



SHORT COMMUNICATION

SOIL EROSION TRIGGERED BY THE ARCHEOLOGICAL EXCAVATION AND CONSERVATION OF TRENCHES. THE CASE OF “CERRO DE LAS TRINCHERAS” IN BAILÉN (JAÉN, SPAIN). AN OPEN DISCUSSION

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ABSTRACT. Gully erosion is a landform developed due to accelerated soil erosion rates. Gullies can be identified by human impacts on geomorphological processes, as well as hydrological and erosional systems. In Spain, the trenches or "trincheras" from the Spanish Civil War (1936-1939) are considered of archaeological interest for several reasons. At Cerro de las Trincheras in Bailén (Jaén, Spain), a trench was built during the Spanish Civil War. In 2020, an archaeological excavation took place to restore the ruins, triggering the development of gullies and rills and a decrease in vegetation quality. We present a first approximation of the variations in vegetation cover and the decrease in quality (using NDVI, the normalized difference vegetation index) due to the trench acting as a gully (1956, 2005-2020) and the increase in rills and gullies after the excavation. We strongly advocate for future archaeological excavations to include a protocol (soil mapping, vegetation survey, and hydrological connectivity index) to reduce soil degradation and prevent damage to vegetation and associated ecosystems, thereby curbing the increase in soil erosion rates.

Erosión del suelo provocado por la excavación arqueológica y conservación de trincheras. El caso del “Cerro de las Trincheras” (Bailén, Jaén, España). Una discusión abierta

RESUMEN. Las cárcavas son formas de relieve desarrolladas por tasas aceleradas de erosión del suelo. Las cárcavas pueden identificar los impactos humanos sobre los procesos geomorfológicos y los sistemas hidrológicos y erosivos. En España, las trincheras pertenecientes a la Guerra Civil (1936-1939) se consideran de interés arqueológico por varias razones. En el Cerro de las Trincheras de Bailén (Jaén, España) se construyó una trinchera durante la Guerra Civil Española y en 2020 se llevó a cabo una excavación arqueológica para restaurar las ruinas, lo que desencadenó el desarrollo de cárcavas y regueros, y un empeoramiento del estado de la cubierta vegetal próxima. Presentamos una aproximación de las posibles variaciones de la cubierta vegetal y su disminución de calidad (mediante el NDVI, índice de vegetación de diferencia normalizada) debido a la presencia de la trinchera actuando como cárcava (1956, 2005-2020) y al aumento de surcos y cárcavas tras la excavación alrededor. Reclamamos firmemente que futuras

excavaciones arqueológicas deben incluir un protocolo (cartografía de suelos, estudio de vegetación y el uso de índices de conectividad hidrológica) para reducir la degradación del suelo y evitar el daño a la vegetación y a los ecosistemas asociados que provocan el aumento de las tasas de erosión del suelo.

Keywords: Trenches, soil conservation, land management, archeology, gullies, erosion.

Palabras clave: Trincheras, conservación del suelo; gestión del territorio, arqueología, cárcavas; erosión.

Received: 17 May 2023

Accepted: 30 October 2023

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1. The “trincheras” (trenches) as monuments defeating natural areas recovery and Enhancing gully erosion

Trenches were structures of warfare, where soldiers would dig long, narrow ditches in the ground to shield themselves from enemy fire. The trenches were frequently filled with mud and water, making living conditions extremely challenging for soldiers. They were often interconnected by a network of tunnels and heavily fortified with barbed wire, sandbags, and machine guns (Hutchinson *et al.*, 2008). The soldiers would spend weeks or even months in the trenches, facing constant danger from enemy fire, disease, and harsh living conditions (Dunkley *et al.*, 2011). The fighting in the trenches was often brutal and close quarters, with soldiers using bayonets, grenades, and other hand-to-hand combat techniques (Marshall *et al.*, 2016). Trench warfare was a significant factor in the stalemate of World War I, as neither side could make significant gains without suffering heavy casualties. The war eventually ended with the signing of the Armistice on November 11, 1918, bringing an end to the fighting and leading to the eventual collapse of the Central Powers (Gilbert, 2016).

The Spanish Civil War was an armed conflict that took place between 1936 and 1939 in Spain, and the use of trenches was widespread during the three years of war. The war was primarily fought between the forces of the Spanish Republican government and the Nationalist ones led by General Francisco Franco, who initiated the conflict with a "Coup d'État" involving part of the Spanish Army. The conflict was complex and multifaceted, with political, economic, and social factors contributing to its outbreak. The Spanish Civil War was a turning point in Spanish history, and its impact on the country's political, social, and cultural landscape was profound (Gonzalez Ruibal, 2023). The war resulted in the establishment of a military dictatorship under Franco, which lasted until his death in 1975. During the conflict, numerous defensive fighting positions (DFPs) were designed (González-Ruibal, 2007; 2023). One of the most famous types of defensive fighting positions (DFP) constructed as earthworks were the "trincheras" (translation of trenches). They were large enough holes to hide from one to a fire team unit. They are also similar to the *Tobruk*, defined by the Italian army in Libya, foxholes or fighting holes used by U.S. soldiers, fire trench by the British, and gun and fighting pits by the Australian or New Zealand forces, respectively.

As archaeological monuments, the “trincheras” from the Spanish Civil War have several advantages, including the preservation of historical heritage. These “trincheras” serve as a tangible reminder of a significant event in Spain's history. By conserving these monuments, future generations will be able to understand and appreciate the country's past. Moreover, they can promote tourism, as

many people may be interested in learning about history and visiting historical sites. Conserving the “trincheras” from the Spanish Civil War can attract tourists, thereby helping to boost local economies and provide employment opportunities (López Martínez *et al.*, 2020). On the other hand, they can foster national identity as they are part of Spain's cultural heritage, supporting a sense of national identity and pride among Spaniards. Finally, they could provide educational opportunities for schools and universities. By visiting these monuments, students can learn about the events of the war, the people who fought in it, and its impact on Spanish society, serving as memorials to those who lost their lives during the conflict. Preserving these remains can honor those who were involved in the Civil War.

Trenches are similar to a specific soil erosion feature: gullies. In geomorphology, a gully is a landform characterized by a steep-sided channel cut into the Earth's surface by the erosive action of water (Bocco, 1991; Castillo *et al.*, 2012). Gullies are typically found in areas with steep slopes and high intensity rainfall events on usually bare soils or modified by intensive human changes, where water runoff can rapidly erode the soil and create deep channels (Gómez-Gutiérrez *et al.*, 2009; Nadal-Romero *et al.*, 2014). Gullies can vary in size from small incisions in the soil to large channels that span several meters wide and deep (Arabameri *et al.*, 2019; Casali *et al.*, 2003; De Ploey, 1991). Gullies can form through a variety of processes, including concentrated runoff, landslides, or the collapse of underground channels (pipes). Therefore, gullies can have significant implications for soil erosion, land degradation, and sediment transport. Gullies identify changes in the landscape and are formed when there are alterations in vegetation and soil properties (Amare *et al.*, 2019; Prosser and Soufi, 1998; Vanwalleghem *et al.*, 2005). The study of gullies and their formation processes are an important area of research in geomorphology, environmental science, and land management (Kirkby and Bracken, 2009; Rodrigo-Comino *et al.*, 2017). There is a lack of assessment and monitoring research on gully formation as a consequence of trenches and archaeological excavation.

Therefore, this note provides information about the “trincheras” (trenches) and their environmental impact. We use the example of the “Cerro de las Trincheras” located in the municipality of Bailén (province of Jaén, Spain) and demonstrate that archaeological excavation could be contributing to high soil erosion rates that should be controlled. We discuss the need to consider restoration (or not) of these archaeological sites and propose strategies to mitigate environmental impact, especially focusing on vegetation restoration and soil erosion, during and after archaeological restoration.

2. Cerro de las Trincheras (Bailén, Spain): Study site

We use Cerro de las Trincheras, Bailén (Andalusia), as a pilot area where cultural heritage and landscape management are under discussion. The study site is situated in the north of the province of Jaén within the municipalities of Bailén and Baños de la Encina, with an elevation of 400 m above sea level (Fig. 1).

The Rumblar River flows from the town of Baños de la Encina into the Guadalquivir River. Within the Rumblar River, a reservoir has been built, whose area presents archaeological remains of great importance, such as the Peñalosa site, or historical events of great magnitude in contemporary history, such as the Battle of Bailén (1808). This area is close to Sierra Morena and is considered the natural path to enter Andalusia from the Spanish altiplano (Meseta), serving as the gateway to communication routes from the north. It has geological formations of marly sandstones, marls, and conglomerates, as well as a large outcrop of metamorphic slates and sandstones in the area of the Rumblar basin, all oriented in a NE-SW direction. The vegetation is dominated by holm oaks (*Quercus Ilex*) and wild olives (*Olea europaea var. Sylvestris*), with extensive cultivation of olive trees of the Picual variety. The Cerro de las Trincheras is a small mountain located in the Dehesa de Burguillos, a public forest belonging to the municipality of Bailén, bordering with that of Baños de la Encina. This area covers 9.55 ha and is situated next to the Rumblar River. This location was a strategic point for controlling the passage of the upper course of the Rumblar River.

The “trincheras” found in the municipality of Bailén form a defensive system excavated into the rock, with a length of around 400 meters and an undulating route. It comprises two machine gun nests and lookout points, situated at the western end of the trench and another towards the middle, both currently filled with soil and featuring a circular plan delimited with a rock overlay area. They have a width of 1.60 meters and an estimated depth of 1.80 meters, according to fortification manuals on the battlefield. Various drains have been excavated inside the trenches, utilizing the terrain's inclination and also constructed directly into the rock (granite, sandstones, etc.) (López Martínez *et al.*, 2020).

The undulating route presented by the trench in question is designed to prevent a potential enemy overrun of the defensive line. In the event of having to engage in direct combat on the created parapet, this design ensures that there is no straight shot for enemy forces, reducing the likelihood of causing numerous casualties among the defending forces (Merino Chica, 2021). In addition, it is a place of shelter in case of artillery fire.

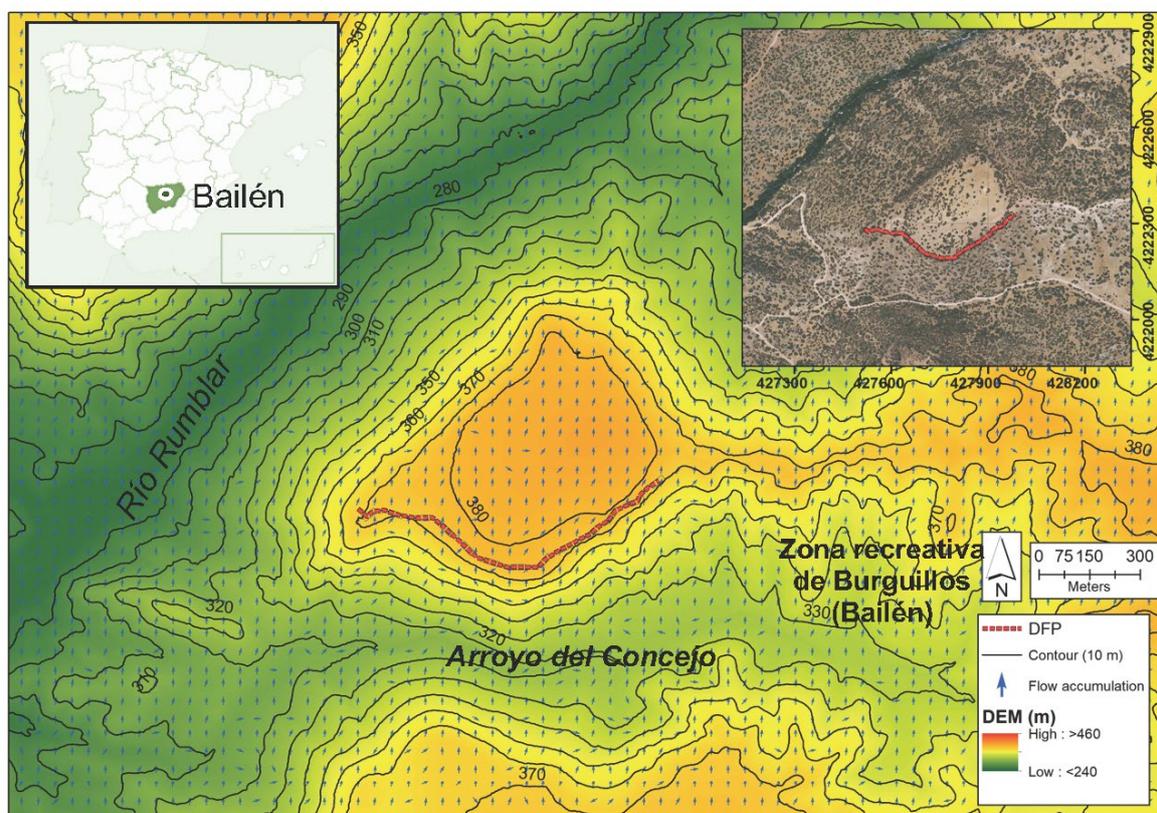


Figure 1. Location, topography, and hypothetical flow accumulation direction of the Cerro de las Trincheras and DFP (defensive fighting positions, “trinchera”).

3. Results obtained from a first approach

In figure 2, different historical aerial photos (1957, 2005, 2006, 2007, 2011 and 2020) are shown to inform about the evolution.

The latest available aerial photograph is from 2020, the year when the archaeological excavation commenced. In this last aerial photograph, it can be observed that the southern part of the area exhibits bare soil and barren vegetation cover compared to the northern part. The southern section of the gully remains bare, displaying soil erosion features. However, as shown in figure 3, soil erosion features are present near the trincheras with bare soils, rills, and gullies, forming a landscape resembling badlands. The lack of vegetation serves as evidence of land degradation processes, especially considering that this

area was managed under a restoration plan related to natural ecosystems by the township and province deputation. We utilized the Auravant app from Buenos Aires, Argentina (<https://www.auravant.com>) to assess the NDVI (normalized difference vegetation index) trends using Sentinel 2 images from 2015 to May 2023. The NDVI values range from 0 to 1, with lower values representing worse results and values close to 1 indicating better ones. We observed a decrease in vegetation status from 2015 to 2023, with this reduction intensifying from 2020 when the excavations began (Fig. 4). This decline serves as evidence of the impact of the excavation process.

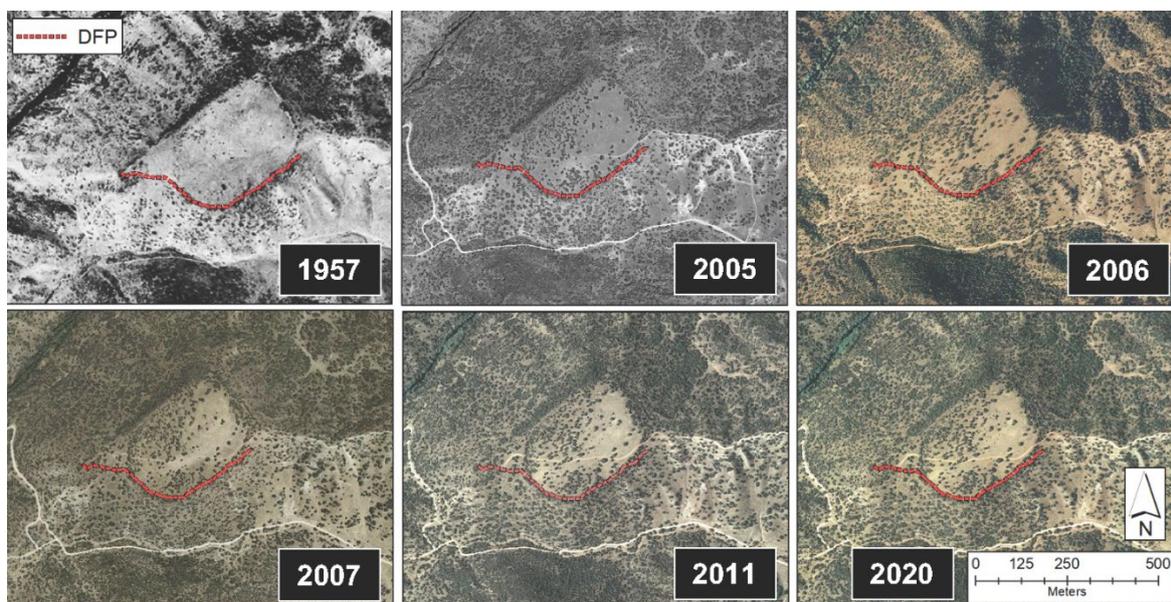


Figure 2. Aerial photography dataset of the Cerro de las Trincheras and near areas. The length of the trincheras (DFP) is marked with red colour.



Figure 3. Rills triggered by the archeological excavation at the Cerro de las Trincheras.

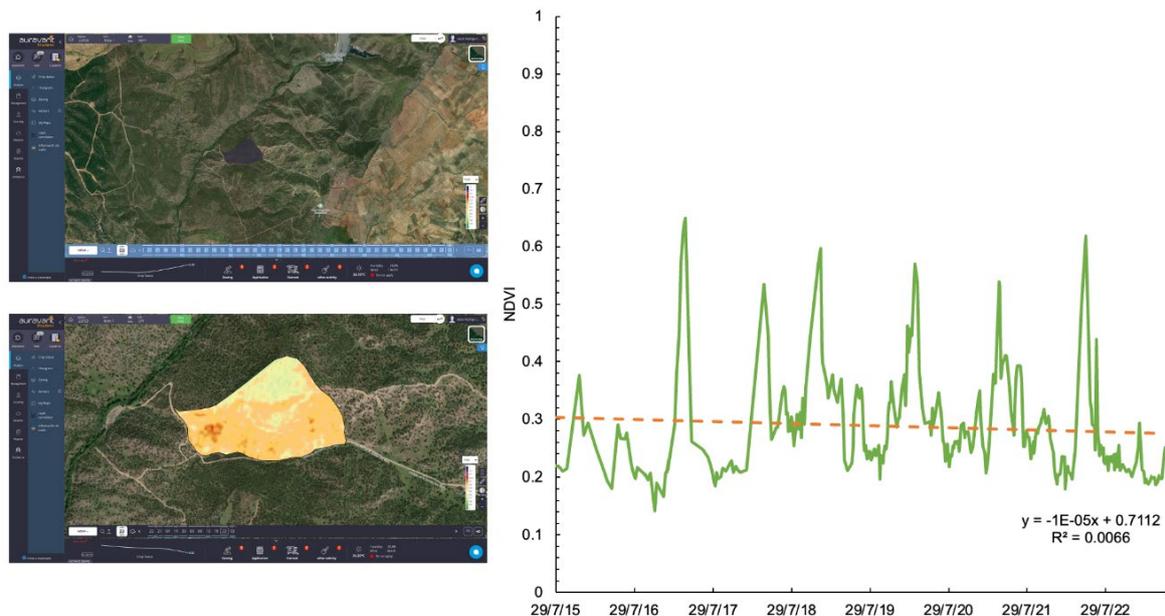


Figure 4. Screenshots of Auravant (Buenos Aires, Argentina) internet application and NDVI (normalized difference vegetation index) trend analysis.

4. Final remarks: The restoration of war trenches. An open discussion

The question of whether it is ethical to conserve Spanish Civil War monuments is a complex and contentious issue that has been debated for many years (Owley and Phelps, 2018). On one hand, these monuments are important historical places, sites, and spaces belonging to the memorial landscape that serve as a reminder of a nation's past and should be preserved for future generations (Sheehan and Speights-Binet, 2019). Others may argue that these monuments are symbols of racism, oppression, and supremacy, and should be removed or destroyed (Evans, 2021). This debate is not unique to the Spanish Civil War, as other societies have also discussed this issue. As scientists, it is challenging to express opinions or beliefs without considering data or highlighting visual processes, as the impacts could be irreparable.

In Spain, many of the Civil War monuments were erected during the mid-20th century, a period when Spain was grappling with issues of racial inequality and segregation. These monuments were not only intended to commemorate the war but also to promote a particular view of history and reinforce specific types of supremacist ideas (Ferrándiz, 2019; González-Ruibal, 2007). For this reason, many people argue that these monuments are not simply historical artifacts but rather symbols of oppression that promote inequality (Delgado, 2015; Labanyi, 2007). In recent years, there has been a growing movement to remove these monuments from public spaces and place them in museums or other locations where they can be studied in their proper historical context. Ultimately, whether or not it is ethical to preserve Civil War monuments is a complex and multifaceted issue that involves considerations of history, culture, and social justice. There is no easy answer, and citizens have different opinions based on their own experiences, beliefs, and political opinions. It is clear that wars resulted in geomorphological changes due to the trenches, bombing, use of heavy vehicles, and the construction of infrastructures (Waga *et al.*, 2022). Valjavec *et al.*, (2018) found in the Kras Plateau (Slovenia) a hundred kilometers of I WW trenches. The recovery of this cultural heritage shows that some trenches and bomb craters are today gone due to sedimentation or human use of the land. Remote sensing and GIS become the most used methodology such as Koch and EL-Baz (1998) already claimed after the Gulf War in Kuwait. Most of the impact of a war on the landforms is lost after some decades due to natural processes such as erosion or soil development (Kiernan, 2015; Thestorff and Makki, 2022). The

impact of the war on vegetation cover and dynamics results in changes in soil erosion with higher erosion rates such as we found at the research site here and Abdo (2018) in Syria. Almohamad (2020) also studied in Syria the impact of the vegetation changes because of the war and conclude that there was a development of soil erosion features such as gullies and rill due to the lack of vegetation. Another recent example is the current Israel and Palestine or Ukraine war and Russian conflict is experiencing. The devastating consequences in a country on soil quality (Rawtani *et al.*, 2022) with previous land degradation issues (Stebelsky, 2015) can be environmentally irreparable.

In our research, we confirm that there is a lack of vegetation during the archaeological excavation that caused the increase in soil erosion, as evidenced by the gullies shown. It is already known that the lack of vegetation induces high erosion rates, and vegetation is commonly used to control soil erosion in agricultural land or reduce soil sealing, serving as a nature-based solution (Fini *et al.*, 2017; Keesstra *et al.*, 2018). We propose that during the archeological excavation, a cover of vegetation or mulches will be used to reduce the soil erosion rates, a solution that it was insisted to be considered since several years ago (Barnett *et al.*, 1967). Also, as Dmytruk *et al.*, (2023) mentioned the foreseen negative impacts of the Ukraine conflict, an accurate diagnosis pre- and post-excavations demands details at the scale at which war operated. They highlight a lack of information, coincident with Southern Spain, specifically the absence of a soil map at least 1:10000 scale, which is necessary to design a predictive model and be able to manage the land correctly (Rodrigo-Comino *et al.*, 2018). Therefore, we strongly propose that future archaeological excavations should include a protocol (soil mapping, vegetation survey, and hydrological connectivity) to reduce soil degradation and avoid damage to the vegetation and associated ecosystems, which can trigger an increase in soil erosion rates.

Acknowledgements

The first author would like to thank his uncle, Mr. Francisco Javier Comino Oriola to organize the field excursion to the Cerro de las Trincheras and other ones around the wonderful landscapes of Jaén province.

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