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Written in soil and paper. Investigating environmental transformations of a monastic landscape by combining geoarchaeology and palynology with historical analysis at Samos (Spain)

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ABSTRACT

Palaeoenvironmental and historical approaches have often been used separately to investigate past land-use change, but they are still rarely combined, especially in places where the most suitable archives are sediment sequences. Here we used a transdisciplinary approach combining a multiproxy palaeoenvironmental study of two pedosedimentological sequences around a medieval Benedictine abbey at Samos in north-west Spain. A robust chronology was built using OSL apparent ages, conventional OSL and radiocarbon ages and used to date geochemical and palynological proxies which were then analysed alongside an exhaustive historical review of medieval and modern ecclesiastical records. The aims were to reconstruct the agrarian history of the place in a diachronic way and to deepen understanding of the interplay between palaeoenvironmental and historical sources. We demonstrate the potential value of using geoarchaeology, palynology and written sources together to address both the physical and socioeconomic aspects of land-use change.

1. Introduction

Researchers in pre- and proto-history have traditionally been more open to palaeoecological studies than historians and historical archaeologists. The reasons for this are on one hand related to the degree of chronological uncertainty that these disciplines usually tolerate (Dumayne et al., 1995; Tipping, 2005), and on the other to the degree of importance that scholars of different time periods have attached to human-environment interactions. Despite these apparently insurmountable differences, improvements in chronological control over environmental archives and the growing interest in environmental history offer a compelling framework for collaboration. In fact, the number of interdisciplinary papers linking history and palaeoecology to respond to both historical (e.g Bosi et al., 2009; Izdebski et al., 2016, 2022) and ecological questions (Graze et al., 2019) has rapidly increased in recent years,Pioneer and systematic comparison of pollen records and documentary evidence was carried out by palynologists like Hall (2006, 2000), Lomas-Clarke and Barber (2007, 2004), Tipping (2010, 2005) and Wimble et al. (2000) in the UK and Ireland. These examples, together with other palaeopalynological research from peatlands and lakes in France (Noël et al., 2001), Austria (Breitenlechner et al., 2010), Germany (Stolz and Grunert, 2010), Norway (Hjelle et al., 2010) and Iceland (Hallsdóttir, 1993; Riddell et al., 2018) have shown that intense environmental transformations were linked to monasteries across Europe. Monastic orders were implicated in land clearance, the development of both arable and pastoral landscapes and technological innovation such as the introduction of new agricultural species (Tipping, 1997). Despite calls for the increased use of paleoenvironmental evidence (Greene, 2017), relatively little work has been carried out in areas lacking peatlands or lakes in their surroundings. In those cases, the most common environmental approach relies on archaeobotanical studies focusing on carpological (Åsen, 2021; McKerracher, 2017; Moffet, 2018)

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or, more exceptionally, palynological evidence (Gil García 2004, Roubis et al., 2008), (which has also yielded some very unusual archives, for example from peat bricks (Deforce et al., 2007) or dust recovered from ancient manuscripts (Jankovská, 1995)).

Work on the economic role of rural monasteries has shed light on their importance as power centres where decisions about the exploitation of natural resources were made, from livestock and arable farming to water management (mills and fishponds), salt production and mining (Gilchrist, 2014). In north-west Iberia, the monastic control of agrarian resources has largely been studied through the historical sources. Although some research has considered less well-known sites (Sánchez-Pardo and Fernández Ferreiro, 2019), the majority has focused on major power centres such as San Millán de la Cogolla (García de Cortázar, 1969), San Salvador and San Santa María de Sobrado (Pallares Méndez, 1979), San Xulián de Samos (Arias Cuenllas, 1992; Rodríguez González, 2008) and the cathedral of Santiago de Compostela (López Alsina, 2013).

Recent advances in the archaeology of northern Iberian rural landscapes have underlined its importance for the study of agrarian history (e.g. Ballesteros-Arias et al., 2006; Fernández Mier et al., 2014; Fernández Mier and Alonso González, 2016; Ferro-Vázquez et al., 2014; Quirós Castillo et al., 2014). Nevertheless, this type of archive has unexplored potential for monastic landscapes. Expanding the focus of agrarian studies to to sediment sequences in the vicinity of monasteries will not only enable scholars to gain insights on the role of monastic communities in the transformation of the environment, but also to evaluate their role in the creation and maintenance of cultural landscapes (Zanini et al., 2021).

In this paper, we present a diachronic agrarian history of the land around Samos Abbey (Galicia, Spain) by combining palaeoenvironmental and text-based approaches. Analysis of an two terraces located in the surroundings of the Abbey using optically-stimulated luminescence profiling and dating (OSL-PD), geochemistry and palynology are linked to an analysis of texts recorded in two key sources, the medieval *Tumbo de Samos* ('Cartulary of Samos') and the early modern *Apeos de la feligresía de Samos* ('Demarcation of the parish of Samos'). Our objectives were not only to understand better the agrarian history of Samos Abbey, but also the relationships between analyses using environmental proxies and written sources.

2. Material and methods

2.1. Site description and sampling

Samos is located on the Sarria river valley over a Precambrian slate bedrock at an elevation of ~ 550 m above sea level. The climate is temperate and present land use comprises a mosaic environment comprising river forest, deciduous oak, chestnut woodland and grassland with small-scale arable and horticulture. The Benedictine abbey at Samos was first documented in an inscription dating to AD 665 which records a renovation by Ermefredo, the bishop of Lugo, though the site may have been founded as early as the 6th century (Arias Cuenllas, 1992). Samos enjoyed royal protection from the 8th century, becoming one of the richest monasteries in north-west Iberia during the Middle Ages (Rodríguez González, 2008)). It held many properties across Galicia and the Bierzo area until the 19th century, when most of these estates were given to lay owners.

Seven pedosedimentary sequences were sampled in the surroundings of Samos Abbey in 2017. Samples were collected manually down-profile at 10–5 cm intervals, stored in zip-lock plastic bags in the field and transferred immediately to the laboratory for subsequent analyses. In order to avoid pollen contamination, the exposed surface of the pedosedimentary profile was eliminated immediately before sampling. Samples for OSL analysis were collected and stored in light-safe conditions.

The two sequences with the best chronological resolution (T2A and T1C) were investigated further by applying multiproxy palaeoecological analyses (Fig. 1). The T2A sequence (260 cm) was collected from an earth terrace located on the mid-slope of the hillside *c.* 250 m south-west of the monastery. The feature is about 100 m in length and is aligned roughly east–west. Today oak-chestnut woodland extends northwards from the top of the earthwork and a grassy field extends southwards from its face, though air photographs show the whole area was in use for agriculture in the 1950 s. T2A is a polycyclic soil with three phases of soil formation (Fig. 2). A first layer of large, rounded stones occurred from 230 to 260 cm over a saprolite layer, with a 3A horizon at 220–230 cm. The second phase of soil formation comprises a second line of smaller stones from 210 to 220 with a 2A horizon at 190–210 cm. The last phase of soil formation consists of a 20 cm A horizon followed by a B horizon from 20 cm to 190 cm. The natural vs anthropogenic formation process of T2A is discussed below.

On the opposite, eastern side of the Sarria valley, samples were collected from a 160 cm profile (T1C) which was excavated at the eastern end of a short length of retaining wall (*c.* 15 m) located in the lower part of a very steep slope (Fig. 1). This small field, which lies approximately 250 m south-east of the main monastic complex, is currently used as pasture with a few fruit trees; other terraces have been built to retain sediment further up the slope. To the east and south is an extensive oak-chestnut woodland with evidence of many abandoned terraces; as on the other side of the valley, historic air photos show that this area was formerly used as farmland. As a typical cultivation soil, T1C lacks a proper A horizon (Fig. 2). Three different B sub-horizons with a total thickness of 160 cm over a saprolite layer were distinguished in the field according to colour and surface characteristics with limits at 70 cm and 110 cm. B1 appeared a darker brown colour whilst B3 was characterised by a lustre surface. The retaining stone wall behind T1C extended from a depth of 60 cm to 128 cm.

2.2. Geochemical analyses

A total of 55 samples were studied for granulometry and Loss on ignition analysis (LOI): 32 samples from section T1C (5 cm intervals) and 23 samples from section T2A (10–5 cm intervals). Samples were analysed at the Ecopast facilities in the Biology faculty of the Universidade de Santiago de Compostela. Samples were air dried and sieved to separate the coarse (>2 mm, gravel) and fine earth (<2 mm) fractions. LOI was performed at 550 °C over 5 h. As organic matter is the main soil constituent that volatilises at such temperature LOI gives an indirect measurement of the organic matter content of a soil/sediment sample. Subsequently 10 g of ashes were mixed over 20 min in an HCl 1 N suspension to break up mineral concretions of Fe and Al. Suspensions were then separated into three fractions by wet sieving: <2–0.2 mm (coarse sand); <0.2–0.05 mm (fine sand) and < 0.05 mm (silt + clay). Macrocharcoal > 2 mm was collected when present and dry until constant weight to determine its concentration in the sediment (data shown as dry weight per 100 gr of fine earth).

Sediment elemental composition was analysed by X-ray Fluorescence (XRF) at the RIAIDT facilities of the Universidade de Santiago de Compostela. Concentrations of major and minor (Si, Al, Ti, Ca, K, P and S), trace lithogenic (Rb, Sr, Zr and Th), redox-sensitive elements (Fe and Mn) and halogens (Cl and Br) were determined using X-ray fluorescence dispersive EMMA-XRF analysers (Cheburkin and Shotyk, 1996). The calibration was performed using 36 certified reference materials, consisting of rocks and minerals (GSR6, SG1a, SRM1d, SRM278, SRM2780, SRM688, 5365, AGV1, DTS1, SRM607, SRM70a), sands and clays (SRM1413, SRM81a, BCSCRM348, SRM679, SRM97b, SRM98b), ashes (SRM1633a, SRM1633b, SRM2690, SRM2691), soils and sediments (SO2, SO3, SRM2586, BCRCRM277b, LKSD1, LKSD2, MAG1, PACS1, RM8704, SRM1646, SRM1646a, SRM1944, SRM2702, SRM2703) and industrial sludge (SRM2782). Quantification limits were as follows: Si (0.05 %), Al (0.2 %), K (0.05 %), S (0.03 %), Ti (0.002 %), P and S (0.01 %), Mn (30 μg/g), Sr and Th (5 μg/g) and Br (2 μg/g), As (1 μg/g).

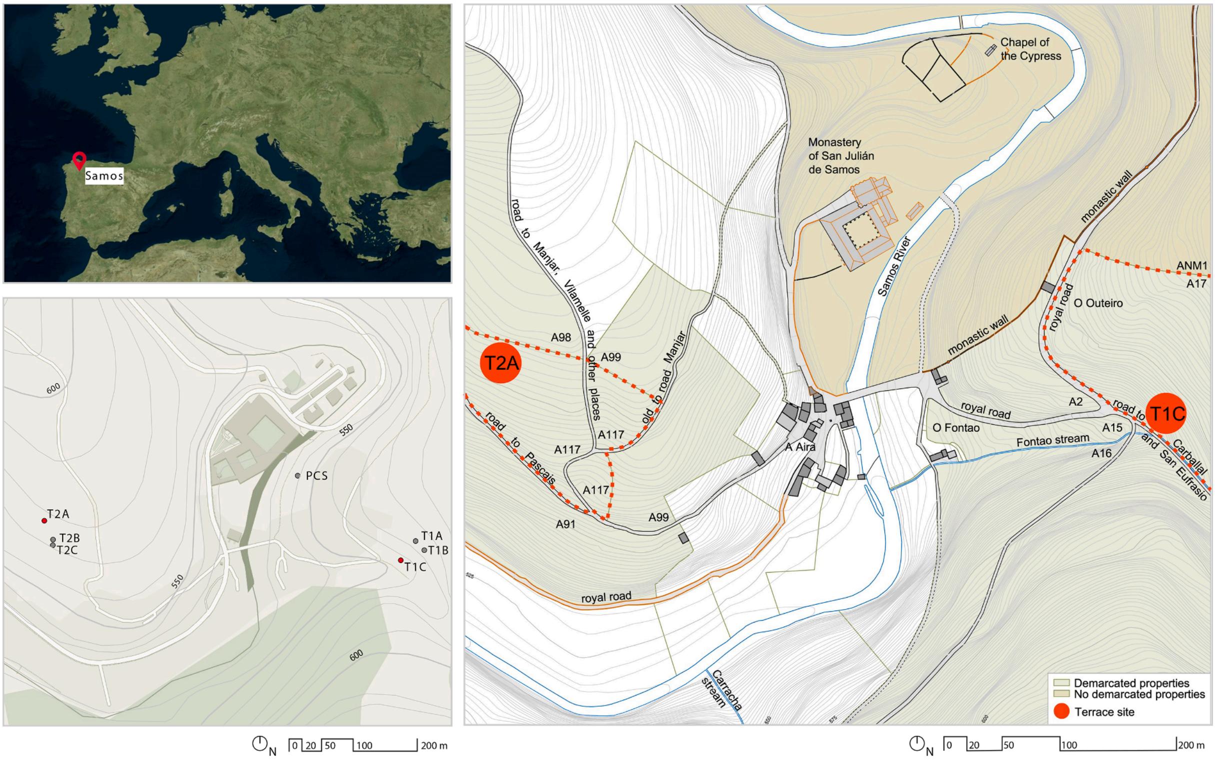

Fig. 1. Left panel: location of T1C and T2A sediment sequences, with an indication of other sediment sequences sampled within the same field campaign at Samos. Right panel: detailed map of Samos with an indication of the identification codes given to the fields demarcated in the early modern documentation *Apeos de la feligresía de Samos* ('Demarcation of the parish of Samos', 1660).

Fig. 2. T1C and T2A sediment sequences stratigraphy.

Carbon and nitrogen analysis were performed at SAI facilities of the Universidade de A Coruña. Analysis is based on the dynamic combustion of the sample (EA1108, Carlo Erba Instruments). Samples were weighed in tin capsules (MX5 microbalance, Mettler-Toledo) and introduced into a quartz reactor containing chromium oxide and silvered cobaltous/cobaltic oxide. Following combustion, excess oxygen and oxides of nitrogen were reduced in a reduction column (reduced copper at 650 °C). N2 and CO2 were separated on a GC column (Porapak, 2 m). Acetanilide standard was used for N and C calibration.

2.3. Palynology

A total of 26 samples were studied by pollen analysis. The T1C sequence was sterile below 75 cm depth so only the first 13 samples were studied. At T2A 13 samples were included in the analysis. Pollen and non-pollen palynomorph (NPPs) extraction was performed by acetolysis following Barber (1976) at the School of Geosciences at the University of Aberdeen. A minimum sum of at least 300 total land pollen (TLP) was achieved for all sub-samples in order to produce a statistically significant result (Birks and Birks, 1980). Data are expressed as a percentage of the TLP, with spores and aquatic taxa excluded from the TLP sum. NPPs were also counted and they are expressed as a percentage of TLP plus total NPPs. Rare types are indicated by a cross (+), where one cross is equal to one pollen grain or NPP. Pollen samples were spiked with *Lycopodium clavatum* tablets (Stockmarr, 1971). Pollen identification, including cereal-type pollen, was aided by reference keys (Fægri and Iversen, 1989; Moore et al., 1991), and supported by Reille's (1992) pollen and spore Atlas and a personal modern type-slide reference collection. Non-pollen palynomorphs classification follows the Hugo de Vries (HdV) Laboratory (University of Amsterdam).

2.4. Dating and age depth modelling

Luminescence stratigraphies were generated for the seven investigated sections following the methodologies of Kinnaird et al. (2017) and Turner et al. (2021). In total, 129 samples were appraised in the field using portable OSL equipment to provide a preliminary assessment of luminescence behaviour and the means to generate relative luminescence stratigraphies. The measurement cycle involved an interleaved sequence of instrument dark count, infra-red stimulated luminescence (IRSL) and OSL, similar to that described by Kinnaird et al. (2017). This method allowed for the calculation of IRSL and OSL net signal intensities, IRSL and OSL depletion indices and IRSL: OSL ratios. This proxy information, plotted versus depth in the profile, provided an insight on the depositional histories of the sediment, and the means to relate the sedimentary sequences to the construction of the terrace walls and earthworks. The luminescence stratigraphies for profiles T1C and T2A were used to position samples in the sequences for dating purposes: 4 from section T1C and 3 from T2A (Table 1, Fig. 2). 3 samples from T2A were submitted for AMS dating at Beta Analytic (Table 1, Fig. 2).

Prior to formal quartz SAR OSL dating, further characterisation of the profile samples occurred in the laboratory, with 27 samples from T1C and 15 samples from T2A progressed to this stage. Luminescence sensitivities (photon counts per Gy) and stored dose (Gy) were evaluated on paired aliquots of HF-etched quartz concentrates, using procedures modified from Burbidge et al. (2007) and Kinnaird et al. (2017). The measurement cycles involved a readout of the natural signal, followed by a 1 Gy test dose, then readouts of the regenerated cycles following nominal doses of 5, 10 and 50 Gy, each with a subsequent 1 Gy test dose. For all, OSL followed a preheat of 220 °C, and was measured at 125 °C for 60 s. This dataset reproduced the maxima and trends observed in field profiling, confirming the inferences drawn from the field profiles, to the extent that the dynamic ranges observed in OSL signal intensities are replicated in the stored dose estimates. Thus, the positioning of the dating samples in profiles T1C and T2A was justified.

Age depth modelling was performed using both OSL dates, radiocarbon dates and OSL apparent ages by Clam (Blaauw, 2010), (Fig. 3).

Table 1
OSL and Radiocarbon dating.

Dating technique	Material	Lab ID	Depth (cm)	Radiocarbon years	Calendar years
T2A					
OSL	Sediment	T2A 33	33		CE 1870 ± 20
OSL	Sediment	T2A 147	147		CE 1690 ± 30
C^{14}	Sediment	Beta – 588,463	190–195	830 ± 30 BP	CE 1166–1268
C^{14}	Charcoal	Beta – 588,462	200–205	320 ± 30 BP	CE 1484–1644
OSL	Sediment	T2A OSL1	217		410 ± 220 BCE
C^{14}	Charcoal	Beta – 616,102	225–230	2180 ± 30 BP	364–150 BCE
T1C					
OSL	Sediment	T1C 75	75		CE 1630 ± 30
OSL	Sediment	T1C 120	120		CE 1240 ± 60
OSL	Sediment	T1C OSL1	130		CE 1280 ± 40
OSL	Sediment	T1C OSL2	148		CE 1230 ± 40

2.5. Numerical methods

When dealing with a large set of variables, the use of multivariate statistical approaches helps summarize common patterns of variation beyond the raw data and to get insights into the underlying environmental factors. For geochemical data, principal component analysis (PCA) was applied using SPSS 26.0, in correlation mode and by applying a varimax rotation. Prior to analysis, the data were standardized (*Z*-scores) to avoid scaling effects and obtain average-centred distributions (Eriksson et al., 1999).

2.6. Written sources

The *Tumbo de Samos* is a compilation of donations, transfers and other succession documents related to all of Abbey possesions in NW Iberia dating from AD 785–1209 which was compiled at the very beginning of the thirteenth century (*ca.* CE 1200). It is currently stored in the University of Santiago de Compostela Historical Archive (https://arquivo.usc.es/ahus2/index). Although the written charters included in the *Tumbo* are structured in similar ways, the scribes did not record information systematically. For this reason some lands and properties are richly described (including detailed information on the composition of estates, their location, etc) whereas others are simply listed under the name of their village or parish and by identifying either the grantor — and former owner — or the tenant who occupied or used that estate. Information about all properties listed in the *Tumbo de Samos* was compiled in a database searchable for specific terms, for example records of crops such as cereals, fruit trees and flax (for production of linen). Translation and definitions from the words used in the analysis are included in Table 2.

The second written source, the *Apeos de la feligresía de Samos*, is stored in the Spanish National Historical Archive (https://pares.mcu.es/). It was drafted by a royal scribe in 1660 to define the property that belonged to the monks at the heart of their large jurisdiction in the parish of Samos. An *apeo* is a written demarcation of a property that may comprise one or several agricultural plots and buildings held by a specific owner. The following data were collected from the text: names of the owner and tenant, the boundaries of the property, the area, the type of crops, the type and number of trees, and whether there were enclosing walls. Analysis of this written source not only provides information about how the farmland was laid out and used in the past, but also makes it possible to re-imagine its physical characteristics (López-Salas, 2017, 2015).

3. Results

3.1. Charcoal, soil physical properties and elemental composition

Charcoal is present throughout profile T2A. A high charcoal accumulation occurs at 200–210 cm (2A horizon), and two minor ones at

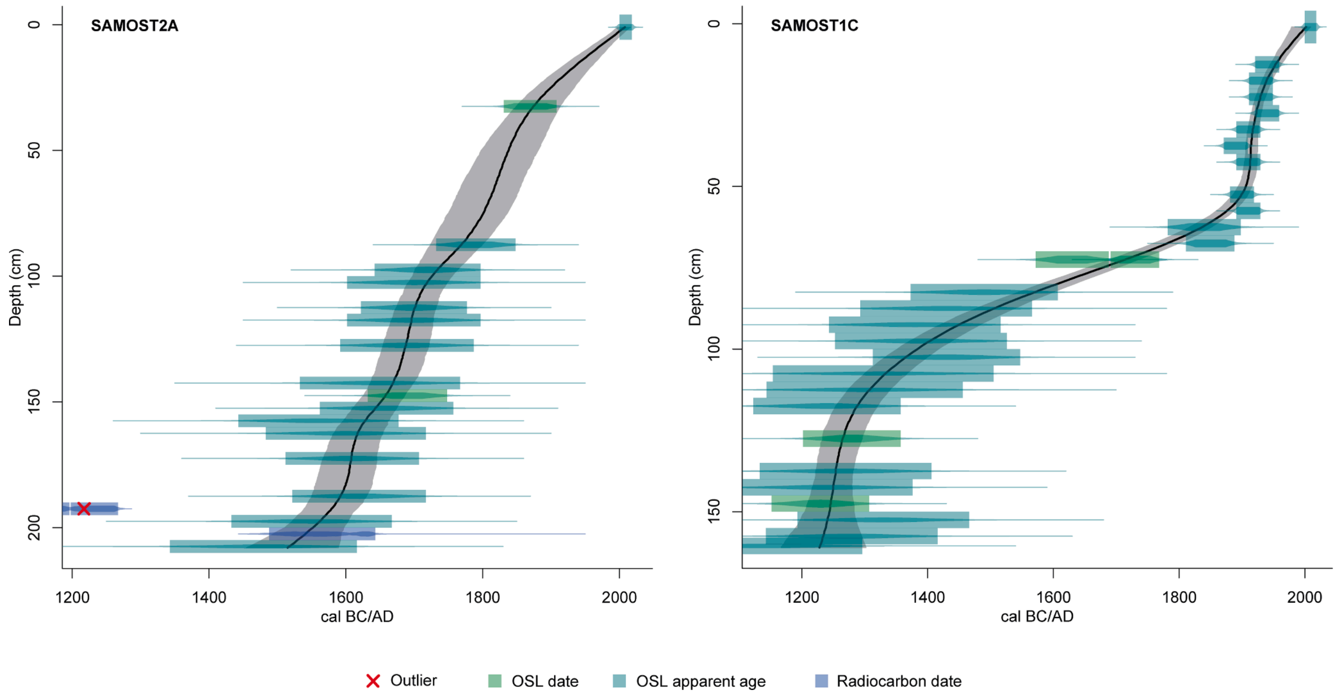

Fig. 3. Age depth model of T1C and T2A sequences.

Table 2
Translations and definitions of target and other important words used in the analysis of Tumbo de Samos book (AD 785-1209).

Tritico	Wheat
Panizal	Millet plantation
Senara	Cultivated land
Nogarias	Nut plantation
Ceresiale	Cherry plantation
Perares,	Pear plantation
Sautos/Castaniares	Chestnut plantation
Linaria	Flax crop
Vinea	Vineyard
Pumar	Apple orchard

220–230 (3A horizon) and 25–35 cm (at the top of the B horizon). T1C also reveals the continuous presence of charcoal, but here the higher values occur in the top 60 cm of the sequence (B1 horizon).

Granulometry, LOI, pH and elemental composition variations (Supporting information) are summarised according to principal components (Fig. 4). Five principal components account for 83.6 % of the total variance at T2A (Supporting Information 2). The first two, which together explain 58.5 % of the variance, have high factor loadings for more than one variable and consequently they are discussed in this paper. The first principal component (PC1) explains 38.1 % of the variance and shows high factor loadings for As, Mn, K, Silt & Clay and Fe; moderate positive loadings for Ca, N, LOI and Th; high negative loadings for Si and Fine sand and moderate negative loadings for gravels, Al, coarse sand and Br. This analysis suggests that PC1 at T2A reflects a compositional fractionation according to granulometry, with a silt and clay fraction enriched in As, Mn, K, Fe, Ca, N and Th and fine sand and gravel fractions enriched in Si and to a lesser extent Al. The distribution of PC1 Factor scores (FS1, Fig. 4) shows two clear tipping points. Below 200 cm FS1 are negative, from 200 cm to 50 cm remains around zero and in the top 50 cm are positive. T2A PC2 explains 20.4 % of the variance: C, LOI, N and S show high positive loadings, whereas Br and S moderate positive loadings. On the negative side, there is Ti with high negative loadings and Fe with moderate negative loadings. According to these results, T2A PC2 reflects enrichment with organic matter. T2A PC2 factor scores (FS2, Fig. 4) are positive below 200 cm (except the basal sample) and in the top 50 cm.

At T1C six principal components explain 84.1 % of the variance but again only the first two (67.1 % of the variance) have high factor loadings for more than one variable. T1C-PC1 explains 44 % of the variance and shows high positive factor loadings for N, P, C, Ca, LOI, Mn, S, and Sr; high negative loadings for pH and K; and moderate negative loadings for As, Th, Ti and Br. According to these loadings, PC1 is interpreted as indicative of the organic matter content of the soil. Ca and Sr adscription to this component may be related to an independent process, with Ca biocycling and isomorphic Ca-Sr substitution the most probable explanation. The distribution of PC1 factor scores (FS1, Fig. 5) shows a clear tipping point at 60 cm. Below 60 cm factor scores remain fairly constant and negative indicating more mineral composition than in the top 60 cm where FS1 is positive and the organic content of the soil is higher.

T1C-PC2 explains 14.1 % of the variance and shows high positive loadings for coarse sand and high negative loadings for the silt and clay fraction, with this component thus reflecting a granulometry turnover. Br is linked to this component with moderate negative loadings, indicating an enrichment in the silt and clay fraction at this site. Below 110 cm FS2 scores tend to be negative or around zero; from 60 cm to 110 cm they are generally positive with only one negative sample and in the top 60 cm FS2 show fluctuating values around zero.

3.2. Palynology

The palynological composition of T1C (Fig. 5A) showed the profile was palynologically sterile bellow 65 cm, probably directly due to a shift in pH conditions (data not shown). In fact 60 cm represented a tipping point in organic matter and granulometry conditions too as reflected by T1C-PC1 and T1C-PC2. This means that palynologycal information is only available for the B1 horizon. There, the palynological composition is quite homogenous, although two different pollen zones (T1C-Pz1 and T1C-Pz2) are distinguished by CONISS with a limit at 35 cm. The whole record is characterised by a tree dominance with *Castanea* being the dominant pollen type with percentages between 37.5 and 83.1 %. Shrubs are just testimonial (<1.6 %) whereas, among herbs, the signal is

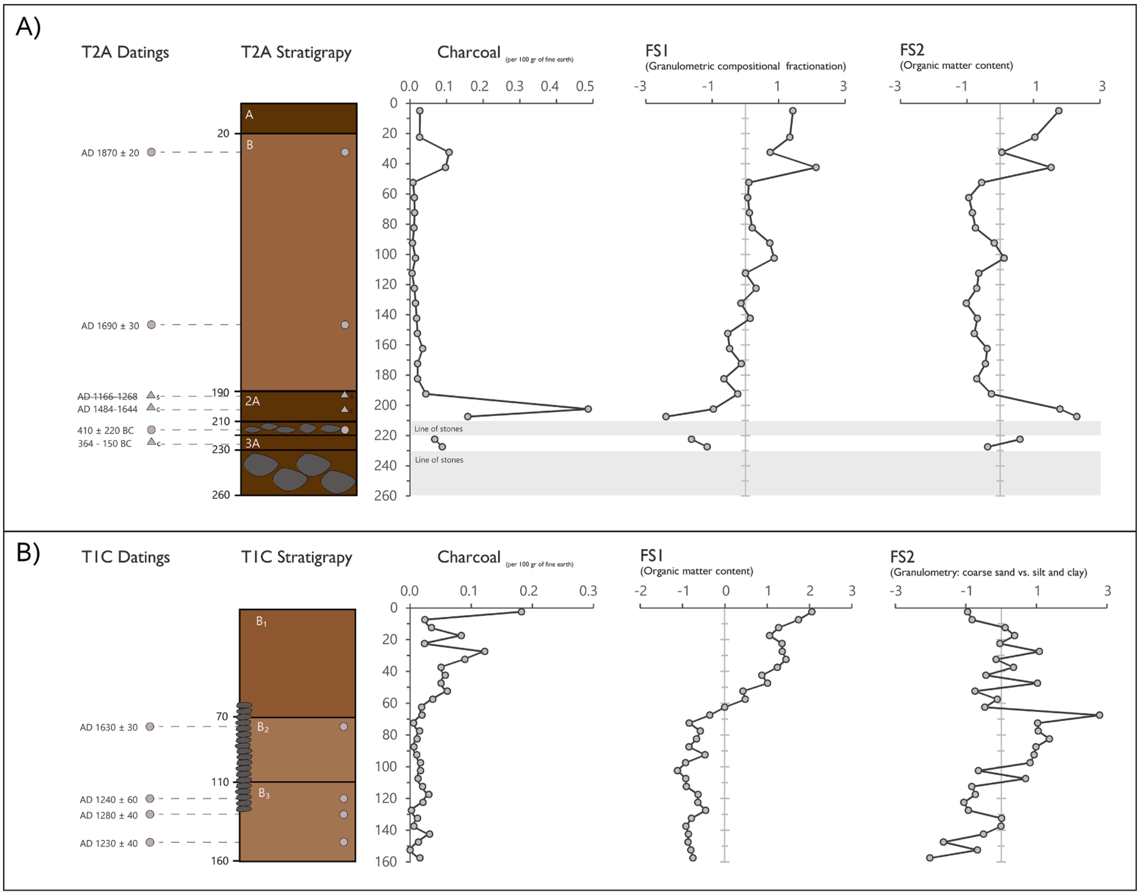

Fig. 4. Summary diagram representing soil stratigraphy, charcoal record and factor scores of the main principal components extracted from the statistical analysis of the physical properties and the elemental composition variations at T2A and T1C.

dominated by Poaceae (7.3–30.4 %). Cerealia undiff. and *Secale cereale* are present but in small percentages (0.9 ± 1.1 and 0.2 ± 0.3 respectively). Percentages of total cereals (considering together Cerealia undiff. plus *Secale cereale*) ≥ 3 % occurs at 22.5 and 32.5 cm (3.5 and 2.9 %), in the T1C-Pz2 pollen zone, coinciding with the lowest *Castanea* values. Coprophilous fungi *Sordaria* and *Sporormiella* also show their highest values at these depths.

At T2A, three pollen zones were distinguished (Fig. 5B). In all zones, the herbs dominate the signal (47.9–87.3 %), with Poaceae (35.3–64.2 %) the main constituent. However, in the second pollen zone (T2A-Pz2) at 200–230 cm, trees and shrubs are better represented (~30 and 10 % respectively) than in the T2A-Pz1 and T2A-Pz3 pollen zones where trees are ~ 10 and 20 % respectively and shrubs are just testimonial. Among trees, *Castanea* and deciduous *Quercus* were the most important taxa, whereas the shrub signal is dominated by *Calluna*. Regarding anthropogenic indicators, total cereal percentages are over 3 % both in T2A-Pz1 (4 %) and T2A-Pz3 (6.1–22.7 %). At T2A-Pz2 tree and shrub content was higher, with total cereals at 0.3 in the lower sample and 4.7 in the higher one, where a slight increase in trees and shrubs was already detected. Cophrophilous fungi mirror this behaviour.

3.3. Written sources

3.3.1. Tumbo de Samos

Fig. 6 reflects the number of transferred properties (donations, exchanges and recapitulations of assets) where an indication of fruit tree plantations and other crops exists in the *Tumbo de Samos*. In some cases, there was a specific entry for the cultivated land identifying it for a specific purpose, e. g. the transferred property was a *vinea*, a *senara* or a *linaria* (Table 2). In other cases, the term referring to a crop appeared in a more general record, i.e. properties that could include several types of lands and products, but without providing details (e.g. '*villa*' or '*hereditate*'). Definitions and translation for the medieval Latin terms used in the analysis are shown in Table 2.

Fruit was by far the most frequently cited crop in the *Tumbo de Samos*. In particular, *pumares* were mentioned in 101 records and *vineas* appeared in 77 records. Just a few mentions were found of *sautos/castaniares* (five records), *perares* (four records), *ceresiale* (three records) and *nogaria* (one record). *Linarias* were registered seven times. Regarding cereal cultivation, it is noteworthy that the most common entries used the word *senra* or *senara* (19 occurrences). References to specific types of cereals such as *tritico* or *panizal* are infrequent with a single entry for each and none for rye, oats or barley.

3.3.2. Apeos de la feligresía de Samos

Table 3 summarises information concerning lands demarcated in the *Apeos* (where T1C and T2A were both located) as well as data related to neighbouring properties. The field containing T1C is numbered A17, which was described as an *agro* that also comprised forest, *chousa* and *lamelo*. It could bear about *siete fanegas de centeno*, 'seven bushels of rye'.

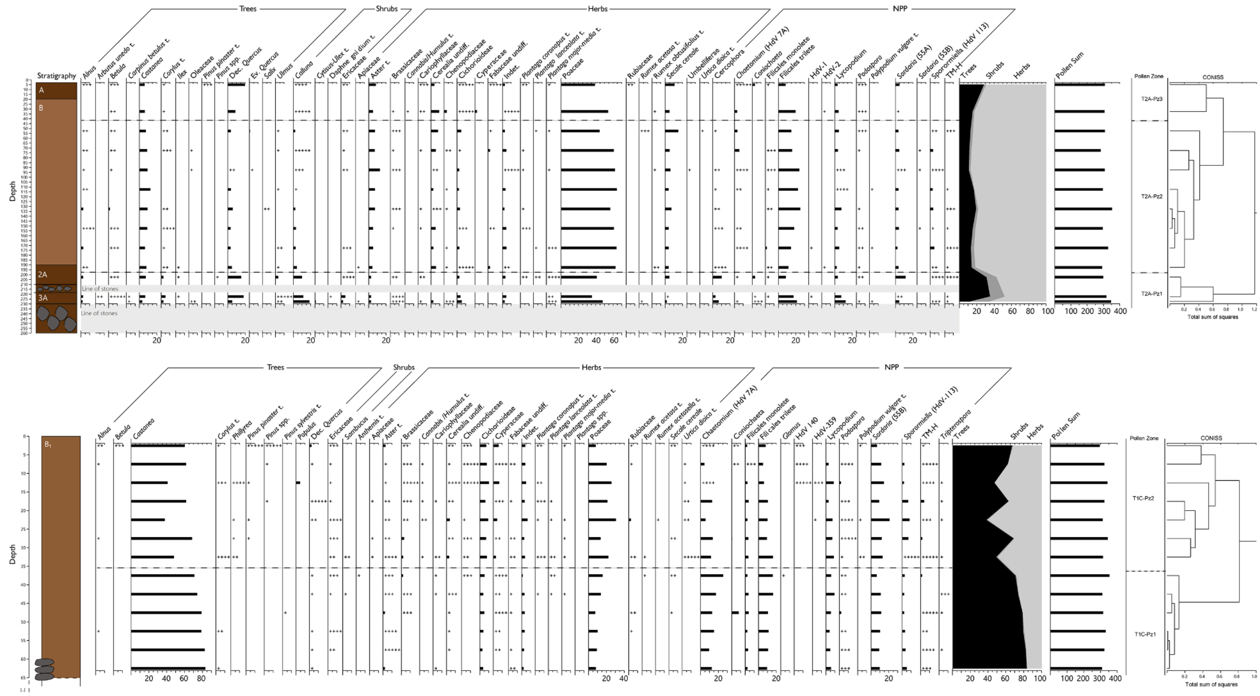

Fig. 5. Palynological diagram of T2A (A) and T1C (B).

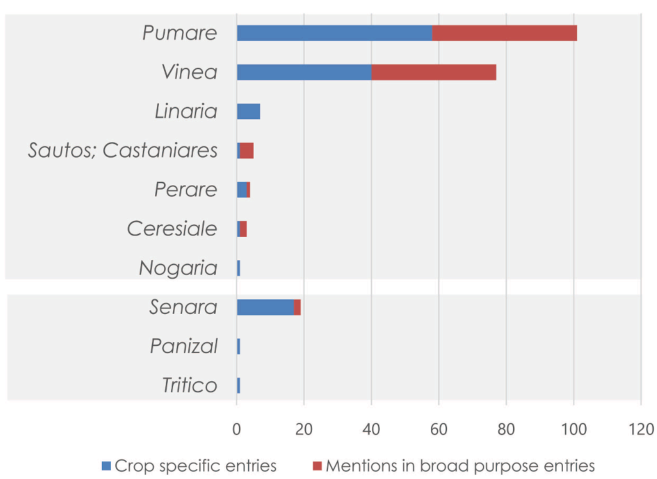

Fig. 6. Number of entries for fruit tree plantations and crop fields in the *Tumbo de Samos* (AD 785–1209). Blue sections represent entries for possessions defined by a crop. Orange sections represents other types of possessions (e.g. *villa* or *hereditate*) where the specific type of crop is mentioned (e.g. a *villa* that is transferred with all its vineyards, apple orchards, etc).

Based on the *Dictionary of the Galician Royal Academy*, a proper definition of those Galician terms, used to name different types of farmland, is also included at end of Table 3. We also know that in the fields bordering A17 where TC1 was located, there were a total of 31 chestnuts, 5 apple trees, 4 oaks and 1 pear.

T2A was located in the demarcated property labelled A117. It was described as an *heredad* that could produce about *tres anegas de centeno,* 'three bushels of rye'. There is no information about tree plantation on this land, but we know that neighbouring lands had 32 fruit trees, 30 oaks, 7 chestnuts and 2 pear trees.

4. Discussion

The methodological approach of combining established techniques in the fields of geoarchaeology and palaeoenvironmental studies with the construction of a detailed chronology and the study of historic monastic texts allowed us not only to reconstruct the agrarian history of the study area but also to deepen in the interplay between sources of information that are rarely considered together.

4.1. Shaping the landscape: Diachronic evolution of Samos Abbey surroundings

4.1.1. Pre-monastic activity at Samos: Agrarian activity in the iron age

Linking the OSL profiles, the sedimentological-geochemical and the palynological information about the formation and development of the T2A sequences there is a reasonable body of evidence pointing to the existence of agricultural land modifications and terraces at Samos long before the first written evidence of the monastery's foundation in AD 665. The palynological composition of the T2A-3A horizon gives evidence of highly anthropized landscape with a reduced forest cover. The total cereal content is $>$ 3 % (Sum of *Secale cereale* and Cerealia undiff. equal to 4 % at 225–230 cm) providing evidence of local cultivation (following López-Sáez, López-Merino, 2005). The presence of significant amounts of coprophilous fungi *Cercophora* and *Sordaria* may be interpreted as indicators of animal husbandry, though considering the evidence for local agriculture they might have been incorporated into the profile as a type of animal manuring. The presence of charcoal remains at this cultivated level may be indicating the use of fire related to agricultural activities. The high total cereal content from the T2A-3A horizon linked to the regularly-constructed features of the stone layers, suggest anthropogenic rather than natural origins for the T2A sequence (Fig. 7). The T2A-3A horizon and the stone layer above were dated to the Iron Age (364–150 BCE by radiocarbon dating charcoal at T2A-3A and 410 ± 220 BCE by OSL dating of the stone layer). These data suggest that T2A should be considered an agrarian terrace established during the Iron Age. Further evidence for Iron Age activity in the local area comes from the high density of hillforts (Rodríguez Fernández, 1994): in a radius of 4.5 km around the monastery there are 16 known examples, with the closest one, *Castro de Pascais*, just 800 m from T2A.

In north-west Iberia, as elsewhere in Europe, the history of agricultural terraces remains poorly understood due largely to problems

Table 3
Historical data about the demarcated properties where T1C and T2A were located in 1660 and their bordering ones.

Sequence	ID*	Property in 1660	Owner	Tenant	Area (*sembradura*)	Trees
T1C	A17	Farmland (*agro*), forest (*monte*), '*chousa*' and '*lamelo*'	Abbey	Felipa Fernández and Antonio Baldés	7 bushels of **rye** (*7 fanegas de centeno*)	-
	Bordering properties:					
	A2	'*Cortiña*' in Outeiro	Abbey	Pedro de Bales	1 bushel of **rye** (*1 fanega de centeno*)	-
	A15	Field with a garden inside (*Prado con huerto dentro*)	Abbey	Felipa Fernández and Antonio Baldés	1 bushels of **bread** (*1 anega de pan*)	5 apple trees, **7 chestnuts**
	A16	Forest (*monte*)	Abbey	Felipa Fernández and Antonio Baldés	8 bushels of **bread** (*8 fanegas de pan*)	**24 chestnuts**, 4 oaks, 1 pear
Sequence	**ID**	**Property in 1660**	**Owner**	**Tenant**	**Area (*sembradura*)**	**Trees**
T2A	A117	Landed property in Bargado (*Heredad de Bargado*)	Abbey	Sebastián Capón	3 bushels of **rye** (*3 anegas de centeno*)	-
	Bordering properties:					
	A99	Landed property in Bargado with a forest (*Heredad de Bargado con un monte*)	Abbey	Juan Davila	2,5 bushels of **rye** (*2,5 anegas de centeno*)	**20 oaks**, 2 chestnuts
	A98	Landed property in Bargado (*Heredad de Bargado*)	Abbey	Juan Davila	8 bushels of **rye** (*8 anegas de centeno*)	**8 oaks**
	A26	Landed property in Bargado (*Heredad de Bargado*)	Abbey	Francisco López	6 '*tegas*' of **rye** (*6 tegas de centeno*)	-
	A91	Farmland in Bargado (*Agro de Bargado que es vergeo*)	Abbey	Eufrasio López and Juan Davila	2,5 bushels of **rye** (*2,5 fanegas de centeno*)	5 chestnuts, 2 pears, **32 fruit trees**, **2 oaks**

*ID is represented in Fig. 1.

Translations and definitions of types of agricultural properties

Agro	Farmland or a piece of land for farming
Chousa	An enclosed farmland, generally small and nearby a house, or an enclosed piece of forest that is not very large
Cortiña	A piece of land closed to a farmhouse, which is usually enclosed, small, and used for growing cereal, vegetables, or potatoes
Heredad	A piece of land which is use for farming and usually belongs to only one person, family or entity
Huerto	Garden or vegetable garden
Lamelo	The word '*lamelo*' is not currently described by the *Dictionary of the Galician Royal Academy*. However, there is the word 'lameiro' that means a field with running water where only grass and some bushes grow
Prado	Field, meadow
Translations and definitions of former Galician units of area	
Anega	One '*anega*' can be considered as one '*fanega*'
Fanega	One '*fanega*' is about 6,440 m^2
Tega	One '*tega*' is about 584 m^2
Translations and definitions of selected crops	
Centeno	Rye
Pan	Bread

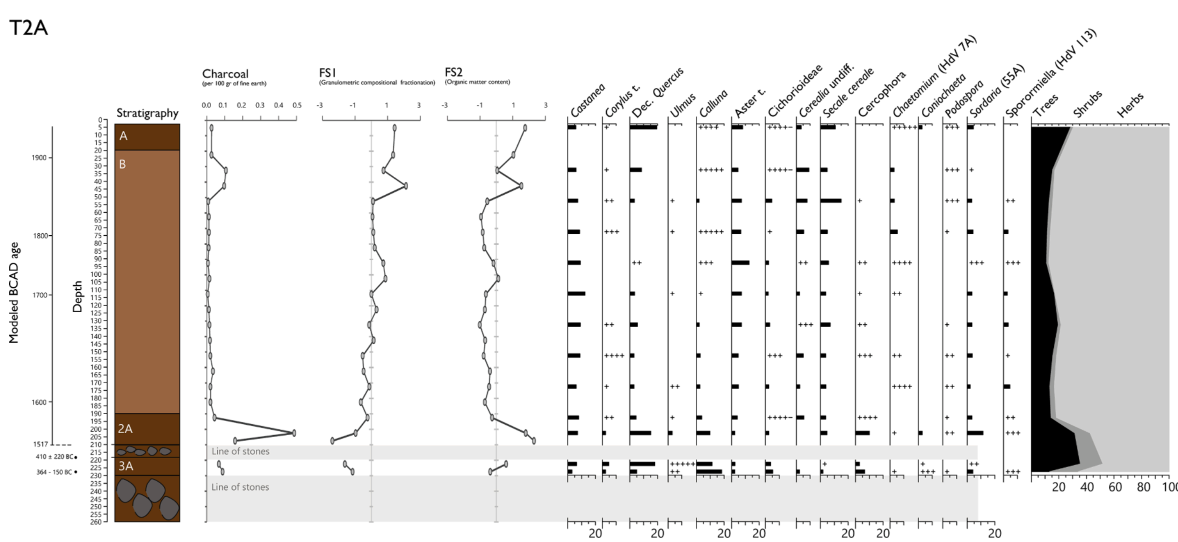

Fig. 7. Synthetic figure summarising the main geochemical and palynological properties of T2A and T1C sequences.

associated with dating their construction and use (Turner et al., 2021). Terracing appears to have reached its apogee in the Middle Ages (Ballesteros-Arias, 2010; Turner et al. 2021), and although it is likely to have been fairly common long before (Grau Mira and Pérez Rodríguez, 2008), dated examples remain scarce. Notable exceptions in north-west Iberia include a first generation of man-made terraces dating to 1330 BCE (2σ 1520–1150 BCE) identified in the Saa valley (Fábregas Valcarce et al., 2003) and a possible late Iron Age-Roman terrace at Castro de Follente (López Sáez et al., 2009). The results presented here for T2A provide further evidence of prehistoric terrace building in the region.

Unfortunately, environmental changes between the Iron Age and the end of the Middle Ages cannot be traced back as the stratigraphic record of T2A presents a significant hiatus (from the second stone line to the 2A horizon), coincident with FS1 and FS2 major changes at 200 cm.

Explanations for this hiatus may include cutting back or erosion caused by anthropogenic or natural processes.

4.1.2. From monastic foundation to modern times: Terracing develops and the textual archive begins

At Samos, the evidence from the T1C and the T2A sequences preserved late medieval and early modern signals of terracing respectively (Fig. 7). The three OSL dates from the T1C-B3 horizon, which is below and in the basal section of the retaining wall, consistently provide a 13th century age (1230 ± 40; 1280 ± 40 and 1240 ± 60) with the resumption of T2A terracing (T2A-2A horizon) dated between CE 1484–1644. An inherent problem of studying agrarian features is the fact that later activities can mask earlier transformations (Chouquer, 2007). This could be the case at T2A where the hiatus in the sediment archive includes the period of the early Middle Ages. Thus, the lack of evidence for early medieval terracing in these two profiles does not necessarily mean that during the monastery's earlier centuries (6th to 10th century) there was no terracing at Samos. In fact, according to a study which provided information about 12 agrarian terraces in Galicia (Ballesteros-Arias, 2010), most were established during the early Middle Ages, with just one late medieval and two modern exceptions. Other remarkable examples of early medieval terrace building in north-west Iberia were also identified at El Manso (Asturias; [(Fernández Mier et al., 2014)]), and at Torrentejo and Aizarna (Basque Country; Narbarte-Hernández et al., 2020, 2019).

Early medieval times could not be investigated by palynology due to the presence of a sedimentological hiatus in the sequence T2A and the existence of palynological sterility in the older levels of T1C. Fortunately, the monastic texts provide a new source of data for this time.: Analysis of the *Tumbo de Samos* provides valuable information about the agrarian resources of the monastery for the period AD 785–1209. Analysis of entries related to land use at Samos (Fig. 6) suggests the Benedictine community had a special predilection for *pumares* (101 citations) and *vineas* (77 citations) which were recorded both as specific crops and growing areas, followed by *senaras* (19) and *linarias* (seven), which were recorded only as specific crops.

When interpreting clerical documents, it is crucial to remember that the data they provide depends on what the monks thought was most important to record. The predominance of *pumares* and *vineas* in the documentation may be related to the importance of wine and cider production. Several Christian monastic orders including the Benedictines and Cistercians had strong viticultural and pomological traditions (Bond, 2017; Fernandes, 2012; Martinez Tomé, 1991). In the Iberian Peninsula, the production of wine had been established in the 7th century BCE (Buxó, 2008), though it was not until the late Middle Ages when viticulture spread through the country, probably related to the expansion of Christian kingdoms accompanied by the establishment of the monastic orders (Cunha et al., 2020). We do not actually know when and where cider making starts but the first recorded references to cider date back to the classical periodand during the Middle Ages apple orchards were common in European monasteries (Bond, 2017). At Samos the monks recorded a *pomar* as a type of land valuable enough to be granted, implying that apples were important for them – perhaps because they were used to produce cider.

4.1.3. Modern times: Landscape transformation and property inventories

Palynological evidence from the western side of the monastery (T2A) shows that during modern times a deforested landscape comprised a mosaic of dispersed deciduous trees, localised agriculture (Sum of *Secale cereale* and Cerealia undiff. equal to 4.7 and 9.3 %) and animal husbandry. The evidence of fire use at this time was very clear with an important macrocharcoal level dated to CE 1484–1644. This fire event would have affected primarily Dec. *Quercus* (decreases from 18 to 4.5 %), *Corylus* (from 4.7 to 0.7 %), and *Calluna* (from 11.4 to 3.8 %) whereas *Castanea* appear to have slightly increased their prevalence (from 6.3 to 7.9 %) (Fig. 7A). This is coherent with the available knowledge about the regional vegetation history. In north-western Spain the typical mesophilous forest is dominated by *Quercus* and *Corylus* (e.g. Mighall et al., 2006; Silva-Sánchez et al., 2014). The good agreement between macro-charcoal increase and *Quercus* and *Corylus* pollen decrease indicates the local presence of these tree species in the surroundings of the T2A sequence. Conversely, the independence of the charcoal record with the *Castanea* pollen signal may be revealing that the low percentages detected here may be the product of dispersed trees not affected by fire or, more probably, the product of woodland located at a medium distance from the site. Data from the *Apeos de la feligresía de Samos* and the pollen record from T1C on the eastern side of the monastery – although only available from the 1800 s – tend to support this hypothesis.

Many pollen diagrams from north-west Iberia have recorded an increase in chestnut during Roman times that were further intensified during the Middle Ages (Mighall et al., 2006; Muñoz Sobrino et al., 2014; Silva-Sánchez et al., 2014). As in the case of vine and apple cultivation it seems that Cistercian and Benedictine monastic orders would have played a role in the spread and technological evolution of chestnut management (Lucas Álvarez and Lucas Domínguez, 1996a, 1996b; Romaní Martínez, 1989).

Although the evidence of terracing at Samos dates back to the Iron Age, the most intense geomorphological transformations were recorded in modern times. The 1600 s-1900 s were characterised by intense use of terracing for cereal cultivation that led to extreme geomorphological transformations at Samos, especially on the western side of the valley. There, at T2A, an enormous accumulation of sediment took place during the 17th-19th centuries. The process involved accretion of nearly 2 m of sediment in only 300 years. According to the OSL net intensities this accumulation occurred gradually. The high cereal percentages recorded throughout the T2A-B horizon (6.1–22.7 %) combined with the relatively moderate slope here suggest the most likely explanation for this high sediment accumulation was terracing with episodic fill. On the eastern side of the monastery, a second phase of terrace construction was detected in the 17th century CE. This corresponded to the T1C-B2 horizon, which was characterised by a coarser granulometry than the lower T1C-B3 horizon representing the first stage of terrace building in the 13th century.

Palynological information for modern times at T1C and T2A give evidence of contrasting land use to the eastand west of the Abbey. At T1C the palynological signal is dominated by *Castanea* andcereal percentages are generally lower than 3 %. Interestingly, the predominance of chestnut in the western sector was already documented in the *Apeos de la feligresía de Samos*, so it is possible that the terrace at T1C was mainly constructed to keep the slope stable and avoid earth moving down towards the stream below, rather than directly for cereal cultivation. Nevertheless, it is likely that arable cultivation occurred further up the hill where the slope was more gentle and further terraces were built (Sánchez Pardo et al., forthcoming).

Furthermore, the *Apeos de la feligresía de Samos* and the pollen data both indicate possible differences in the type of cereal grown on the eastern and western sides of the monastery. In the pollen data, the relative content of *Secale cereale* in relation to the total cereal content is much higher at T2A than at T1C. A similar pattern was found in the *Apeos de la feligresía de Samos* where the land around T2A was assessed in bushels of rye, whereas the land near T1C was assessed both in bushels of rye and bushels of bread wheat.

4.1.4. Historical and environmental archives: Congruence and divergence

All disciplines and sources of information are to some extent fragmentary and biased. Even with the application of accurate dating methods, sediments do not always account for a continuous record since hiatuses occur in their stratigraphies. In palynology, the taxonomical degree of identification does not always allow research questions about certain plant species to be addressed. For example, the possibilities of distinguishing among different fruits from the *Rosaceae* family is limited due to frequent hybridation and the presence of polyploid races (Moore et al., 1991). Cereal identification may also be limited to rye, maize and undifferentiated Cerealia type. Written sources are generally fragmentary because information was not recorded in a systematic way or at regular intervals. In addition, they were always compiled with specific uses in mind, and this can provide insights into the priorities and values of the writers.

In our example, Modern documentation provides snapshots in time that are geographically limited to the surroundings of the Abbey. Nevertheless, in some respects it agreed with with palynological data, for example in both types of showing reflecting tge predominance of chestnut plantations on the western side of the Abbey. By contrast the medieval documentation comprised a compilation of documents produced over centuries and covering a large area. Here, a discrepancy emerged between the documents and soil archives in relation to cereals and chestnuts. Before the introduction of maize and potato from the Americas, native cereals and chestnuts were crucial for early medieval societies, a fact which is s reflected clearly in the pollen record (Adua, 1999; Conedera et al., 2004). Documents from the monastery of San Vicenzo de Pombeiro suggest that the economic productivity of chestnut was second only to vines (Lucas Álvarez and Lucas Domínguez, 1996a). However, in terms of the number of entries, medieval records of chestnut are minimal at both Pombeiro and Samos. By contrast, the medieval documentation of Samos provides much more detail of apple, grape and flax management which is of great value given both that apple pollen is not easily discernible from other Rosaceae undiff., and that *Vitis* pollen is generally very uncommon (for a further discussion see Montecchi and Mercuri 2018) and its dimorphism may further hinder its identification (Mercuri et al., 2021). The central importance of vines and flax to medieval society is underscored by references in the Galician documents to *vinatarios* and *lenzarios*, two classes of servile agrarian peasants linked to the production of these crops (Fernández Ferreiro, 2021). In the Samos documents only a *lenzarios* was recorded even though vines are more commonly recorded than flax in the *Tumbo de Samos*.

Even so, the medieval documentation at Samos still makes an important contribution to understanding the Abbey's agrarian history for two reasons. Firstly, there was a hiatus in pollen data from the soil archive examined at both T1C and T2A. The OSL apparent ages showed that at T1C sediment was deposited in the Middle Ages but pollen was not preserved, whereas at T2A sediment dating between the Iron Age and later Middle Ages was absent. Secondly, some of the most economically significant species recorded in the texts could not be distinguished or occur only rarely in the environmental archives.

5. Conclusions

Even though the possessions of many monasteries were located kilometres away from the abbey buildings, the concept of monastic landscapes are still rather limited and geographically restricted. The study of ecclesiastical texts rarely explores aspects relevant to land management in a systematic way and archaeological studies of monasteries rarely include palaeoecological approaches. In this study of two sediment sequences from the surroundings of Samos Abbey, results from sedimentology, geochemistry and palynology (with robust chronological control using OSL and radiocarbon dating) were combined with detailed study of agrarian resources from medieval and early modern documentation.

Intense environmental and geomorphological transformations involving forest clearance, cereal cultivation and very likely also terracing have occurred at Samos since at least the Iron Age. Environmental changes at the time the Abbey was founded were not preserved in the two pedosedimentological sequences studied, but successive episodes of terracing during late medieval and early modern times were identified. The palynological analysis provided evidence of a mosaic pattern of land management with cereal fields and chestnut forest predominant at those times. By analysing medieval and early modern texts associated with the monastery it was possible to appreciate the significant role of fruit tree plantations such as apple orchards (taxonomically indistinguishable in pollen analysis), as well as crops such as vines and flax, which are difficult to identify in the regional palynology. By using both texts and pollen data it is possible to obtain information about the local vegetation that would be impossible to achieve by focusing on either source independently.

The interplay between geoarchaeological, palaeoecological and historical archives helps to illuminate the social and economic dimensions of environmental management. The systematic application of this approach to other monastic environments would provide valuable information about past monastic landscapes and provide further insights on the role of monastic communities in the creation of cultural landscapes.

CRediT authorship contribution statement

Noemí Silva-Sánchez: Conceptualization, Writing – original draft, Writing – review & editing. **Kinnaird Tim:** Conceptualization, Writing – original draft. **Marcos Fernández-Ferreiro:** Writing – review & editing. **Estefanía López-Salas:** Writing – review & editing. **Sam Turner:** Conceptualization, Writing – review & editing. **José-Carlos Sánchez-Pardo:** Conceptualization, Funding acquisition, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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