this analytical capability, as aerial images provide a panoramic view of the landscape that reveals patterns and features that may not be evident from the ground (Sevilla and Rodríguez 2015). These images provide crucial visual data for analyzing changes in

land use, erosion, urban expansion, and other geographic phenomena. Based on these premises, this paper presents the design of a practical methodology that enables the extraction of information from aerial photographs integrated into GIS. This methodology employs digital processing techniques to apply visual interpretation, aiming to stimulate debate based on the changes observed.

This methodology enhances the accuracy of spatial analysis by combining high-resolution aerial images with GIS, which allows for the detection of changes in land use and environmental patterns. Historical and contemporary images can be compared to track long-term changes, such as soil erosion or urban growth. However, the precision of the analysis depends on the quality and resolution of the images used, making careful data selection and validation important to ensure reliable results.

Objectives

1. Promote digital, spatial, and innovation competencies among teachers through the implementation of GIS.
2. Establish comparative frameworks using GIS to reflect changes in the landscape, aiming to document the conservation status of identified heritage and its potential changes and deterioration over time.
3. Evaluate threats through geospatial data analysis to identify risk areas in terms of erosion or deterioration of landscape heritage, thereby facilitating awareness and planning of possible conservation and risk management measures.
4. Promote education and awareness through GIS, including interactive maps and photographic galleries within an educational material model that can be extrapolated to other European regions.

Methodology

To promote the use of GIS in general, and ArcGIS Online in particular, within Spanish school classrooms, a proposal was sent for a classroom activity focusing on depopulated Spain, specifically La Ribagorza (Aragon) and its heritage, as a model for secondary and high school activities. The proposal consisted of comparing two rural areas on a map of the region, chosen by the students based on their interests or curiosity. The proposed historical landscape review is based on cartographic viewers like those from the National Geographic Institute (Instituto Geográfico Nacional) and its National Aerial Orthophotography (Plan Nacional de Ortofotografía Aérea) orthophoto comparator (Centro Nacional de Información Geográfica 2020), available for verification and use via the provided https://ggeomentoresesp.maps.arcgis.com/apps/webappviewer/index.html?id=115b84cb2fa9413eb42b3bc86401fed6. To observe the changes in their surroundings over the last 68 years, students filled out a form noting the changes perceived in the landscape from 1956 (American

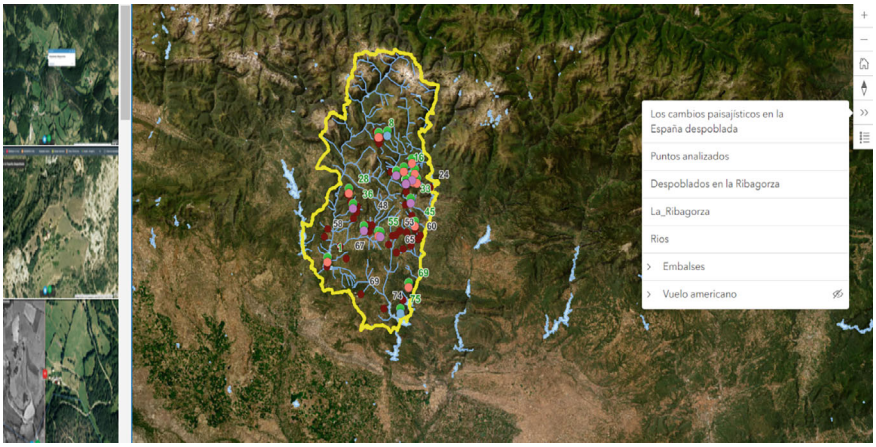

Fig. 1 Screenshot of the La Ribagorza region with screenshots of the points selected by the students on the left margin

flight) to the present (current orthophoto). This approach aimed to verify how the integration of aerial photographs into GIS analysis allows for direct observation of landscape changes over time, thereby facilitating the identification of trends and the formulation of hypotheses based on real data. On the website, students could switch between different periods instantly, maintaining various layers or filters on the map that enabled them to identify depopulated towns, rivers, and reservoirs, with the option to zoom in or out (Fig. 1).

To gather as much data as possible, participants were divided into two groups:

1. Teachers and future educators who are interested in implementing such practices in the classroom. This included students from the Faculty of Education at the University of Zaragoza enrolled in the Master's in Secondary Education, specializing in Geography and History (2023–2024) and active teachers, totaling 30 participants. The goal was to analyze their feedback, identify potential improvements and difficulties, and gauge their expressed interest in conducting this comparison in class.
2. A practical implementation in the classroom to evaluate perceptions and learning in real-time. A session was conducted at the Joaquín Costa Institute in Cariñena with students aged 11–15 (21 students). This institute serves secondary education students from surrounding municipalities and some from the Campo de Daroca region (Herrera and Villar de los Navarros), some of whom face the challenge of depopulation. This approach aimed to achieve a dual purpose: first, for students from rural backgrounds to analyze how depopulation influences the current landscape configuration; second, for the Geography and History teachers to recognize the educational potential of GIS in reflecting on their territorial reality.

The intervention was designed to be completed in 10–15 min, either in the classroom or outside, but in practice with secondary students, a full session was

conducted to allow maximum freedom for the teacher. The activity focused on the Ribagorza region and its heritage in depopulated areas to address its heritage, the possible changes and deterioration suffered over time, and to identify areas of risk or deterioration of landscape heritage.

Once a point of interest was selected, students could capture an image to make a comparison and identify changes in the analyzed environment according to the following categories:

- Urbanization
- Agricultural Changes
- Temporary Changes
- Infrastructure
- Abandonment/Neglect
- Environmental Changes.

Through the qualitative and quantitative analysis of the collected data, we expect students to gain a deeper understanding of how depopulation has impacted their local landscape. In past sessions, we have noticed that when students discuss the changes identified in different categories, they not only engage with the material but also start reflecting on their environment and the challenges it faces. For instance, during the analysis of earlier images, some students were surprised to discover the impacts and changes they observed in the region. These discussions encourage meaningful dialogue, allowing both students and teachers to connect these changes to broader socioeconomic trends. By the end of this process, we believe students will recognize the importance of preserving their landscape heritage and feel motivated to get involved in conservation initiatives within their communities.

Results

Geographical Analysis of the Location of Points on the Map

The analysis of the chosen points reveals that some generated more interest, whether due to personal reasons or because they reflected significant changes in the landscape. This might be linked to the diversity of transformations observed or the accessibility of those locations for the respondents.

Point 55 was the most selected, with 4 mentions.

Points 8 and 18 were chosen 3 times each.

Points 7, 19, and 28 were selected 2 times each.

Other points, such as 1, 16, 17, 24, 33, 36, 53, 61, 67, 69, 74, and 75, were chosen only once (Fig. 2).

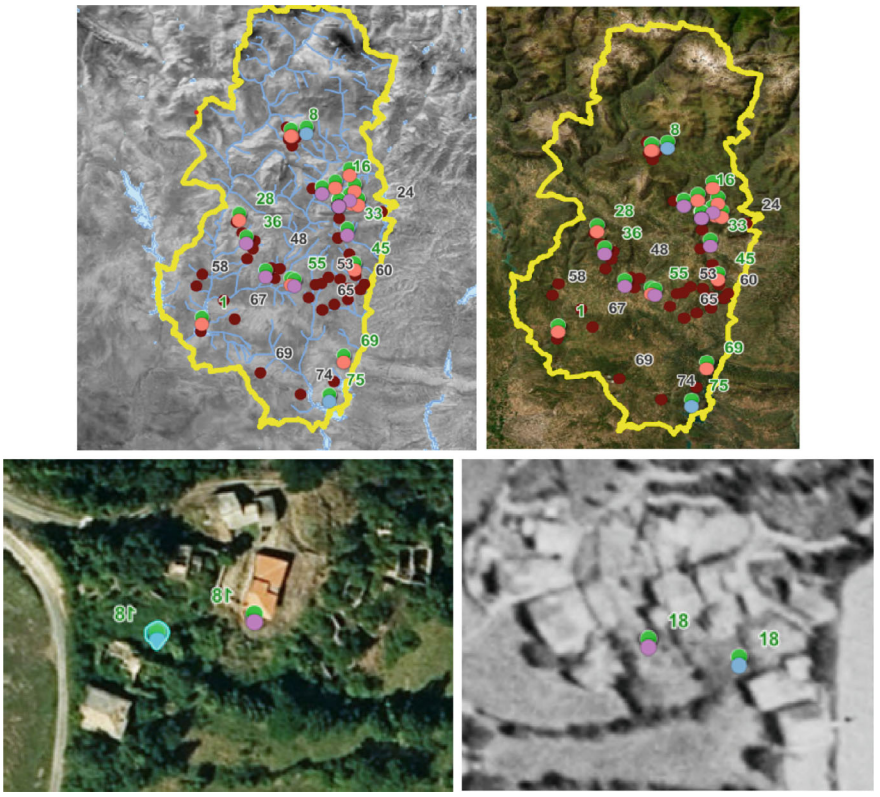

Fig. 2 Images of La Ribagorza without zoom and with zoom from point 18

As can be seen, some points have a higher level of interest and are likely to show more notable changes in the landscape. A more detailed analysis of the location of the selected points in La Ribagorza reveals relevant aspects of their distribution and changes.

General Distribution

The points are mainly dispersed in the central and northeastern parts of La Ribagorza, with a notable concentration near river networks and low-altitude areas, such as valleys and flatlands, which are more accessible and have historically been more populated. This concentration in the northeast might relate to proximity to urban centers or areas with a higher population density and economic activity.

Relationship with the Hydrographic Network

Many points are located near rivers and streams, such as the Ésera River and its tributaries. This proximity suggests that landscape analyses have particularly emphasized areas where water plays a key role, whether in terms of water resources, flood risk, or as a factor influencing land use. These water-adjacent areas are vital for managing water resources and conserving riparian ecosystems, highlighting the importance of protecting and sustainably managing these zones.

Topography and Accessibility

The points are also distributed along slopes and valley bottoms, reflecting a particular focus on changes in agricultural and forested landscapes typical of these areas. Accessibility may influence the selection of analysis points; more remote or difficult-to-reach areas, such as higher mountains, have fewer points, limiting direct observation of landscape changes in those regions.

Urbanization and Depopulation

Points located near towns and population centers reflect urban changes, such as the expansion or reduction of human habitats, as well as the direct influences of urbanization or abandonment of structures. The dispersion and density of these points could correlate with rural depopulation phenomena, a challenge in territorial management for many mountainous areas in Huesca.

Natural and Cultural Heritage

La Ribagorza is rich in cultural and natural heritage, including natural parks and historical sites. The location of these places indicates an interest in analyzing how these heritages are being affected by environmental and human changes, such as landscape erosion or alteration of traditional routes. This focus is crucial for developing preservation and promotion policies for heritage in the region.

Implications for Territorial Management

The distribution of the points provides a clear guide on where landscape analysis efforts are concentrated in La Ribagorza. These points highlight key areas for territorial management, including the conservation of natural resources, adaptation to climate change, and land use planning to prevent uncontrolled expansion or degradation of landscapes.

Geographical Analysis of Changes in the Analyzed Environment

The changes observed in the analyzed environment are categorized as follows (Fig. 3):

- Urbanization (44 mentions): This category includes changes related to the development of urban centers, expansion of towns, and the construction of houses and other buildings.
- Agricultural Changes (35 mentions): Refers to transformations in crop fields, the expansion of agricultural areas, and other shifts in land use.
- Temporal Changes (33 mentions): Includes references to changes over time, such as comparisons between past and present (e.g., "now," "current," "before," "1956").
- Infrastructure (17 mentions): Related to modifications in communication networks, roads, and other infrastructures.
- Abandonment/Neglect (15 mentions): Reflects deterioration, abandonment, or disappearance of elements in the landscape.
- Environmental Changes (14 mentions): Includes alterations in vegetation, trees, water bodies, and other natural elements of the landscape.

The bar graph illustrates the number of observations for each change category (such as urbanization, agricultural changes, infrastructure, abandonment, and environmental changes) at the most frequently selected points. Analyzing this data reveals that the most commonly observed changes are related to urbanization and agricultural shifts, followed by variations over time and modifications in infrastructure.

The most common themes in the responses regarding changes in the analyzed environment included terms related to transformations in land use and landscape structure. The frequently used words were as follows:

- "Fields": Indicates changes in rural areas, possibly related to agriculture or the expansion of cultivated land.
- "Nucleus" and "Town": Refers to changes in urban areas or population centers, such as town expansions or infrastructure changes.
- "Crop": Suggests modifications in cultivated areas, whether in terms of size or types of crops present.

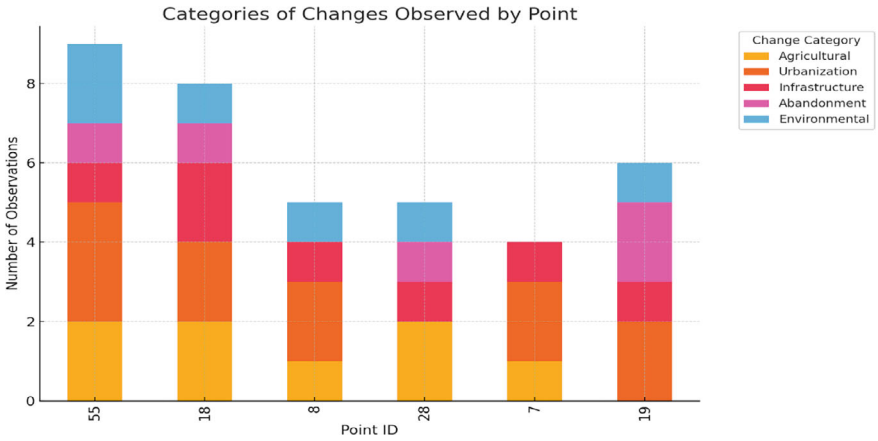

Fig. 3 Graphical visualization of change categories observed by each point

- "Routes" and "Paths": Indicates changes in transport infrastructure, such as the appearance or disappearance of roads.
- "Abandonment": Signals the deterioration or neglect of certain areas, possibly linked to a decline in human or agricultural activity.
- "Disappeared": Refers to the loss of landscape elements, such as structures, cultivated areas, or vegetation.

These terms imply that the main changes observed in the landscape are related to shifts in land use, the expansion or contraction of inhabited and cultivated areas, and changes in transport infrastructure, reflecting a process of humanization or abandonment of the environment. The results regarding types of change in the analyzed environment indicate urbanization (44 mentions), agricultural changes (35 mentions), temporal changes (33 mentions), infrastructure (17 mentions), abandonment/neglect (15 mentions), and environmental changes (14 mentions). As seen, the results show that the most frequently observed changes are linked to urbanization and agricultural shifts, followed by variations over time and modifications in infrastructure.

Finally, the analysis of the feedback on the utility of GIS for landscape analysis reveals:

- "Very Useful": The vast majority of respondents (22 teachers) consider GIS to be very useful for landscape analysis. This indicates a positive perception and strong appreciation of GIS as an effective tool for this type of analysis.
- "Fairly Useful": 7 respondents believe GIS is useful, reflecting a favorable view, albeit with slightly less enthusiasm compared to the previous group.
- "Not Very Useful": Only 1 respondent thought GIS was not very useful for landscape analysis, suggesting a negative perception, although this is a minority opinion.

Overall, the results indicate a positive consensus regarding the usefulness of GIS for landscape analysis, with most participants acknowledging its value and effectiveness in this context. This is particularly true for both current and future teachers, who highlighted GIS's significance for studying the landscape heritage of rural areas, taking into account aspects like student interest and proximity. Participants emphasized that the tool facilitates the visualization of phenomena such as landscape heritage, depopulation, and rural heterogeneity—essential aspects for understanding the contemporary rural geographical reality (Bandrés and Azón 2021). In this context, both current and future teachers underscored GIS's high potential to shed light on the causes and consequences of depopulation in Spain.

Additionally, the qualitative analysis of feedback from students at IES Joaquín Costa de Cariñena shows that this practice generated more meaningful learning experiences. This aligns with similar research findings (Palmer 2013). The choice of spaces to explore through aerial photography provided a sense of virtual excursion or, as some may prefer, a sentimental journey through a part of Spanish geography. This freedom for students to select comparison spaces and combine various layers of geographical information translates into a deeper understanding of the complex interplay between physical and human factors shaping landscapes, fostering critical and creative thinking. Consequently, participating students were able to effectively identify and analyze changes in the landscape over time, demonstrating how the visual comparison of aerial photographs aids in grasping complex geographical concepts, such as the consequences of rural exodus and the transformation of rural spaces.

Discussion

As observed in the practice, the points on the map represent locations where changes in the landscape have been observed and analyzed, which have direct implications for territorial management. In this regard, several key aspects emerge regarding how these points can influence territory management:

1. Identification of Critical Areas: The points concentrated in certain areas, especially near rivers and valleys, indicate zones of high interest or concern. These areas may be experiencing significant changes such as urbanization, agricultural expansion, or erosion. Knowing these locations allows land managers to prioritize interventions and resources at these critical points.
2. Urban and Rural Planning: Points that show a high degree of urbanization or abandonment can guide decisions regarding urban and rural planning. For example, in areas where uncontrolled urban expansion is observed, authorities might implement stricter zoning policies or develop adequate infrastructure to mitigate environmental impacts.

3. Environmental Conservation: Points located in regions of high biodiversity or near water bodies suggest the need for conservation strategies. For instance, if points indicate negative changes in vegetation or loss of natural habitats, managers can develop reforestation programs or watershed protection initiatives.
4. Water Resource Management: The proximity of many points to river networks highlights the importance of properly managing water resources. This may include protecting aquifer recharge areas, preventing water contamination, and managing flooding in vulnerable areas.
5. Climate Change Adaptation: Changes observed at these points, such as the abandonment of agricultural areas or urban expansion, may also be linked to climate phenomena. Understanding the location and nature of these changes can aid in developing climate change adaptation plans, such as creating green barriers or planning resilient infrastructure.
6. Sustainable Development: Information derived from these points can support sustainable development initiatives, promoting a balance between human development and environmental conservation. This includes advocating for sustainable agricultural practices, regulating land use, and preserving cultural landscapes.

In summary, the points on the map are fundamental for understanding the local dynamics of the landscape and are therefore crucial tools for decision-making in territorial management. They enable managers to prioritize actions, tailor policies to the specific needs of the territory, and promote more efficient and sustainable land use. Consequently, we can assert that through this activity, students create, plan, organize, and articulate new knowledge with a higher level of cognitive complexity.

Existing literature on the use of geo-media and GIS in educational settings emphasizes the importance of generating innovation in the teaching of the discipline, highlighting the need to foster active and inductive methodologies, discovery learning (learning by doing), and ultimately, autonomous, critical, and functional learning (De Miguel 2013a, b; De Miguel and Sebastián 2022; Kolvoord 2012; Milson et al. 2012) that respond to these types of proposals.

In this context, for many years, the use of textbooks as a predominant and fundamental tool in the teaching and learning process of Geography, rather than serving as a supplementary resource, has tended to promote a traditional, lecture-based, fragmented, and encyclopedic approach to teaching. Despite advances in didactic resources outlined in Geography textbooks for Secondary Education and Baccalaureate (De Miguel 2013b), this reality partly accounts for Spain's distance from the necessary didactic innovation implemented in other countries (Buzo-Sánchez et al. 2022). In the case of depopulated Spain, the absence of rural geography in the curriculum and textbooks addressing significant changes in the rural environment over recent decades further complicates matters (Quintá et al. 2018). In this sense, developing this activity provides teachers with a new tool to enhance the significance of learning derived from their teaching activities (Zapettini et al. 2008).

The teachers responsible for conducting the activity in the classroom recognized the importance of applying GIS to renew and enrich geography education, expressing interest in carrying out similar exercises focused on their territorial context. However,

the lack of teacher training in the use of such tools (Albert and Nieto 2014) poses a barrier that must be addressed to ensure that the development of these workshops is not a one-time event but a consistent part of the academic curriculum.

Thus, it is evident that GIS not only represents a technological tool filled with possibilities for classroom use but also acts as a catalyst for motivation, engagement, and collaboration to understand and solve problems that, from the specific, affect the global (Milson et al. 2012). In other words, it promotes thinking globally from the local perspective, leading to actions and considerations that are "glocal." Ultimately, this perspective fosters a geography of "social value" by offering a more dynamic view of the environment and a sense of belonging through analytical strategies that impact awareness of the social dimension of heritage, the sustainable connections between people and their surroundings, and the consequences of its deterioration. In this way, by aligning with a reformulation of the landscape, it enables education in the landscape rather than merely studying it (Busquets 2010; Lestegás et al. 2024), emphasizing the role that human action has played and continues to play, interpreting it as a social product or collective creation.

Notably, reinforcing its historical and cultural dimension highlights human actions, generating landscapes that evoke admiration, trivialization, or indifference (Busquets 2010), and placing it in a constant process of construction (Liceras 2013). Consequently, following proposals that contribute to developing civic awareness in students, enabling them to address various societal challenges (Sebastián-López and de Miguel-González 2017: 244), there is an opportunity to use digital platforms to revitalize these connections and help form a "glocal community" capable of recognizing the emotional ties people have with their environment, regardless of their physical location. An illustrative example of this social dimension is found in the memories of communities displaced by dam construction in Spain. These "drowned memories" reflect the lives of those forced to leave behind villages, land, and livelihoods, voices that were never consulted or heard (Marcos and Fernández 2024). Incorporating such perspectives into classroom work is not only educational but also an ethical gesture, recovering testimonies that deepen understanding of rural change and its human consequences. Such integration ultimately strengthens democratic awareness and a shared sense of heritage.

Conclusions

In light of the results obtained and to synthesize the possible aspects that facilitate improvements in learning processes, we understand that practices like the present one highlight three fundamental points or axes, namely:

- The need to promote the use of GIS and new technologies as instruments in educational processes and as elements for accessing landscape heritage.
- The creation of specific materials that facilitate the use and access to this heritage in the classroom.

- The promotion of collaboration between schools and/or educational institutions and universities to facilitate training, dialogue, access, and the creation of common programs based on synergy and the integration of educational institutions and universities.

As we have observed, the combined use of GIS and aerial photography in education not only enhances the understanding of geospatial concepts but also develops valuable technical skills. Students learn to operate advanced software, interpret spatial data, and apply analytical methods that are fundamental in the field of geography and many other disciplines. Furthermore, this integrative approach fosters critical thinking and the ability to solve complex problems, preparing students to face challenges in the professional realm and in scientific research. Thus, GIS and aerial photography consolidate as key tools in the training of future geography experts, contributing to a more dynamic and relevant education in landscape analysis.

The educational transposition of the rural heterogeneity of Spain and its landscape requires a deeper study in terms of methodology and analysis that allows for greater awareness and sensitivity to be brought into the classroom, as well as increased projection, protection, and promotion (Scazzosi 2018). Applications like the one presented allow for attention to the integrity of the landscape as a key identity marker, as noted by UNESCO (Gullino and Larcher 2013) amid the deterioration affecting depopulated rural Spain, in connection with demographic decline and the consequent abandonment of traditional activities such as agriculture and livestock farming. This abandonment leads to the loss of cultural landscapes that progressively deteriorate, including terraced fields, rural paths, or historic buildings. Similarly, it fosters soil erosion processes, uncontrolled vegetation growth, and an increased risk of fires, which ultimately affects not only the physical landscape but the entire social and cultural heritage linked to traditions and ways of life associated with the land. In summary, the disconnection between inhabitants and their environment alters a whole natural and cultural equilibrium and, therefore, a landscape that is a fundamental resource.

Reversing this situation requires emphasizing the importance of valuing landscape heritage in education as a basis for revitalizing these areas through awareness of their significance. GIS can facilitate the establishment of this heritage as a pillar upon which educational efforts should be built, necessitating certain changes in school organizations such as promoting collaborative work, improving teacher training in both specific technical aspects and didactic, pedagogical, and even cultural dimensions, and ultimately providing greater weight as a mediator of landscape heritage so that it feels a part of it and, therefore, plays a leading role in its conservation and dissemination within the educational sphere.

In conclusion, we understand that practices such as the present one demonstrate the opportunity that GIS offers for providing research-based learning about current events using real-world data, such as that related to depopulated Spain, in an environment of awareness, consciousness, and problem-solving driven by technology. The results show that the use of aerial photographs as a model for comparisons over time serves as a primary tool for generating participatory learning processes,

monitoring heritage, and engaging the educational community in the collection, analysis, and representation of geographic data or information, promoting collaborative approaches to information, awareness, and conservation.

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