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Assessing tourism impact on cultural landscapes using mobile phone data: the case of Las Médulas (Spain)

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Abstract

Cultural landscapes often pose problems for planning and management because of insufficient information regarding visitor movements, interests and infrastructure burden. Traditionally visitor surveys have helped to fill this gap, albeit limited to their incomplete and occasional nature. This paper presents a methodology for using cellular antenna metadata for understanding tourism flows. This information is collected systematically by the mobile phone network but only recently has its big data potential begun to be exploited for understanding socio-economic phenomena. The present case study of the Roman gold mine of Las Médulas (León, Spain) provides a model for tourism impact analysis using anonymized data from cell phone towers.

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Key words: World Heritage, Cultural heritage management, Socio-economic impact, Tourism flows, Cellular antenna data, Big data analysis

Resumen

La planificación y la gestión de los paisajes culturales a menudo plantea problemas debido a la falta de información sobre los movimientos de los visitantes, sus intereses, así como su impacto sobre las infraestructuras locales. Tradicionalmente, las encuestas a visitantes han ayudado a llenar este vacío, aunque limitadas a su carácter incompleto y ocasional. Este artículo presenta una metodología para utilizar los datos de las antenas de telefonía móvil para comprender los flujos turísticos. Esta información es recopilada sistemáticamente por la red de telefonía, pero sólo recientemente se ha comenzado a explotar su potencial para comprender fenómenos socioeconómicos mediante análisis de big data. El presente cso de estudio de la mina de oro romana de Las Médulas (León, España) aporta un modelo para el análisis del impacto del turismo utilizando datos anonimizados de antenas de telefonía móvil.

Palabras clave: Patrimonio Mundial, gestión del patrimonio cultural, impacto socio-económico, flujos turísticos, metadatos de antenamóvil, Big data.

1 Introduction.

Cultural landscapes are complex realities that result from the interaction of Human activity in a natural environment. Historical processes shape a territory across time, as well as the perception and sense of belonging of the communities that inhabit and experience it. By listing multiple cultural landscapes as World Heritage since the 1990s, UNESCO has greatly contributed to their embodiment as tourism destinations that combine outdoors and nature interests with cultural and historical aspects.

Managing cultural landscapes, however, poses numerous challenges which stem from their very nature (Mitchell, Rössler, & Tricaud, 2009). Cultural landscapes are open, and they are bounded by diffuse, dynamic and complex borders which pose a challenge for controlling

tourism flow. In addition, they are living spaces which are constantly changing, and where conflicts between daily necessities of local communities are often at odds with the demands of growing tourism (Castillo Mena & Corpas Cívicos, 2023). They are often rural areas, underdeveloped and with low population density, where tourism entails and outsized impact on the year-round residents (Cfr. Cuccia et al., 2016; Jimura, 2011).

Quantifying the impact of tourism is necessary for developing strategic planning that can provide adequate management. Unlike museums, archaeological sites or parks, access to cultural landscapes is often unregulated and unmonitored, resulting in overall visitor counts being tentative at best. Traditional open-area tourism has been monitored through surveys and estimations based on mathematical modelling and visitor numbers in the select facilities that do tally tourists. But these indicators are only partial, and hence relatively useless.

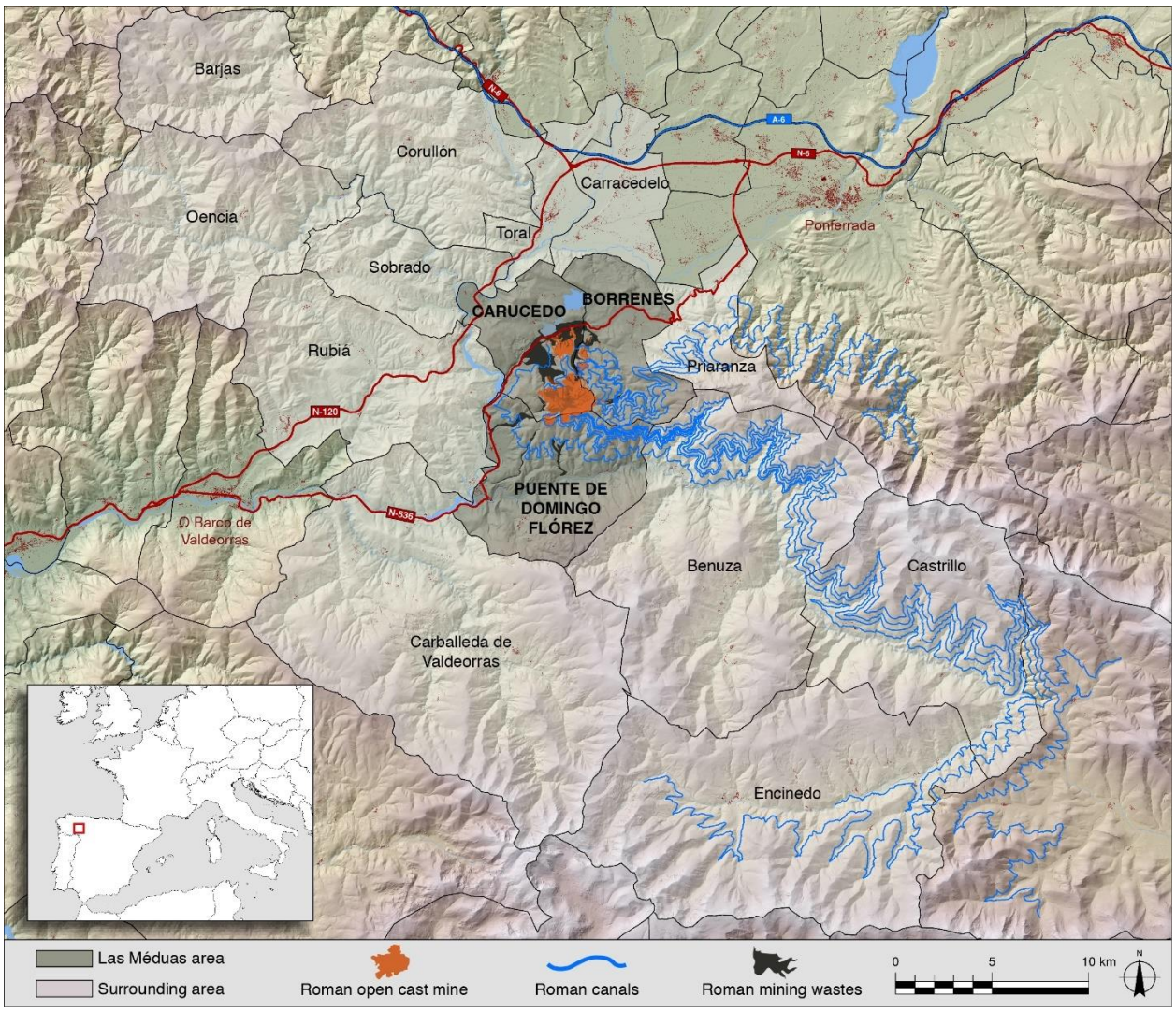
The recent development of mobile positioning data for analyzing tourism (Li, Xu, Tang, Wang, & Li, 2018; Raun, Ahas, & Tiru, 2016; Saluveer et al., 2020; Schmücker & Reif, 2022; Shoval & Ahas, 2016; Xu, Xue, Park, & Yue, 2021) has provided tools to understand visitor behavioral patterns. It has been applied to tourism on a national scale (Xu et al., 2022), by city (Francisco, Ribeiro, Batista, & Ferreira, 2023; Kovács, Smith, Teleubay, & Kovalcsik, 2023; Tian, Wang, Liu, & Wang, 2023; Xu et al., 2021), and for natural parks (Ciesielski & Tkaczyk, 2023; Liang et al., 2022).

The case study presented here, the Roman mining landscape of Las Médulas (León, Spain), will be the test area of an analysis methodology based on the use of anonymized cell phone data which can contribute invaluable data for planning and management of this cultural landscape. We will analyze visitor numbers, duration of stay and provenance, in order to better understand the behavior of tourists, and the strengths and weaknesses which Las Médulas has as a tourism destination. We apply our study to the year 2019, which can be taken as a reference for tourist behaviors before the profound changes produced by the pandemic.

2 The cultural landscape of Las Médulas: Local tourism development and socioeconomic impact.

Las Médulas is a Roman gold mine declared World Heritage by the UNESCO in 1997 (Fig.1). A 600 ha open-pit mine, the largest in Antiquity, produced 4-5 t of gold in in two centuries by extracting it from the refuse (Sánchez-Palencia Ramos, 2000), nearly one million m^3 which formed tailings that also cover an additional 600 ha (Fig.2). The mining technique used involved a complex hydraulic network that required more than 700 km of canals.

FIG.1- Location of the Roman gold mine of Las Médulas.



Source: Own elaboration

FIG.2- Above, the mine from the Orellán lookout. In the background, the village of Las Médulas. Below, view of the village of Las Médulas inside the ancient Roman mine, from the Pedrices viewpoint.

Source: Own elaboration

The inclusion in the WH List was based on criteria that reflected the most outstanding heritage values of the place. First of all, Las Médulas represented Ancient gold mining, and the technique used, known as *ruina montium*, which had been described by Pliny the Elder, was of extraordinary historical value. Gold had underpinned the consolidation of the Roman Empire during the 1st and 2nd centuries AD. This context, therefore, rendered Las Médulas with an exemplary value for local and empire-wide processes, both social and economic, which were key in understanding the Early Empire. The second criterion was that it was a landscape which had been dramatically altered by Human intervention, changing the shape and vegetation of the land. The chestnut tree is characteristic of this land, but it was introduced as a crop by the Romans. The third reason was that both the mining technique, with its sophisticated system of catchment, transportation and accumulation of water, was very well documented, as well as the labor force behind it, which was local indigenous communities, thereby revealing how Roman imperialism facilitated cheap labor as a form of imposing a new territorial and fiscal organization on the land. The fourth and final criterion summed up the rest, by declaring that Las Médulas was a prime example of the use of

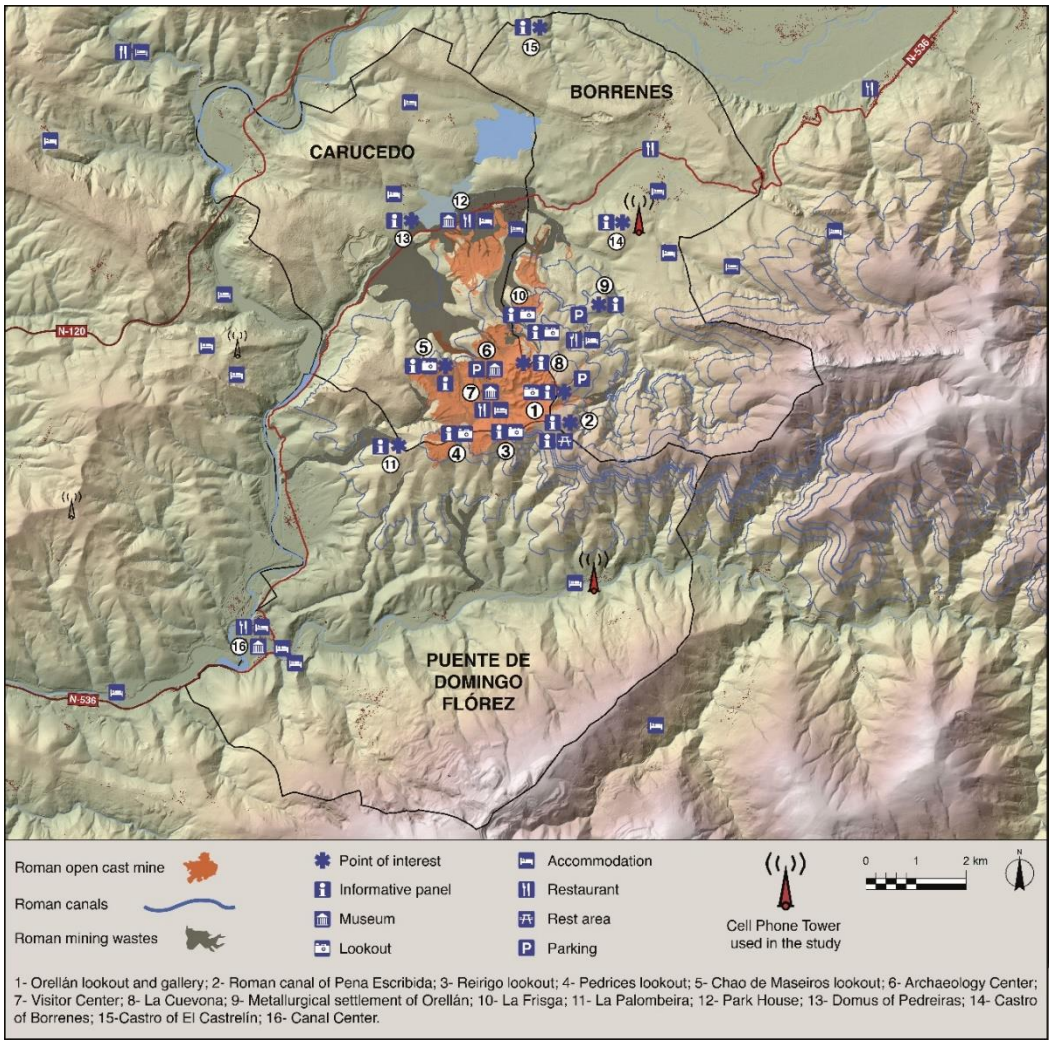
landscape archaeology to understand a transformational period of history. The Early Roman Empire would not have been the same without the concurrence of the wealth extracted from this mine.

The area currently enjoys, apart from World Heritage status, environmental and heritage protections of various types and delimitations. In 1931 the first heritage protection was awarded, and since 1994 there has been permanent environmental protection as well. In 1996, it obtained maximum heritage protection, which was expanded in 2005. Finally, in 2011 the area was awarded the novel Cultural Space declaration, but no further effect has come of it regarding tourism management.

As a cultural landscape, Las Médulas comprises a complex network of layers and relations which have been shaped by humans for more than two millennia. The topography, the settlement, the agriculture and the heritage are features that result from, and are a demonstration of, this long history. This has been seen at the micro-scale of objects and seeds, to the wider scale of the territory. It is a cultural creation with enormous heritage potential, which has been converted into tourism potential. Both the European Landscape Convention (CoE, 2000) and the Faro Convention (CoE, 2005) underline the value that this rich and complex cultural heritage provides to the quality of life and the sustainable generation of resources for local communities.

The area has been undergoing dramatic transformations due to major socio-economic drivers such as the abandonment of farming practices, ageing and emigration, as well as the occasional mining activity. The World Heritage designated area occupies 3000 ha straddling three different municipalities: Carucedo, Borrenes and Puente de Domingo Flórez (Fig.3). The mine, if the hydraulic network is included, is far more expansive: 30,000 ha, and affecting nine townships (Fig.1). The latter, as of yet, has no heritage protection.

FIG.3- Las Médulas area, tourism infrastructures and locations of the antennas used for this study.



Source: Own elaboration

Visiting this outstanding cultural landscape is free and unregulated. Visitors have at their disposal various trails and outlook points with information panels. There is also ample heritage and tourism infrastructure (Fig.4). The Archaeology Center includes videos that help explain the evolution of the landscape from the Iron Age, and the transformations undergone during the Roman period. The Visitor Center, in the middle of the Las Médulas village, provides information on the trails and organizes guided tours. The Park House provides an environmental perspective on the change in the landscape. The Canal Center details the characteristics of the hydraulic network associated with the mine. There are also numerous marked trails with information panels open to the public. There is also a paid-only access to the Gallery at Orellán. Finally, there are four archaeological sites which are also publicly

displayed, two of which are pre-Roman (El Castrelín and the Corona del Cerco de Borrenes), and two Roman (Orellán and Pedreiras de Lago) (Sánchez-Palencia Ramos, 2000). As observed through field work, most visitors tend to visit the Visitor Center in the village of Las Médulas, and then stroll along the trail of Las Valiñas, to the foot of the mining front, where massive caves such as the Cuevona and Encantada reveal the inner workings of the *ruina montium*. They can also drive up to the top for the famous Orellán lookout (Fig.2). Finally, there is also a type of visitor that follows one of the branches of the Way of Saint James, which happens to cross this area, thereby adding an additional layer of cultural tourism. In any case, tourists can do any one of these things in any order they desire.

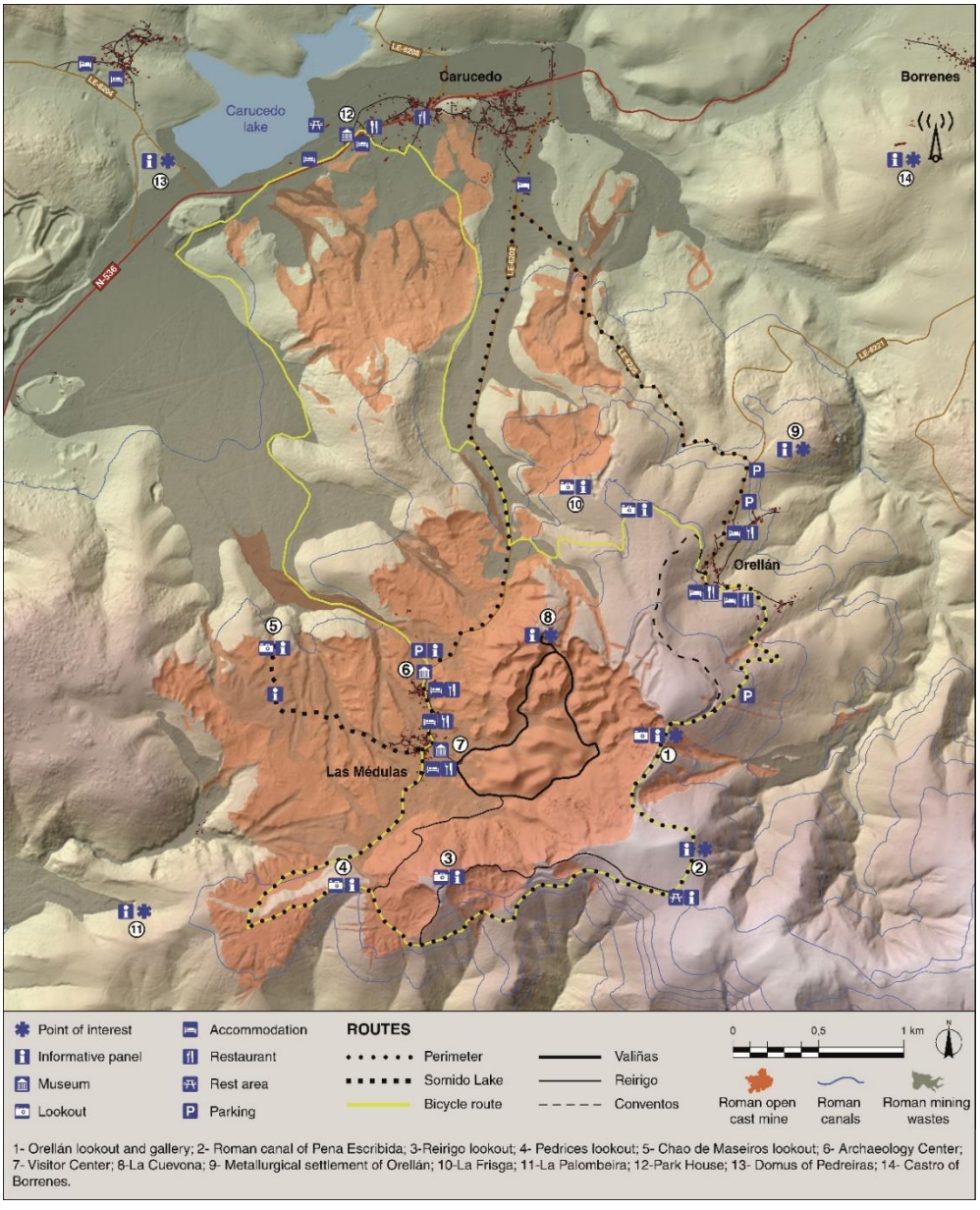
FIG.4-. Tourism infrastructures of Las Médulas: a) Archaeology Center, b) Park House, c) Visitor Center and d) Orellán lookout.

Source: Own elaboration

Las Médulas is a living landscape. There are several villages with a total of over 2000 people: Puente de Domingo Flórez (upward of 1500), Carucedo (nearly 600) and Borrenes (more than 300). A significant part of them benefit directly or indirectly from tourism. Social Security data from 2023 indicate that the proportion of people working in hospitality is significant (5 of 13 in Borrenes, 9 of 39 in Carucedo and 20 of 349 in Puente de Domingo

Flórez). Most others, however work in other sectors or commute daily to other municipalities. In such a broad territory, land use is diverse. Some areas are protected from any use, while the rest combine small farmland and vegetable gardens, or groves of chestnut trees. Local quarries and hydroelectric dams, among other sites, are also important for the local economy. This territory can be accessed in different ways, impeding any monitorization or restriction of visitor inflows (Fig. 5). These are standard characteristics of cultural landscapes, which only make the challenges and the management of tourism all the more complex.

FIG.5- Location of tourism infrastructures at Las Médulas. (Source: Own elaboration).

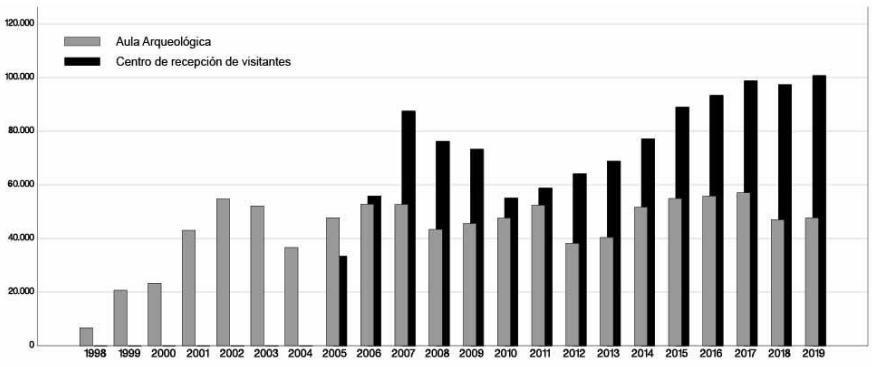


Source: Own elaboration

The archaeological features at Las Médulas also cover an array of sites, lookouts, information points, which dot the landscape. A visitor enjoys a cultural experience which includes witnessing the dramatic transformations from the pre-Roman to the Roman periods due to gold mining. The stellar locations are the lookout of Orellán and its celebrated perspective, or the trail of Valiñas, where visitors can stroll along the feet of the mining front (Fig. 5). Both have marked trails and information panels. Tourists enjoy an outdoor experience, which can be complemented with other trails designed for hiking, running or biking. In addition, the "winter" Way of Saint James also crosses this land, adding an extra layer of cultural tourism. Visitors can do any one of these in any way they desire.

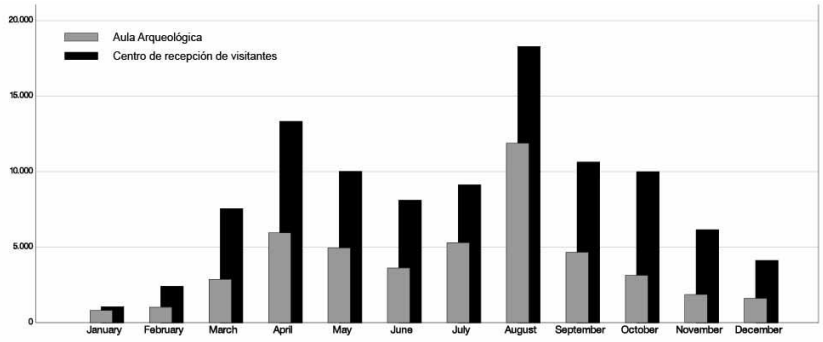
This is an open space, so large and unregulated that any direct quantification of tourism is impossible; making it challenging to know where they come from, how long they stay and whether they stay over. This problem was somewhat lessened when the first visitor facilities -the Archaeology Center- was opened in 1998, and some years later, in 2005, a proper Visitor Center. These infrastructures have been collecting information on any tourists or other visitors who happened to enter them to inquire (Fig. 6 and Fig. 7). This data provides some information on the actual volume of tourists in the area, but it is an incomplete set. Any visitor who does not happen to enter a visitor facility is virtually invisible in these records. Pilgrimage, short visits or even those stopping to have a bite in one of the restaurants remain under the radar. This makes managing this landscape very challenging for the institutions involved.

FIG.6- Annual number of visitors to the Archaeology Center and Visitor Center.



Source Data: Instituto de Estudios Bercianos, Centro de Recepción de Visitantes.

FIG.7- Monthly distribution of visits to the Archaeology Center and Visitor Center in 2019.



Source Data: Instituto de Estudios Bercianos, Centro de Recepción de Visitantes

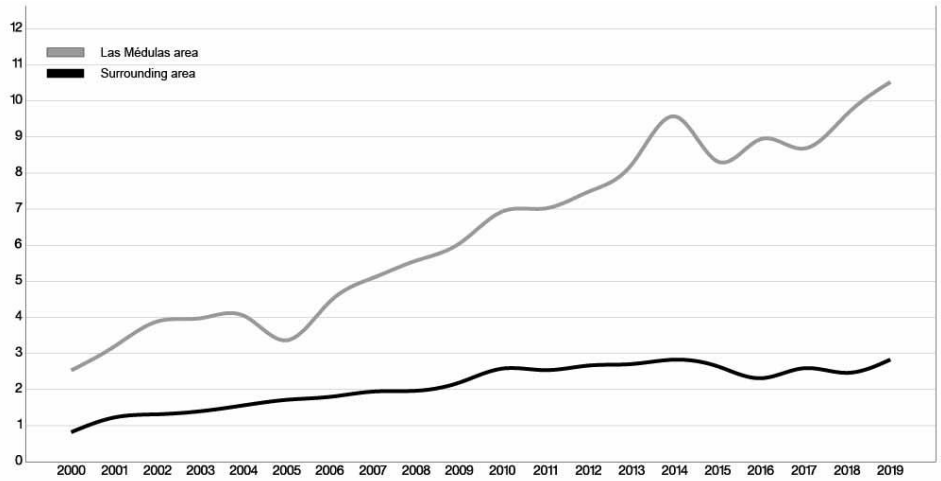
2.1 Direct indicators of economic impact

Socioeconomic indicators have revealed significant local impact as well as the development of burgeoning tourism sector after the designation as World Heritage in 1997 (Guaita et al., 2019; Reher, 2019, 2020). Considering the overall downward trend in population which is affecting the general region -and much of rural Europe-, the municipalities affected by the cultural landscape fare significantly better than their twelve immediate neighbors (Fig. 1). The former are identified as the Medulas area, and the others as the Surrounding area in this study, as per the established methodology, which sets apart a core set of townships and compares it to the surrounding municipalities for reference (Reher, 2018). The resolution of this area and the data obtained made it impossible to use more common indicators such as tourism intensity, used elsewhere (Štefko, Vašaničová, Litavcová, & Jenčová, 2018; Tokarchuk, Gabriele, & Maurer, 2016). They are all small, rural communities undergoing a severe process of ageing and abandonment. But, as we shall see, their outlooks are not at all parallel.

A reliable indicator of a growing tourism market, in places without trade or an industrial sector, is the hospitality business. Regarding accommodation, Figure 8 reveals this quite clearly. Unfortunately, this data is unavailable for the 1990s, but since 2000 the trend has been clearly positive, with Medulas area villages opening many more accommodation establishments, from rural housing to inns, with a 2019 total of 25 (10.5 per 1000 inhabitants), than Surrounding area, currently 34 (2.9/1000). The number of bed places reflects this disparity as well (Fig. 9), with the Medulas area having 270 (114/1000), and the

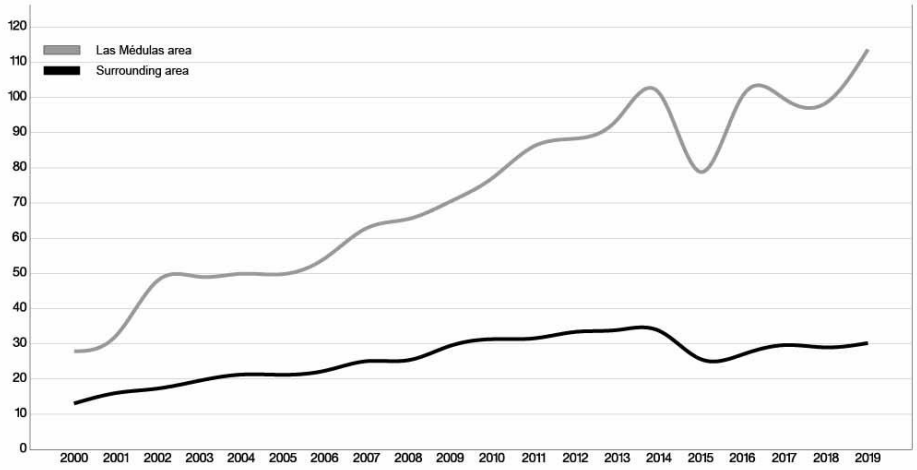
Surrounding area 363 (30.2/1000). Using this formula is common when assessing hospital capacity -hospital beds per 1000 is a staple international statistic-. In addition, it has been used as a measure of Tourism Intensity (bed places per person), directly and indirectly, by other scholars (Baležentis, Kriščiukaitienė, Baležentis, & Garland, 2012; Icoz, Var, & Kozak, 1998; Lozano & Gutiérrez, 2011). In recent years there has been a significant rise in the number of accommodations through the momentous phenomenon of private accommodations. This same gloat has affected the number of beds available, seen in Figure 9. Early on, there were a small number of modest hotels primarily in the Surrounding area, with greater bed capacity. The progressive increase in number of small establishments has prompted a large rise in the number of beds in the Medulas area. One of the factors behind this is the rise in number of private housing and apartments available, of which there were no examples in 2017, and in 2022 there are 10 (6 alone in the Medulas area).

FIG.8- Evolution of the number of accommodation facilities per 1000 inhabitants in the period between 2000 and 2019.



Source Data: Sistema de Información Estadística of Castilla y León.

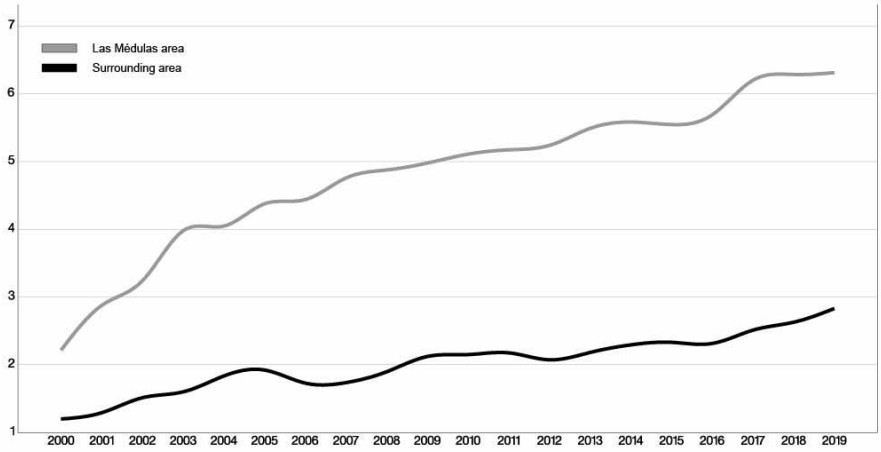
FIG.9- Evolution of the number of beds per 1000 inhabitants in the period between 2000 and 2019.



Source Data: Sistema de Información Estadística of Castilla y León.

An additional, albeit indirect, measure of this emerging sector is that of catering. When archaeological work began in Las Medulas in the late 1980s, there was only one restaurant in the area. Little changed until the late 1990s, when the landscape had already been included in the World Heritage List, hence bearing witness to the impact that cultural heritage had, and still has, on the local economy. Since then, as figure 10 shows, the business has only gotten better, pulling the Medulas area far above the Surrounding area. In Las Médulas there were in 2019 15 restaurants, 6.3 per 1000 people, in contrast with the 34 (2.8/1000) in the Surrounding area. This was a dramatic increase from 2001, when the proportions were 2.2 and 1.2 respectively.

FIG.10- Evolution of the number of restaurants per 1000 inhabitants in the period between 2000 and 2019.



Source Data: Sistema de Información Estadística of Castilla y León.

There is an important caveat for the data presented here. The indicators are factored to represent the proportion of elements to the total population. Hence, the steady decline of population in both Médulas and the Surrounding areas tends to contribute a veneer of steady growth to all the lines included -with some notable exceptions in the form of sudden drops-. In 1986 core municipalities had 3666 people, and surrounding ones had 20307; in 2019 the figures were 2377 and 12018. With this background loss of population, a rise in relative levels of businesses is expected. It is only in the growing difference between both lines, comparing core and surrounding area, that the data become explicit. This figure reveals not only an all-encompassing decline in population, but also a modestly more gradual process for the Médulas area municipalities.

An analysis of the socio-economic impact of the cultural landscape of Las Médulas reveals that a strong tourism sector has emerged, which is highly relevant at a local scale. This sector, however, is far from achieving an arrest of the major abandonment trend that affects these areas, among many others in Europe. This contrasts with other studies that have proved a positive correlation between tourism and socioeconomic opportunity (Jiang, DeLacy, Mkiramweni, & Harrison, 2011; Lagos & Wang, 2023). This case study presents certain advantages which include the relative knowledge of the situation and the resources available, and a prime disposition to render itself to innovative types of analyses which may explain the specific characteristics of what visitors do when they arrive. We know that they eat, and perhaps that they sleep, but little else.

Overall, these data indicate that there is a strong tourism sector run and benefitted by the local community. The 1997 inclusion of Las Médulas in the UNESCO World Heritage List undoubtedly triggered this change, which has had a profound impact on the outlook of the population there. Nonetheless, the open nature of this landscape makes it difficult to establish more definitively the impact it has, as well as manage tourism more efficiently. What people do when they visit, where they stay, what they see, where they eat, where they rest, and how they move about, is completely beyond the control of landscape managers.

3 Anonymized geolocation of cellular signal: a method for analyzing tourism impact

Li et al. (2018) have summarized the three different categories in which big data has been used for tourism analysis: online opinions, data provided by smart devices and online transactions (reservations, searches, etc.). Of these, the metadata provided by cellular networks include various characteristics with plenty of potential: they are very abundant, users do not intervene and they do not require any additional infrastructure. Using this type of big data improves upon more conventional statistical analyses because of the automatic, continuous and geolocated nature of the information. Overnight stays and provenance data can now be collected with ease and reliability (Ahas et al., 2014). An additional benefit is that the database is common to all destinations, networks and nationalities. The data is detailed enough that analyses can focus on details like where visitors went and how long they spent there (Qin et al., 2019). The interoperability of data overcomes many of the traditional handicaps of combining databases.

The records generated by cellular networks are designed so that operators can monitor all communication activity in their networks, which is done through many fields. Big data mining in tourism focus on those which identify the cellular antenna used, the time when communication with it begins and the roaming indicator for visitors from abroad (Qin et al., 2019). Using this metadata, however, does present some shortcomings such as the absence of GPS data, the periods of disconnection from the antenna or the total absence of any

information pertaining the purpose of travel, expenses or type of accommodation (Ahas et al., 2014).

This study uses the tourism indicators provided by KIDO DYNAMICS technology, which is currently in a patent process at the EU. Preliminary analysis ensured the consistency, quality and anonymity of the sample records. The challenge presented by identifying mobility has been solved using a KIDO DYNAMICS methodology with three phases. First, the movements of the visitors are reconstructed using the full network of antennas. This is done by ascertaining the mobility based on the maximum entropy principle as indicated by the operator data (Hernando & Plastino, 2012).

The next step is to map the antenna-based location on to the roadways, enabling an unprecedented perspective into mobility patterns. By modelling movement, the itineraries are filtered to reveal the most probable route taken, given the time, route and distance. The final step expands the sample in order to extrapolate the results onto total population (we only have the metadata of one operator). By interpreting device location across the day and night, we estimate the sample census and categorize it by the minimum administrative unit (municipality). This census is determined by market penetration of the operator, devices and by age group. Afterwards the official population data, by gender and age group, is compared, providing a reliable estimate of how many people of each demographic group is represented by the data collected. Similar foreign visitor information is used by comparing international interconnection agreements of our home operator (for Spaniards visiting those countries), and the presence of said operators roaming in Spain. In order to ensure anonymization three techniques are used in managing the data: pseudo-anonymization, complete anonymization and aggregation.

KIDO DYNAMICS has actively collaborated with Eurostat to define and validate the methodology which can facilitate statistical data from cellular networks. In addition, the technology used by this company has been the basis of several studies regarding the expansion of the COVID-19 pandemic (Hodcroft et al., 2021; Mazzoli et al., 2021).

3.1 The data

The Hosting area, when related to the use of cellular antenna data, refers to the space served by antennas, which can usually service 2 to 5 thousand people. In order to establish a Hosting area that covered the Medulas area it was necessary to include two antennas (Fig.3). As it happens, one of these also serves an additional municipality not within that area, Priaranza del Bierzo. The nature of the data used makes it impossible to segregate the results that township, so it necessarily eschews the data. Fortunately, Priaranza is not a tourism destination in and of itself. Its only interest is the view you can get of Cornatel Castle, which is on the road to Las Médulas. As a result, the potential tilt in the data can be considered insignificant. Another possible bias is the Way of Saint James which, as stated above, has a winter route which crosses the area. Neither it, nor Priaranza, actually have much weight touristically. No major stops for pilgrims are advertised here, and this township had no accommodation at all until 2009. In this latter case, however, 2019 entailed a significant change, with seven new businesses appearing, mostly rural housing, amounting to 31 beds, more than other municipalities around not directly in the Medulas area. This sudden surge is nonetheless dwarfed by the 25 businesses, and 270 beds, in Las Médulas. It is possible that Priaranza, which is less than 30 minutes from the mine, does actually cater to visitors to the World Heritage landscape. Indeed, the strong growth of a tourism industry in Las Médulas appears to have had a certain spillover effect.

Users who live in the area are identified as **residents**. This quality requires that at least 15 consecutive nights, or 18 non-consecutive nights, are spent in the area in the last 30 days. An overnight stay is determined when the last event of a day, and the first of the morning after, happen in the hosting area.

Those users who regularly work in the hosting area are **regulars**. To qualify as a regular a person needs to be present at least 14 weekdays in the last 30 days, or at least 30 minutes every day, between 6 am and 10 pm, in the hosting area.

Unique Visitors are any user who is neither a resident or a regular, and who has been in the area at least 30 consecutive or non-consecutive minutes in a day. A user who eats breakfast in the hosting area, eats outside and dines in it again, is still a single user. Visitors can be discriminated between national and international. Analyzing the data for visitors can reveal various indicators:

- Total number of visits (at least 30 minutes spent by Unique Visitors in the area).
- Total number of overnights stays (number of domestic or international tourists multiplied by the number of nights they spent.
- Days and times of greatest influx.
- Daily distribution of visits or overnight stays, depending on their origin, within a given range, and the average duration of stays (average time/nights spent by a Unique Visitor, without counting time spent sleeping).
- Origin of visitors (place of residence of domestic tourists, municipality or province, and country of residence of international tourists).
- Duration of the stay (classification of Visitors or tourists according to the duration of their stay, in hours or nights, in the area, and depending on their origin).

The time frame of the study is 2019, which is the last period which can be considered representative of usual tourism flows prior to the pandemic. Future studies may focus on the changing realities that ensued during, and after the pandemic, and how they affected tourism.

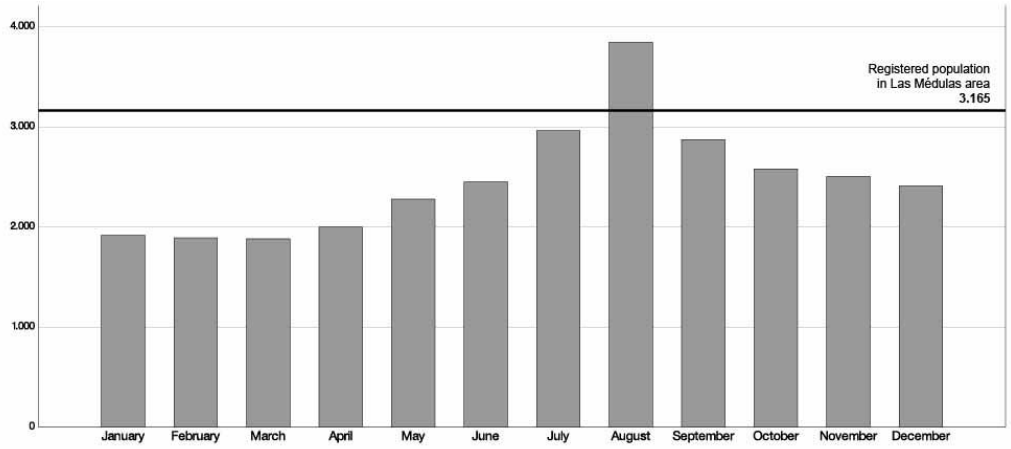
4 Mobile phone data analysis: The impact of tourism in Las Médulas

4.1 Residents

The data sheds light on the behavior of local population. Population registers for 2019 establish a total number of residents in the four municipalities in the hosting area of 3,071. Annual distribution of resident population, according to cellular user data (FIG. 11), reveals that the total population in the area during most of the year is significantly smaller. This difference between registered and attested population could be the result of inhabitants that do not own cellular phones, but official estimates from the Spanish National Markets and Competition Commission (CNMC) indicate that market penetration of these devices is above 100%. A more plausible explanation is that many of the registered residents actually live and work in the county capital of Ponferrada, which is only 30 minutes away from the heart of the mine, and just 15 from Priaranza, already in the hosting area. These people

probably return to the area in the summer, which explains why the resident population increases in July, August and September.

FIG.11- Population residing in Las Médulas area. The line indicates the official number.



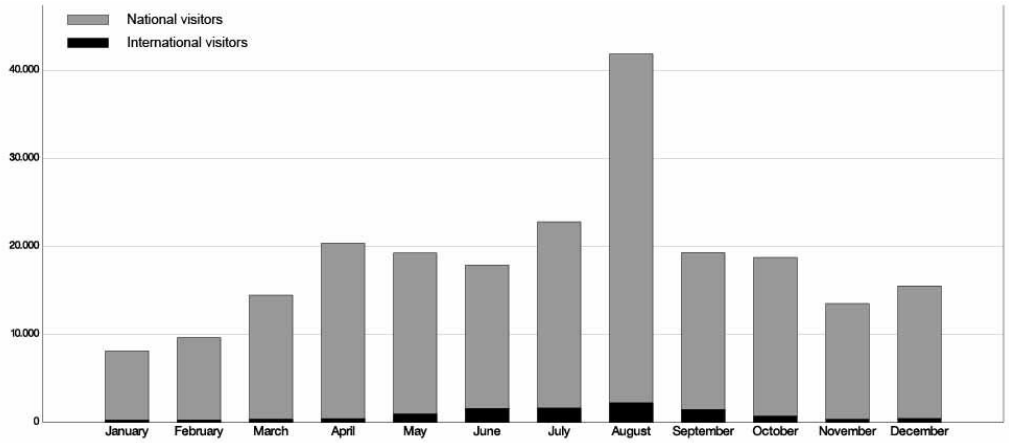
Source: Own elaboration after mobile phone data compared with the registered population in the Instituto Nacional de Estadística, https://www.ine.es/index.htm.

Indeed, the summer sees much more population that qualifies in this methodology as resident; totals add on 700 people to the officially registered population. It is possible that behind many of these residents may be long-stay tourism, renting housing for several weeks or months during the peak season.

4.2 Unique Visitors

The total number of visitors in 2019 was 221,370 (Fig. 12). It is a heavy tourism inflow for such small (2000-3000 population maximum) rural municipalities, which necessarily places much stress on the carrying capacity of the landscape and its public services (refuse, water supply, parking, sewage, etc.). If we compare this figure with the total registered at the Visitor Center we find that only half of them actually step inside it, and only one fifth visit the Archaeology Center. These figures, which have been used up to now, heavily underestimate the real impact of tourism.

FIG.12- Monthly distribution of unique visitors in Las Médulas area in 2019. (

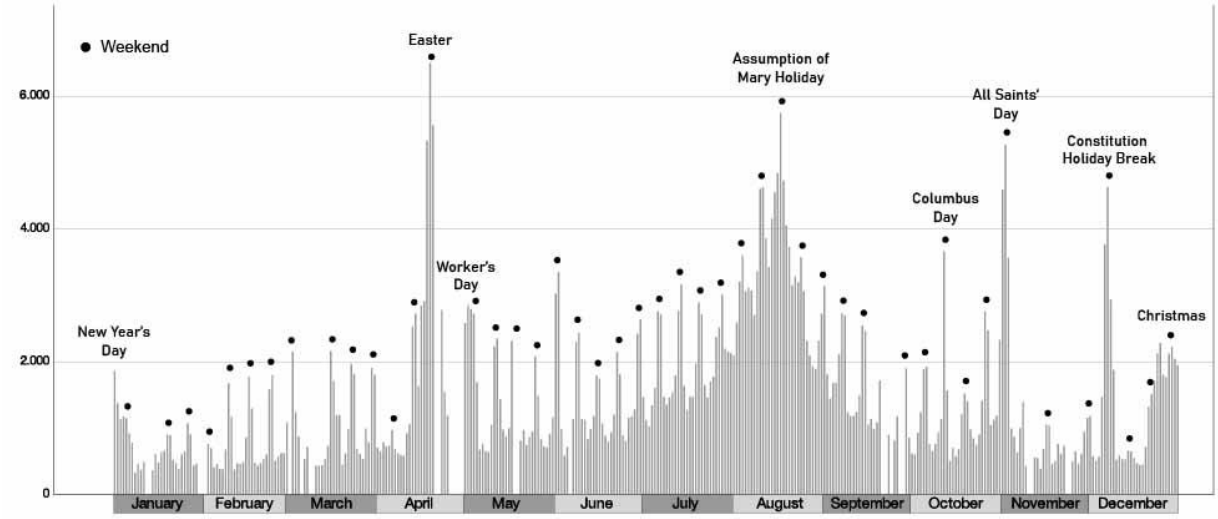


Source: Own elaboration after mobile phone data.

4.3 Annual tourism distribution

Figure 12 reveals that visitors actually come year-round, with only a slight dip in winter and a strong rise in August. When analyzed by days, and disaggregating multiple-day visitors into separate day visits, the data becomes much more revealing (Fig. 13). This way of visualizing the information facilitates understanding year-round tourism flows, and identifying peak days, when tourist pressure is strongest. There is a marked seasonality, with many more visitors in general during the summer. However, Las Médulas is not an exclusively summer destination. Throughout the year weekend visitors come, even more so during national holidays: New Years, Good Friday, Labor Day, Assumption of Mary, Columbus Day, All Saints Day, Constitution Day and Christmas Day. Of all of these there are four peak moments throughout the year: Easter (Good Friday is a national holiday, but in most of Spain so is Holy Thursday), Assumption of Mary (August 15th), All Saints Day (November 1st) and Constitution Day (December 6th, followed, two days later, by another national holiday, Immaculate Conception Day). These are outstanding tourism peaks throughout the country, given that they can easily become 3 or 4-day getaways.

FIG.13- Daily distribution of unique visitors in Las Médulas area in 2019.



Source: Own elaboration after mobile phone data.

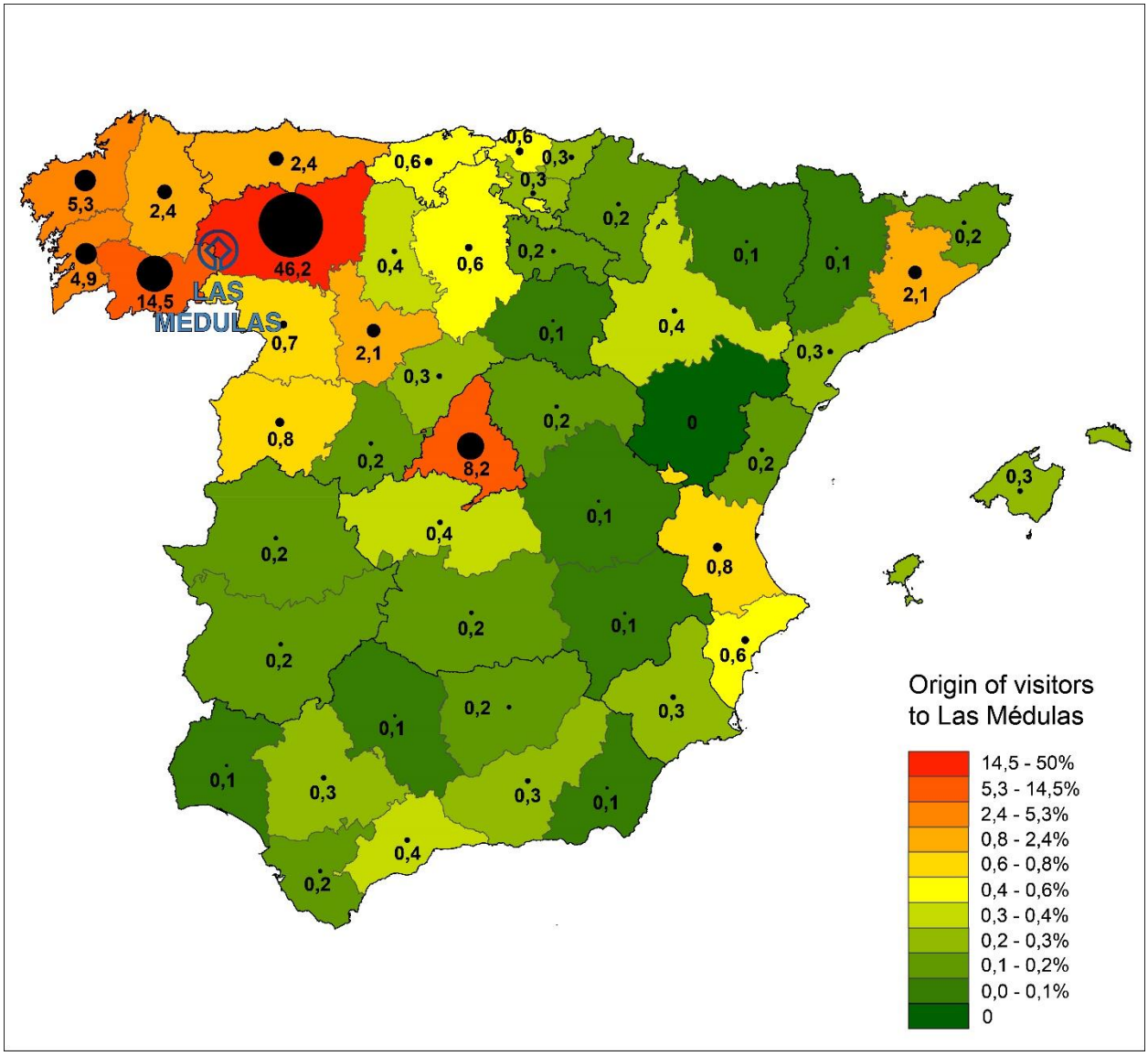
This objective quantification of the number of visitors by day is fundamental in determining visitor pressure on the carrying capacity of the territory, and how it affects local communities. There are 37 days a year when more than 3,000 people visit, mostly in August. The two days with greatest visitors were April 19th (Good Friday that year), with 6,530, and August 17th, with 5,911 tourists. They are not, in and of themselves, enormous numbers, if compared with other destinations that can easily handle that any day of the year. But they are enormous for these small rural municipalities, particularly the villages of Carucedo, Orellán and Las Médulas, which are in or near most tourist facilities (Fig. 5), but whose regular population is just a registered 454 people, a number which is reality is probably smaller, as seen above. These villages, therefore, easily come to multiply by 7 their population for a month every year, and by 13 in peak days.

4.4 Tourist provenance

The data analyzed reveals that most tourism in Las Médulas is domestic. Only 4.7% of the 221,370 visitors each year, 10,416, are international. Provenance studies of this domestic tourist indicates that they are mainly from neighboring provinces (Fig. 14). The largest portion comes from the province of León itself (46.2%) and neighboring Ourense (14,5%). Other provinces, immediately adjacent to these two, account for a large portion (17.1%): A Coruña (5.3%), Pontevedra (4.9%), Lugo (2.4%), Asturias (2.4%) and Valladolid (2.1%). Finally, the two provinces with most population in the country, Madrid and Barcelona, account for 8.2 and

2.1 % respectively. In total, these 9 provinces account for 90% of all domestic tourism in Las Médulas.

FIG.14- Percentage values of national visitors by province of origin in 2019.



Source: Own elaboration after mobile phone data.

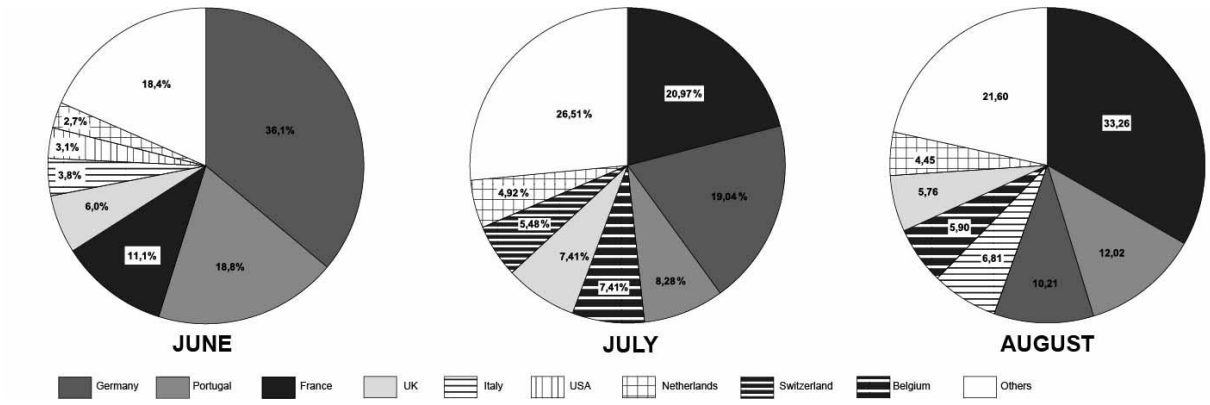
A key feature of this destination is that it can really only be reached by car, and you need a car to visit the various resources around. In addition, two days suffice for said visit, so it is the ultimate weekend destination. Visitors from further away, which would have to spend a whole day just to get there, don't bother coming at all. Madrid is a good four hours by car, so that half a day must be spent on the road, rendering Las Médulas an ideal destination for long weekends like those listed above. In August, nearly 10% of visitors come from Madrid.

Barcelona, on the other hand, is more than twice as far away, so its presence is limited to the vacation month of August.

The relative scarcity of provinces which are between 2 and 3 hours away is also surprising. Zamora only accounts for 0.7% and Palencia 0.4% percent of tourists. Given their low population, however, these two provinces in general contribute little to national tourism as a whole. Thus, while Las Médulas is in Castilla y León, the contribution of other provinces within that Autonomy is very small, compared with Galicia, where all four provinces are generously represented.

Provenance of international tourism is diverse and the numbers are fairly modest, with a lot of seasonal variation. It is an almost exclusively European tourism, with France, Portugal and Germany as main contributors (more than 50%). United Kingdom, Italy, Belgium and The Netherlands are a distant second tier. International tourism is, expectedly, much more seasonal than domestic tourism (Fig. 15), with visitors appearing between June and September, as well as a modest peak at Christmas. Any further nationalities or off-peaks are statistically insignificant.

FIG.15- Percentage values of international visitors by country of origin in the summer months of 2019.

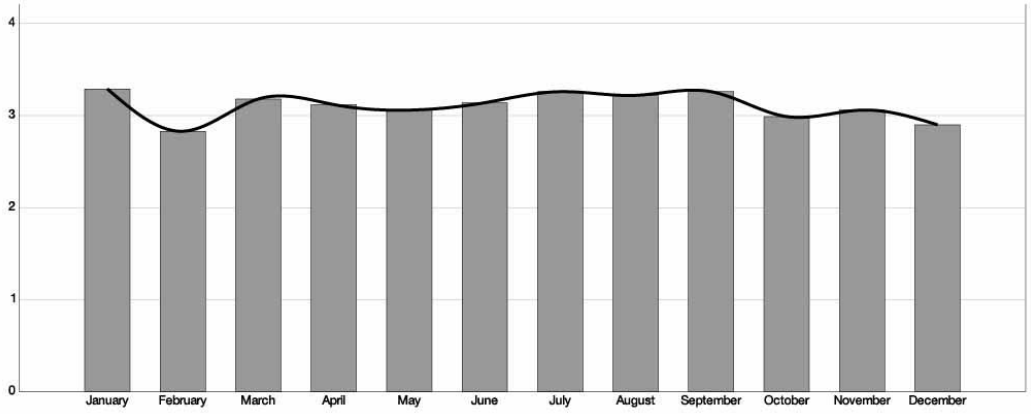


(Source: Own elaboration after mobile phone data).

4.5 Tourism behavior: duration

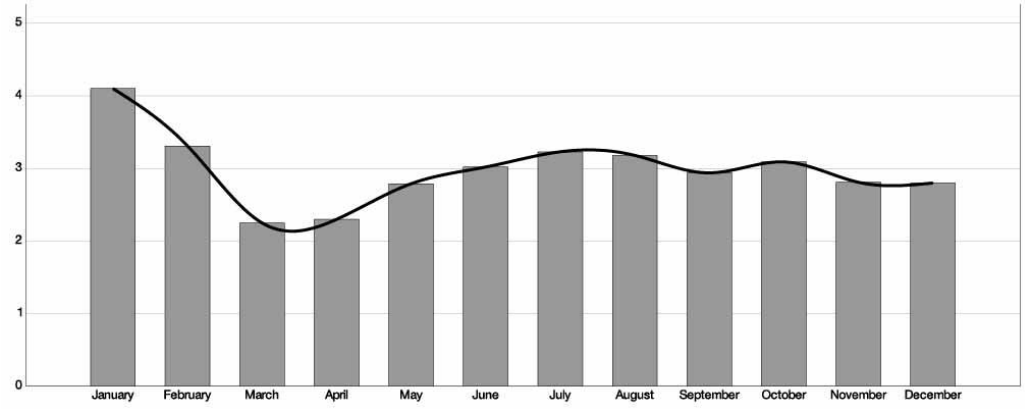
A key parameter for understanding tourism flows is visit duration. This determines whether it is a primary or secondary destination, and reveals how appealing tourism services are. Average visit duration is only 3 hours (Fig. 16 and Fig. 17). This is born out by domestic tourism throughout the year, with a slight increase during the summer, when the pleasant weather and long days facilitate longer stays. International tourism follows a similar trend, albeit with a confusing rise in duration during January and February which, in any case, only affects 250 tourists per month.

FIG.16- Monthly distribution of average visit duration for national visitors. (



Source: Own elaboration after mobile phone data**).**

FIG.17- Monthly distribution of average visit duration for international visitors.

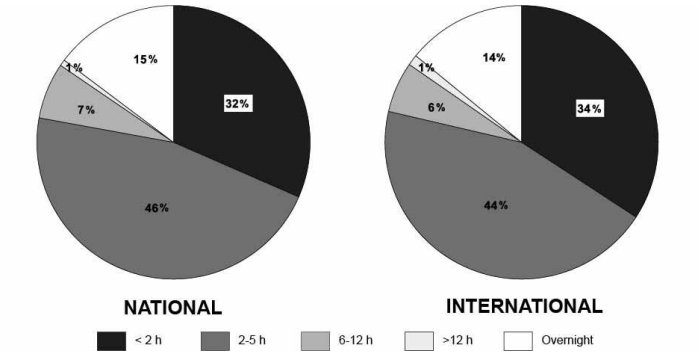


Source: Own elaboration after mobile phone data**).**

Yearly totals segregated by time slots (Fig. 18) point out that 32% of domestic tourists spend less than two hours, 46% between 2 and 5, and only 7% spend between 6 and 12 hours,

which would constitute 'spending the day'. Only 15% of visitors spend the night. Once again, there is no variation to speak of when comparing domestic and international tourism.

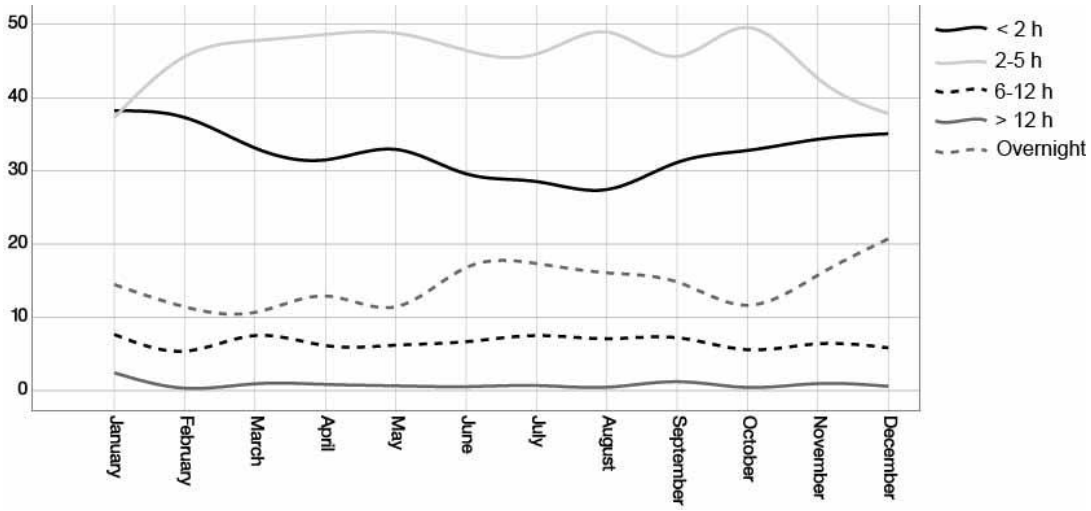
FIG.18- Average duration of national and international visits to Las Médulas area, by time segments.



Source: Own elaboration after mobile phone data.

Throughout the year, this data is fairly constant (Fig. 19). During the summer there is a modest increase of overnight stays, up to 16-17% of the total, hand in hand with a modest decrease of visits of up to 5 hours. All this data is broadly applicable to international tourists as well.

FIG.19- Annual evolution of visit duration for national visitors in 2019, by time segments.



Source: Own elaboration after mobile phone data.

The short duration of visits is a very significant indicator. 77% of visitors spend less than 5 hours, while only 8% spend the day and 15% spend the night. This would underline that Las

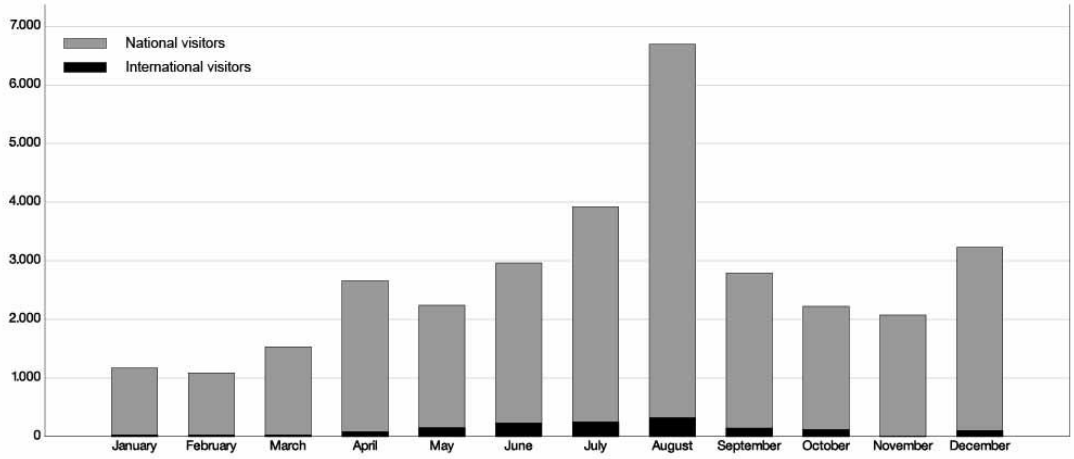
Médulas is not an exclusive destination, but rather one stop of many. This is facilitated due to the nearby major roads (Fig. 1), two main communication axes between Galicia and Castilla y León. It is plausible that many Galicians (27% of tourists) making their way somewhere else could stop in Las Médulas for a brief visit. Similarly, perhaps people from Madrid (8,2%) could stop there before continuing to Galicia.

The heritage resources available and the visitor infrastructure, however, is designed to keep visitors in the area much longer. This cultural heritage requires time for a full understanding. A brief visit of under two hours hardly allows the visitor to understand what he is seeing. This more superficial type of visitor will exclusively go to the hottest spots, like the Lookout at Orellán or the Trail of Las Valiñas. For those that stay a bit longer, 2-5 hours, there is still no time to visit all the archaeological zone and eat as well, but they can enjoy guided routes, enter the Archaeology Center and do something beyond the photo-op at the lookout.

4.6 Tourism behavior: overnight stays

The total number of overnight stays varies greatly throughout the seasons (Fig. 20). Most of these are during the summer, particularly in August. In April there is also an uptick, during the week off schools that takes place at Easter. Another uptick is in December, where both the holidays around Constitution Day in the early month, and the Christmas holidays at the end, provide clear explanation. International tourists stay far fewer nights, and primarily during the summer.

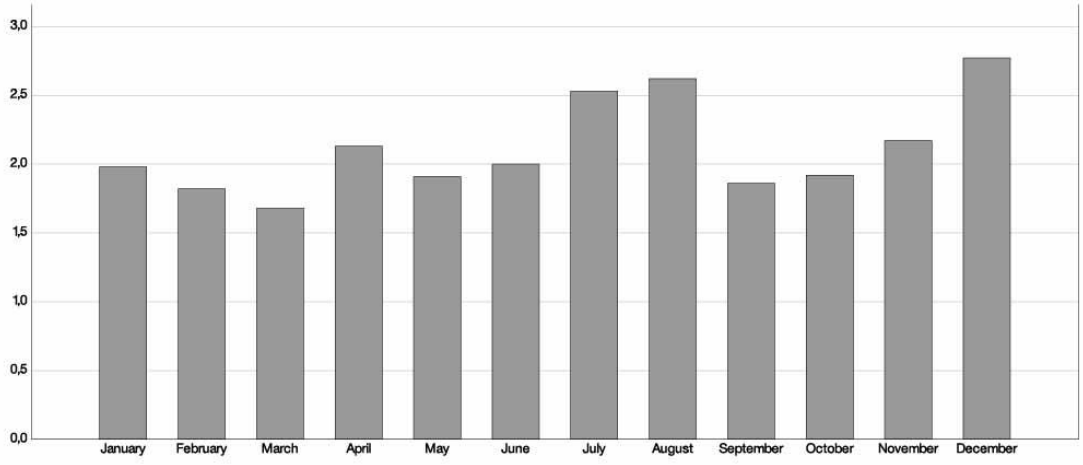
FIG.20- Monthly distribution of overnight stays during 2019. Totals represent number of unique visitors that stay overnight each month, regardless of how many nights they spend.



Source: Own elaboration after mobile phone data.

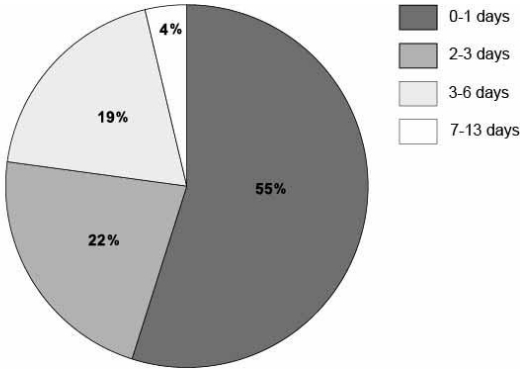
Average number of nights is two for domestic and 1.6 for international visitors (Fig. 21). Seasonal distribution correlates with the total number described above: during the Summer, April and December people stay more nights. If the data is categorized by number of nights, 55% stay one night, 22% two, and a significant 23% three or more (Fig. 22). Two-night stays remain constant throughout the year. Longer stays mainly occur during the Summer, a season when single-night stays become rarer (Fig. 23).

FIG.21- Monthly average of total visit duration for overnight stays in 2019.



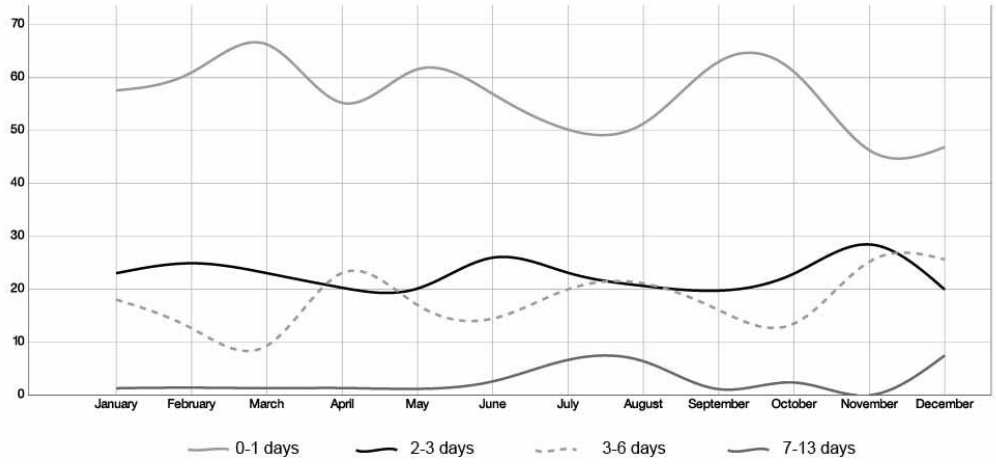
Source: Own elaboration after mobile phone data.

FIG.22- Average duration of overnight stays in days for 2019. (Source: Own elaboration after mobile phone data)**.**



Source: Own elaboration after mobile phone data.

FIG.23- Percentage variation, by monthly averages, of the number of nights overnight unique visitors stay, in 2019. (Source: Own elaboration after mobile phone data)**.**

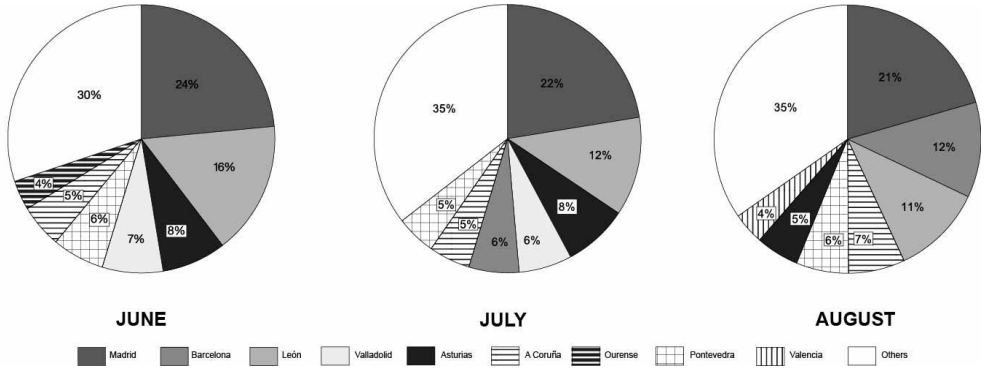


Source: Own elaboration after mobile phone data.

Domestic tourist overnight stays by provenance provides interesting information (Fig. 24). During the summer, visitors from Madrid increase, amounting to 20% of total annual stays. The travel distance from there requires at least a night. Barcelonan visitors also account for 11% of stays in August. León comes in second, 16% in June and 11% in August, which is interesting given that Las Médulas can easily be reached for a single-day visit. Visitors from neighboring provinces like Asturias, Pontevedra, A Coruña and Valladolid also provide significant overnight travelers. These seven provinces account for 70% of all summer stays.

The remaining 30% is shared among other provinces in smaller degrees. Another noteworthy feature is that the neighboring provinces of Ourense and Lugo barely contribute any overnight visitors, in sharp contrast to the number of daytime visitors they do send. In their case, the absence of a need to spend the night surely explains this.

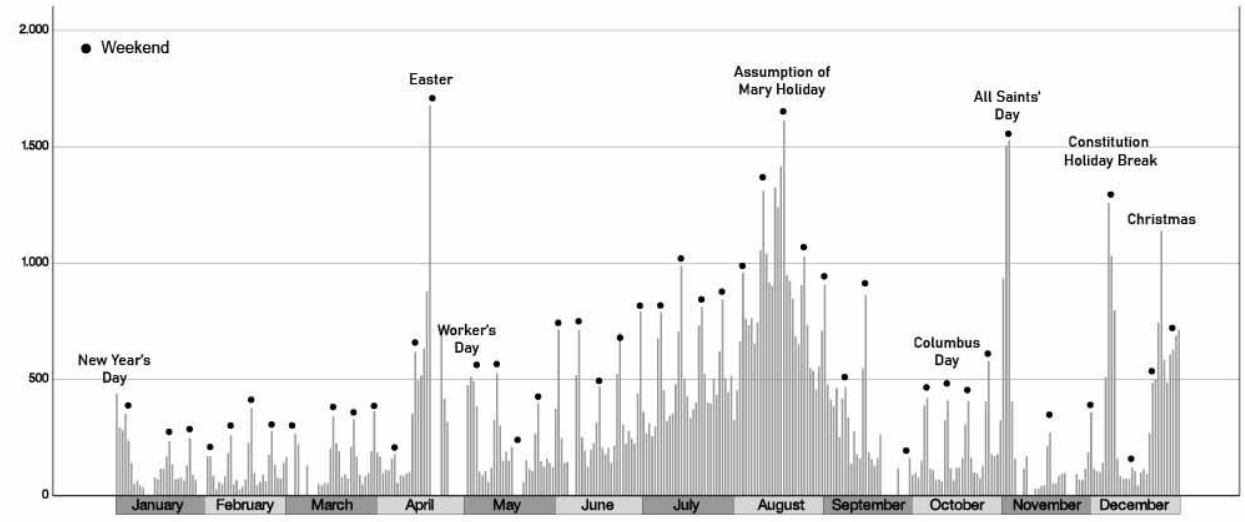
FIG.24- Percentage of the origin of national visitors that spend the night in the summer months of 2019.



Source: Own elaboration after mobile phone data.

Just like in the case of total number of visits, overnight stay data is quite eloquent when analyzed in a daily distribution (Fig. 25). This allows us to overcome the monthly averages and understand in greater detail tourism behavior. Overnight stays populate weekends and holidays. At times, more people spend the night than there are beds available according to official statistics. Some weekends occupancy rates are higher than 100%. This may be due to unregulated tourism such as seasonal rentals, recreation vehicles or problems with official statistics. It is also possible that emigres are classified as tourists although they are merely returning home for the holidays. Indeed, the increase of Christmas visitors (Fig. 13) may well be mostly the latter.

FIG.25- Daily distribution of overnight stays in Las Médulas in 2019.

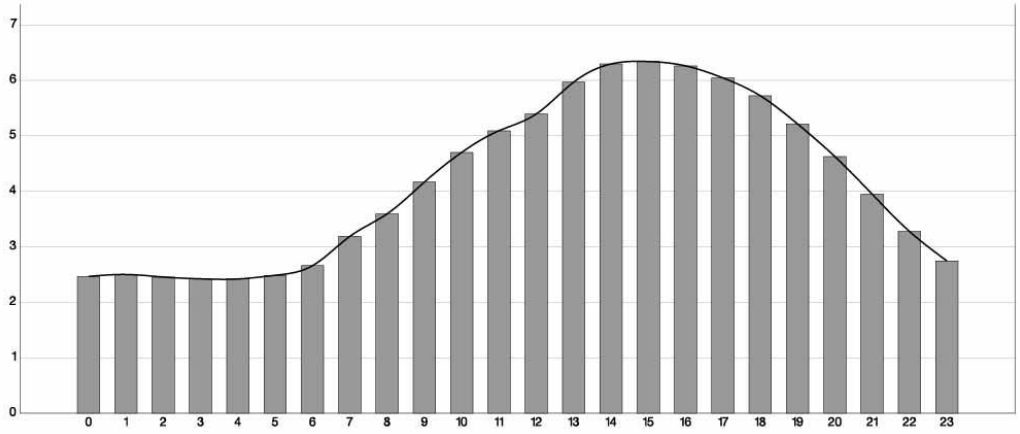


Source: Own elaboration after mobile phone data.

4.7 Tourism behavior: day visits

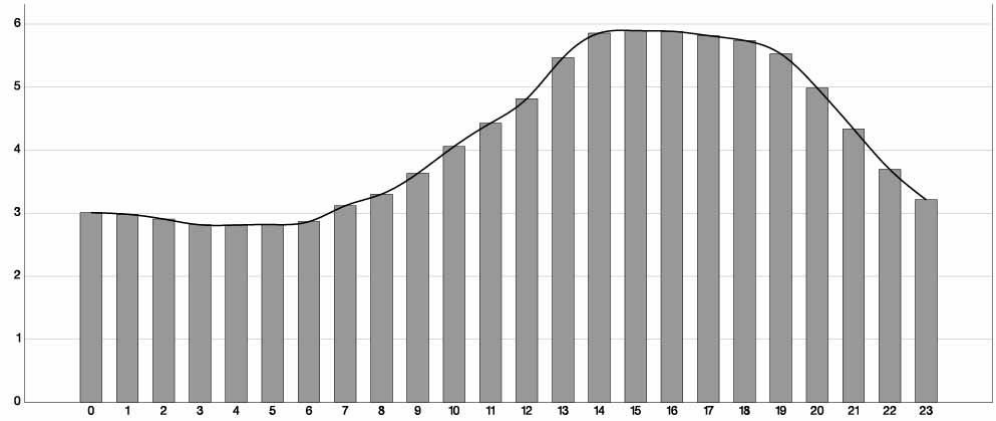
The characteristics of day visit reveals a pattern which is stable throughout the year (Fig. 26). Visitors arrive in Las Médulas around 9 am, and numbers are greater at Lunch time, circa 14-15:00. After that it plateaus for a bit, and then starts dropping off around 17-18:00. In August this data is slightly different (Fig. 27), with a constant progression in number of visitors throughout the morning, with a peak at Lunch time, and a plateau until 19-20:00, when most visitors leave the area. This hourly distribution reveals that there is plenty of business for lunch catering, not so much for dinner. The latter, it would seem, is the exclusive domain of overnight visitors.

FIG.26- Percentage hourly distribution of visitors in 2019. (Source: Own elaboration after mobile phone data).



Source: Own elaboration after mobile phone data.

FIG.27- Percentage hourly distribution of visitors in August 2019. (Source: Own elaboration after mobile phone data).



Source: Own elaboration after mobile phone data.

5 Conclusions

Overall, the consolidation of tourism in rural areas has helped expand the interest tourists have in cultural and environmental assets. In cases such as Las Médulas, as well as other predominantly rural areas with high heritage value, tourism has naturally become cultural tourism. The fact this is an extensive landscape, with many resources and multitude access points has posed a challenge for monitoring tourism flows and visitor characteristics.

The lack of systematic data collection has failed to provide a broad perspective of the problem at hand. Using methods based on massive data analysis will not only provide greater clarity and precision regarding tourism, but also managing it so that saturation is avoided and profits are better distributed (Almuhrzi & Al-Azri, 2018). Certain places, such as the Orellán outlook and the trail of Las Valiñas have a high visitor density, indicating that diversifying the locations may help de-saturate, and prolong, visitor experience.

This methodology is very useful for understanding the internal dynamics of tourists in places where there is little capability to monitor them. The information revealed can inform the design of management tools adapted to a very specific and local reality. In addition, it can serve to identify their weaknesses and strengths. Survey-centered analyses which have dominated the tourism management literature (e.g. Oppermann, 1996) can now be confidently complemented using big data.

The greatest strength is that Las Médulas has been revealed as a great source of visitor attraction. Basic traits of the tourist there: markedly domestic and mostly from neighboring provinces, coming for short-stays which are closely aligned with weekends and short holidays. The visitor likes to stay for lunch, which is a great incentive to foster the gastronomic nature of the experience.

The primary weakness is that most visitors come from areas in the broader Northwestern Quadrant of Spain. They come and spend around 3 hours, leaving no profit for accommodation. Overnight stays do occur, and they last 2-3 nights which always straddle the weekend. This means that occupancy rates are fairly poor, sometimes very poor, most nights of the year. Both people from other parts of Spain, and international tourists -in a country which received 83.5 million international tourists in 2019-, are glaringly absent. It would appear that these visitors should become a priority, given that they spend more nights on average. The strong seasonality of visits is common in tourism destinations, including in rural areas (Guaita et al., 2019). Often, Las Médulas is a major stopover destination, not a trip destination per se. Though this may be construed as a weakness, the whole Bierzo region has always had this role, and accordingly collected abundant tourism benefits from its location as a vital connector of Galicia with Central Spain.

An objective quantification of visitors serves to diagnose precisely the impact on the territory. In communities that barely reach 500 people, some days may see 5 to 6000 visitors. Tourism is very intense during the summer and the days around the main holidays, creating real problems for the carrying capacity of the area. In the summer, villages like Las Médulas and Orellán have serious problems because of the sheer number of tourists and their vehicles. There is insufficient parking, small roads and streets, insufficient water, etc. These limitations lead to tension between the growth of the tourism sector and the local community.

The qualitative visitor information which tourist facilities provide, though demonstrably insufficient in numbers, can provide some interesting insights. Nearly half of real visitors actually went to the Visitor Center and used the official guided tours. A fifth of them also went to the Archaeology Center, demonstrating that it is the cultural heritage which has brought visitors to the area; they are intent not only on experiencing, but also understanding the landscape. The remains of the mine have aesthetic value which any visitor can enjoy, but there appears to be a desire to understand the historical reality behind: how Humans brought the mountain down, only to leave the skeleton standing. Tourism at Las Médulas is a preeminently cultural tourism.

Nonetheless, cultural tourism may also be seasonal. During Spring and Fall, around 50% visit the Visitor Center, with April having a peak of 65%. In the summer, however, there is a decrease in this interest, with only 43% actually using those services. This somewhat subtle difference may be bearing witness to other types of tourism which may be more common in the summer, and which are not so much cultural. In the winter only 13% of visitors go to the Center, an odd result which perhaps indicates that there are people returning home may be qualifying as visitors, thereby eschewing the data. Indeed, international tourism has a modest peak in December, but perhaps it may be émigrés returning home for Christmas.

This article provides a fixed image of the year 2019, last "normal" year before the pandemic. Though the data may be obsolete, the methodology can be replicated for any time frame, and even diachronic studies, and the potential is enormous. In future studies, taking the 2019 data as baseline and including the data for years to the present would facilitate an objective perspective on how the pandemic changed tourist behaviour (Ciesielski & Tkaczyk, 2023;

Della Corte, Doria, & Oddo, 2023; Östh, Toger, Türk, Kourtit, & Nijkamp, 2023), and whether the outdoors and rural nature of Las Médulas became more appealing.

Nota

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