

# Digital Exploration of the Hydrosystems of the Haut Adour (French Pyrenees).

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This research focuses on identifying hydrosystems in the Haut-Adour region of the Pyrenees (France), including lakes, streams, canals, and ancient water infrastructure. These elements reveal long-term human and animal use of the mountain landscape, shaped by cycles of occupation and abandonment. Using digital tools like IGN orthophotos and high-resolution LiDAR, the team developed a method to map and analyze these systems. Fieldwork, drone imagery, and 3D scanning further supported the study, which highlights the evolving relationship between societies and their environment in the face of social and climate change.

## 1. Introduction

The geo-historical exploration conducted in the Haut-Adour basin (Pyrénées, France) between October 28 and November 3, 2024, represents a significant step forward in documenting the hydraulic systems and human occupations that have shaped the high mountain landscapes of the central Pyrenees. This preliminary report focuses on the methodological approach adopted by a multidisciplinary team, emphasizing the integration of photointerpretation, LiDAR data analysis, and fieldwork in a context of limited technological infrastructure. The survey aimed to document and understand small hydraulic features (canals, ditches and rigoles), their association with pastoral structures and their diachronic evolution across a wide mountainous territory.

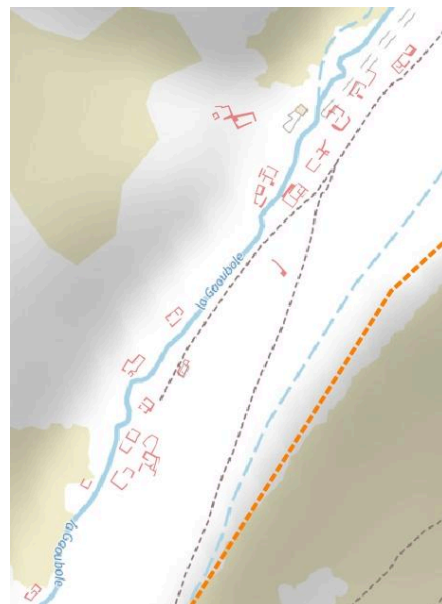
## 2. Objectives and Background

The project, developed by the Consortium Huma-num Projets Time Machine (<https://ptm.huma-num.fr/>) in collaboration with the Observatoire des Patrimoines de Hautes-Bigorre (OAPHB), seeks to understand the historical structuring of the Haut-Adour landscape through its hydraulic systems. Inspired by similar research conducted in the Ossau Valley [RLC16, RLC06, BBB\*23], the survey aimed to trace the flow of water from mountain sources through rigoles to their urban expressions in the form of small canals in Bagnères-de-Bigorre. These hydraulic networks, though modest in appearance, reflect a sophisticated and enduring engineering tradition.

In turn, the expedition team sought to link these hydraulic structures with vestiges of pastoral and possibly earlier occupations. These vestiges include stone enclosures, cabins, terraced fields, and various ephemeral installations preserved in areas that are now largely uninhabited or used only seasonally for transhumance [SRA06]

## 3 Methodological Approach

A crucial first step was the systematic review of publicly available cartographic resources from the Institut géographique national (IGN). Orthophotos at 20 cm resolution and near-infrared images were layered with modern topographic maps to detect any potential anomalies such as linear ditches, mounded enclosures, or ring-like shapes corresponding to former structures (Figure 1) (Cartographic resources were acquired from the IGN and processed for overlays with LiDAR data). Historical documents, notably the Napoleonic cadastre, were then georeferenced to assess whether these features were still visible or in use in the early nineteenth century (Cadastre Napoléonien of Campan (1825), georeferenced for the project's internal GIS).

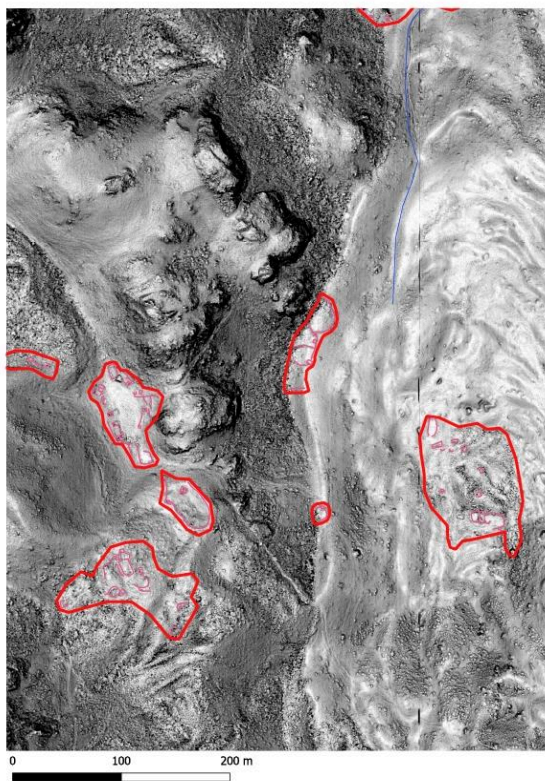


**Figure 1** Preliminary interpretation of the built structures in the Sarroua area based on the IGN orthophoto map

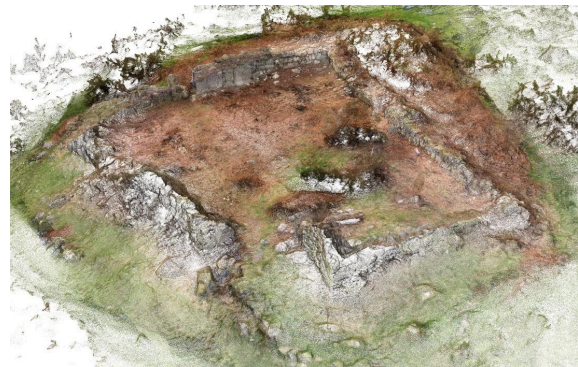
The availability of the LiDAR HD dataset from the IGN (LiDAR HD data from the IGN have been instrumental in

revealing these features at a 50 cm resolution) represented a significant breakthrough. This technology emits laser pulses from an airborne platform, measuring the return times and intensities of each pulse to build a “point cloud” of millions of data points. By “stripping” away vegetation layers, LiDAR can reveal subtle topographic features such as low earthen banks, collapsed walls, or faint water channels. In regions without dense vegetation, the clarity of these findings was remarkable. However, heavily forested zones remain challenging, as the laser may not fully penetrate dense canopies.

While remote sensing can identify potential features (Figure 2), there is no substitute for ground verification. The Club Alpin de Bagnères-de-Bigorre assisted in traversing sections of the rigoles and verifying certain puzzling anomalies. In particular, a drone-based photogrammetric campaign was undertaken near the Lac de Montarrouye and in the Esclozes area. Using a Phantom 4 drone and DJI Matrice 350 RTK, overlapping images were captured to produce detailed 3D reconstructions with texture using stereoscopy. Additionally, a handheld LiDAR scanner (TRION P1) was employed in targeted spots with high structural complexity as shown in Figure 3. This on-site scanning corroborated the remote-sensing findings while also unearthing new details, such as carved crosses and inscriptions at Fontaine des Grious.



**Figure 2** Zoom in on IGN LiDAR data in the Montarrouye du Haut area and initial interpretation of the remains (in red).



**Figure 3** Esclozes: 3D view with a handheld LiDAR scanner (TRION P1) of the area known as the Château. The layout of this monumental complex with its access ramp is clearly visible.

### 3.1. Technical Evaluation of LiDAR and Photogrammetry

The project employed drone-mounted LiDAR (ZenMuse L2 sensor) on DJI Matrice 350 RTK, capturing dense point clouds (846 points/m<sup>2</sup>) over 7.6 hectares in a single flight of 10 minutes (Figure 4). Altimetric profiles, slope analysis, and reflectivity classification provided valuable insights into site morphology. Despite excellent data coherence, the presence of forested zones remains a limitation for ground visibility. The RTK-GPS system ensured sub-centimeter accuracy, essential for reliable feature extraction and comparative landscape analysis. Photogrammetric workflows were developed to generate detailed 3D models of selected clusters, enabling refined morphological interpretations and volumetric measurements.



**Figure 4** RGB LiDAR image from ZenMuse L2 sensor

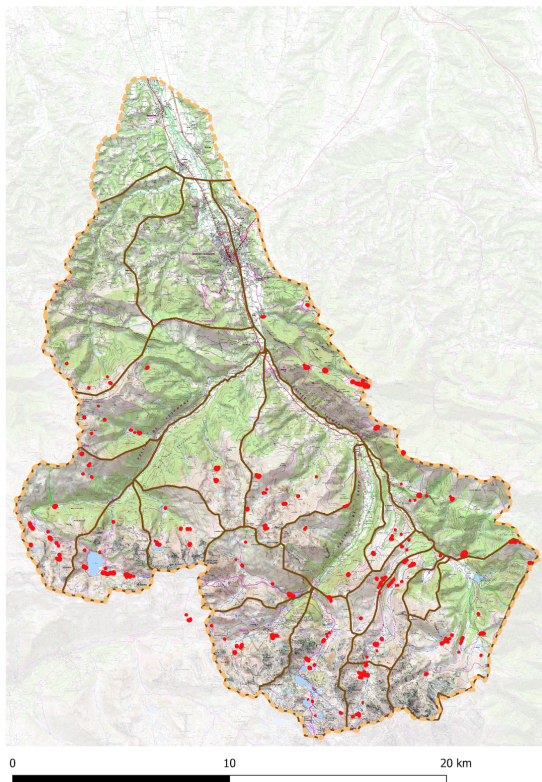
### 3.2. Integrating Local Knowledge and Citizen Science [FHB\*22]

One of the most promising aspects of the Haut-Adour project lies in its participatory dimension. Local hikers, farmers, and amateur historians have contributed significantly to the identification and interpretation of vestiges, especially in inaccessible or undocumented zones. This community-driven approach, often referred to as citizen science, allows for the cross-validation of findings and improves the overall quality and contextualization of the data.

By incorporating indigenous knowledge, oral histories, and traditional ecological practices, researchers can add a temporal and cultural depth to spatial data that pure remote sensing cannot provide. For example, accounts of past pastoral routes and seasonal rituals help explain settlement patterns around certain water sources and enclosures.

#### 4 Findings and Provisional Results

The first round of data collection led to the identification of 185 archaeological clusters (**Figure 5**) indicates a historically intense land use, contradicting older assumptions that these high-altitude zones were sparsely inhabited. Many remain undated, prompting questions about whether they might reflect Bronze Age expansions, medieval transhumance patterns, or more recent pastoral economies. It is not coincidental that large settlement clusters occur along these rigoles. Indeed, the water channels seem to have directly shaped the location and longevity of shepherd huts, dairies, or seasonal encampments called *Courtaous*, they are high-altitude summer settlements, typical of Pyrenean pastoralism. The site of Esclozes, for example, extends around a principal rigole called “ruisseau de Sarrat” on modern IGN maps, featuring a complex arrangement of enclosures known colloquially as the “Château” (**Figure 3**) Multiple enclosed features, located above 2,000 meters near Montarrouye, reflect significant earlier settlement. Today, these sites see only passing hikers or shepherds. Their age, purpose, and forms of construction differ notably from lower-altitude examples, suggesting possible climate-related or socio-economic shifts that influenced transhumance routes.



**Figure 5** : General situation of the study area, with areas of concentrated remains in red.

#### 5 Next Steps

The immediate priority is to refine the chronology of discovered features. Archaeological test pits, radiocarbon dating, and further archival research will help differentiate late-medieval reoccupations from potentially prehistoric pastoral expansions. The forthcoming 2025 field mission

aims to expand the data corpus and stabilize the interpretative framework.

A thorough, territory-wide LiDAR analysis is also planned, especially targeting forested sectors. Enhanced classification algorithms may help detect subtle traces beneath partial canopy openings, adding complexity to the recognized anthropogenic footprints.

By engaging local associations, universities, and specialized research centers (such as the Toulouse-based UMR FRAMESPA teams who have extensive Pyrenean experience), the expedition hopes to coordinate broader, multi-year projects. The results will eventually feed into an online WebSIG (Web-based Geographic Information System <https://page.hn/liwbi5>), facilitating data-sharing across different user communities.

Finally, identifying and mapping these sites is merely the first step toward conservation. Some structures risk further degradation due to natural erosion, uncontrolled tourism, or encroaching vegetation. Local stakeholders might consider measures such as signage, regulated access, or funding for stonework stabilization.

#### 5.1. Perspectives for Machine Learning and Automated Feature Recognition

As the dataset grows in volume and complexity, the need for automated tools to assist in classification and pattern recognition becomes evident. Initial experiments are underway to train machine learning models capable of detecting linear features (e.g., rigoles) or clustering ruins with similar morphological characteristics across the LiDAR-derived DEMs.

This future direction is particularly relevant in mountainous terrains where large-scale field verification is logistically difficult. With the implementation of convolutional neural networks (CNNs: Convolutional Neural Networks are deep learning algorithms widely used in image recognition and classification tasks) it may be possible to generalize detection rules established in Haut-Adour to broader areas of the Pyrenees or similar alpine regions.

#### 6 Conclusion

The preliminary geo-historical survey of the Haut-Adour basin has unveiled a densely occupied and technically sophisticated mountain landscape, shaped by centuries of human-environment interaction. The identification of rigoles and vestiges across altitudes ranging from 1,200 to over 2,000 meters provides new insights into historical resource management, settlement strategies, and adaptation to climatic constraints.

While the results presented here remain provisional, they highlight the value of combining historical cartography, LiDAR analysis, photogrammetry based on aerial photography collected by UAS, and citizen science in landscape archaeology. The forthcoming campaigns and analytical work planned for 2025 will deepen these insights, contributing to our broader understanding of mountain environments.

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