

# Archaeological Landscapes through GIS (Cost Surface Analysis) and Virtual Reality: A Case Study on the Monastic Site of Jure Vetere (Calabria, Italy)

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## Abstract

Thanks to recent archaeological research in Jure Vetere, a monastic site was discovered, founded by the monk Gioacchino da Fiore (12<sup>th</sup>–13<sup>th</sup> century). The multidisciplinary research, carried out by IBAM-CNR (excavations in 2002–2005), put in evidence a remarkably sized ecclesiastical construction. This study examines how the territory of Jure Vetere was exploited during the medieval era. The data processed by the GIS application help us recognize the main areas where the materials came from. The GIS study, has two main components: the first one was cost surface analysis, used to determine principal exploitation territories nearby the site, the second one was a method which allows to determine the classification of the use of potentially exploitable land. In addition the laboratory analysis of different soil samples has allowed us to evaluate the supportive capability of terrains and to come up with a hypothesis about the reconstruction of the plant landscape around the medieval site. Finally, a virtual reconstruction of the ancient environment based on the GIS procedure was created, which offers a 3D model of a medieval landscape in the 13<sup>th</sup> century.

## Keywords

Landscape Archaeology, GIS, Site Exploitation Territory, Cost Surface Analysis, Classification of Land Use, Supportive Capability of Land, 3D model, Virtual Reality

## 1. Introduction

The recent discovery of the monastery founded by Gioacchino da Fiore at the end of the 12<sup>th</sup> century in the uplands of the Sila, on the site of Jure Vetere near S. Giovanni in Fiore (southern Italy), has been of great interest for medieval archaeology in Calabria (Fig. 1).

In this area, IBAM-CNR in 2002 began an intensive programme of archaeological surveys. The place where the monastery was discovered occupies the highest part of a knoll lying in a valley at 1090m above sea level. The

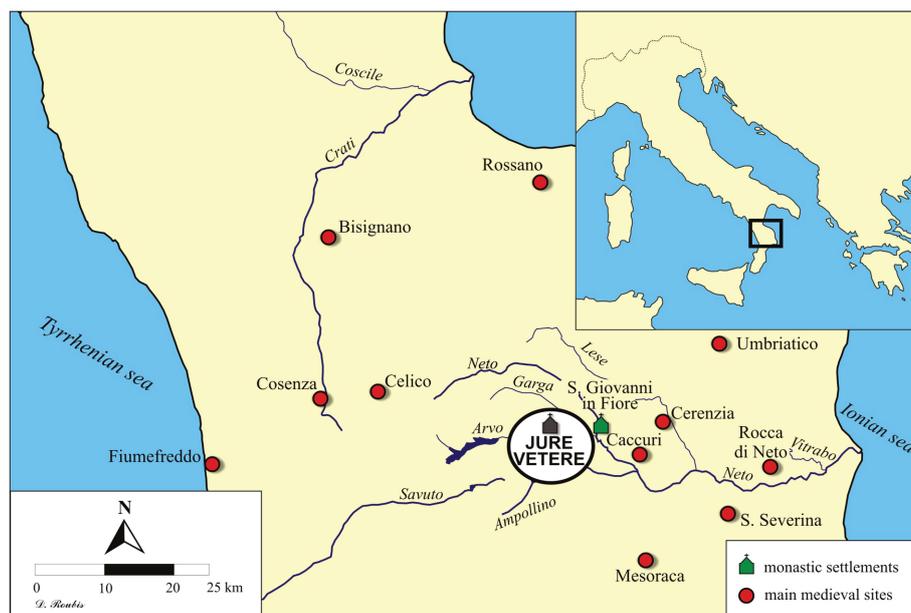


Fig. 1. Location map of Jure Vetere monastic settlement (S. Giovanni in Fiore – CS, Italy).

hill, the site of the medieval monastery, is delimited to the south by the river Arvo and to the north by a tributary of the Arvo, a stream known as “Pino Bucato”.

Thanks to the results of the archaeological research carried out by IBAM-CNR, it has now been established that the site hosted an ecclesiastical building (*Fig. 2*) of considerable dimensions, oriented along an east-west axis, for which two phases of occupation have been recognised: the first,



*Fig. 2. Jure Vetere: the monastic church discovered by archaeological excavations.*

running from the last decade of the 12<sup>th</sup> century until about 1213/1214, corresponds to the construction, occupation and destruction of the entire building. In the second phase, of short duration, work was carried out on the restoration, rebuilding and occupation of the building, until the work was definitively halted. It was, presumably, towards the end of the second phase that the monastic community was permanently moved elsewhere and the site was abandoned.

From the documentary sources we know that before October 1214 a fire caused the destruction of many of the structures standing at that time (Sogliani 2007). Evidence of this fire has been traced archaeologically and has enabled the researchers to deduce that the fire put an end to the construction of the first ecclesiastical building. On the site of this building a new one was built, with a semi-circular apse, using the walls of the central nave and shortening the area of the presbytery by a few metres. The construction technique of this second building, commissioned by Gioacchino's successor, Abbot Matteo, reflects

an architectural project designed to recover spaces and materials, as it is clear from the shortening of the presbytery and the shifting of the apse, using materials recycled from the masonry of the previous building. This second building left numerous traces: storage areas for lime and sand, holes for locating scaffolding poles and an interesting “architectural indicator”, consisting of a series of stones in the southern part of the presbytery arranged in a curve which had to become the arch of the semi-circular apse. The rebuilding does not seem to have lasted as long as the occupation of the monastery which, despite the efforts of the monastic community following the fire, had definitely come to an end by the middle of the 13<sup>th</sup> century, as it is also clear from the written documentation.

It should be stressed that the surveys on this site were conducted in accordance with the multidisciplinary approach that characterises the series of studies known as “Landscape Archaeology” (*Fig. 3*) (Roubis 2007).

The landscape archaeology of the site of Jure Vetere

entailed the integration of historical, archaeological (excavation and survey), ethno-archaeological, geological, geo-pedological, botanical (including pollen), archaeometric and remote sensing data, processed on computer. The results pointed to the existence of a settlement model of a monastic type, which is possible to characterise analysing the specific patterns of land use. For the computerised management of the data, a GIS platform was used, specially created to encounter the needs of this research project.

## **2. GIS analysis**

To model in the GIS environment the growth of the monastic community, we have made reference to the “site exploitation territory” method (Renfrew and Bahn 1991, 224–225). With this aim two main areas were considered to obtain the primary and secondary materials necessary for life in the monastery: an inner area (lying within a radius of about 20 minutes' journey) characterised by intensive exploitation of

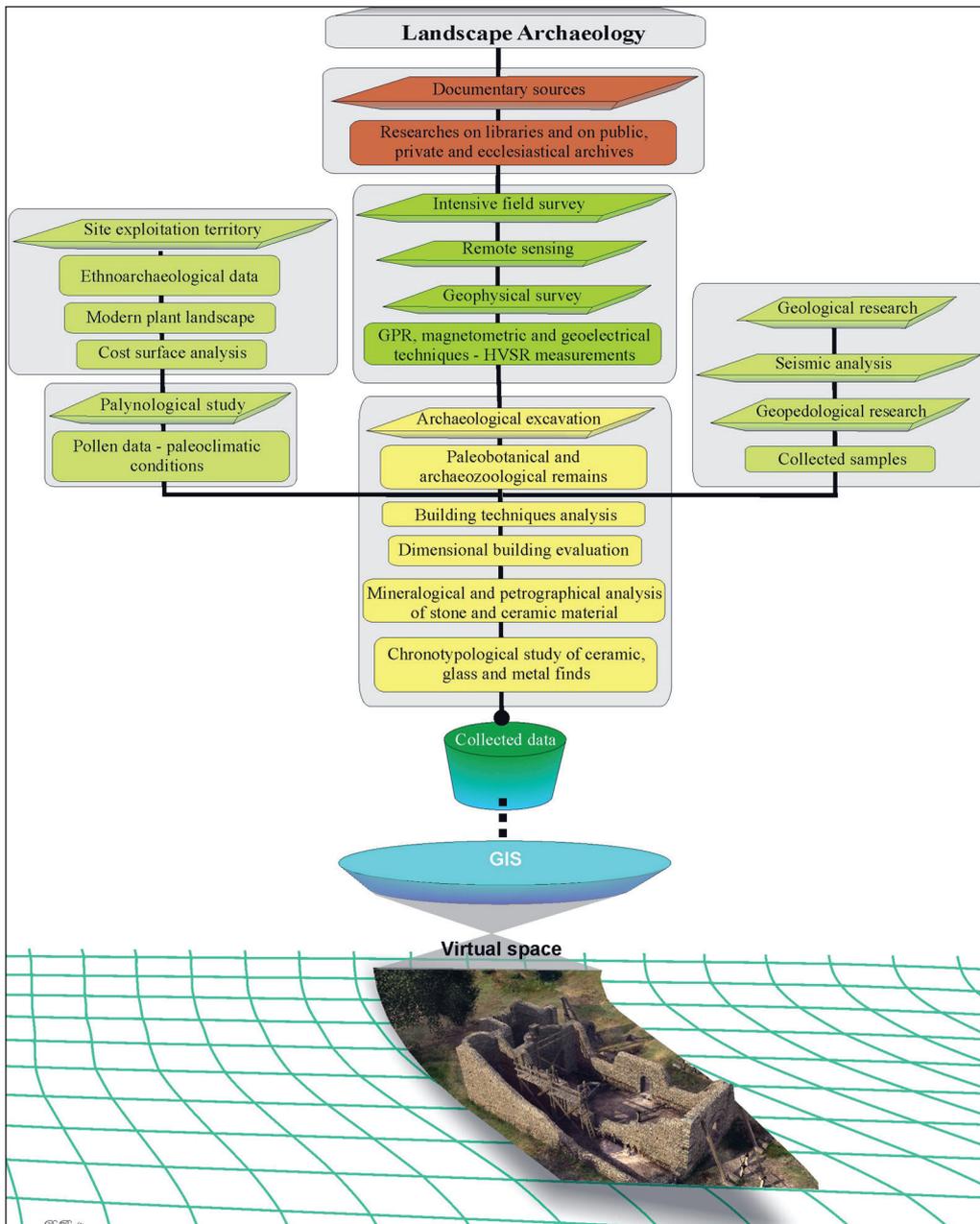


Fig. 3. Diagram with the archaeological research method used on the site of Jure Vetere.

resources, and an outer area (lying within a radius between 20 and 60 minutes' journey) for subsidiary production activities of a more extensive nature (Fig. 4).

### 2.1. Cost surface analysis

The procedures followed in order to realize “site exploitation territory” are generically described as a simple cost surface analysis by different authors (Van Leusen 2002).

The first stage of the procedure is the creation of a TIN model for the area (created from a 5-meter contour) and a consequential raster layer of slopes

deriving from it. This slope can be calculated using degrees or percentage values.

The slope layer is the basic layer for two steps of analysis: the first one is the cost distance analysis, the second is the classification of the different types of soils.

For what concerns the first step of analysis the method used was cost weighted distance, in order to calculate the time for walking on foot considering the real territorial morphology. Therefore, the calculation of the shortest path cannot be made by reference to the concept of Euclidean distance, but the analysis needed to be supported by two specific rasters: cells of the first raster express the journey cost (the time) that does not depend only on the

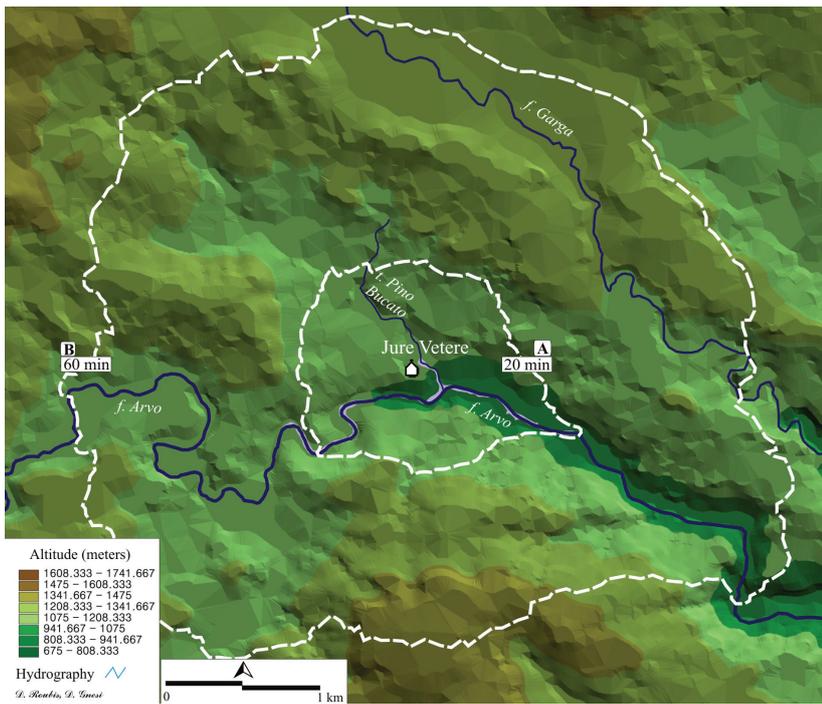


Fig. 4. Jure Vetere: cost surface analysis of the potential exploitation territory around the monastic site.

physical distance, but also on specific morphological factors; every cell of the second raster indicates the direction of travel to be taken to ensure the best path. Different approaches are used to this aim, both to obtain the cost raster (Bell and Lock 2000; Llobera 2000; Van Leusen 2002), and to obtain the distance raster (De Silva and Pizziolo 2001). For what concerns the cost raster, the mathematical formula most used in literature is the Tobler Function (Tobler 1993), but in this study we used expressions derived from empirical measurements taken with GPS. In particular to find the relationship between the morphological factor (slope) and distance covered time, we have proceeded making (with GPS empirical measurements) the time to walk along different paths, characterized by different values of slope. Through a linear interpolation of these measurements it is possible to calculate how the speed of walking in the single cell varies depending on the slope (Fig. 5).

Fig. 5 shows the reported data, diagrams, and the lines concerning downhill and uphill, where  $X$  represents the average slope of each cell and  $Y$  represents the speed to pass through it. Formulas obtained are:

- in the case of uphill:  
 $Y = -0.0143X + 0.854$ ;
- in the case of downhill:  
 $Y = -0.049X + 1.5885$
- in the case of pathways in the plains we calculated the average speed found empirically. The speed obtained is equal to  $Y = 0,92356$  m/s.

With map algebra it is now possible to transform the slope raster with the values found; the result is an output raster with the values of walking speed sought for each cell (cell size between 1 and 4 meters). To determine whether to give to the raster containing the characteristic speed of ascent or descent path, we first calculated the raster containing the direction of slopes, and made use of Boolean operators, following the procedure outlined in Fig. 6, that is: if the aspect is included inside the corner described by the perpendicular direction of travel, then the slope can be considered downhill, or must be considered in uphill.

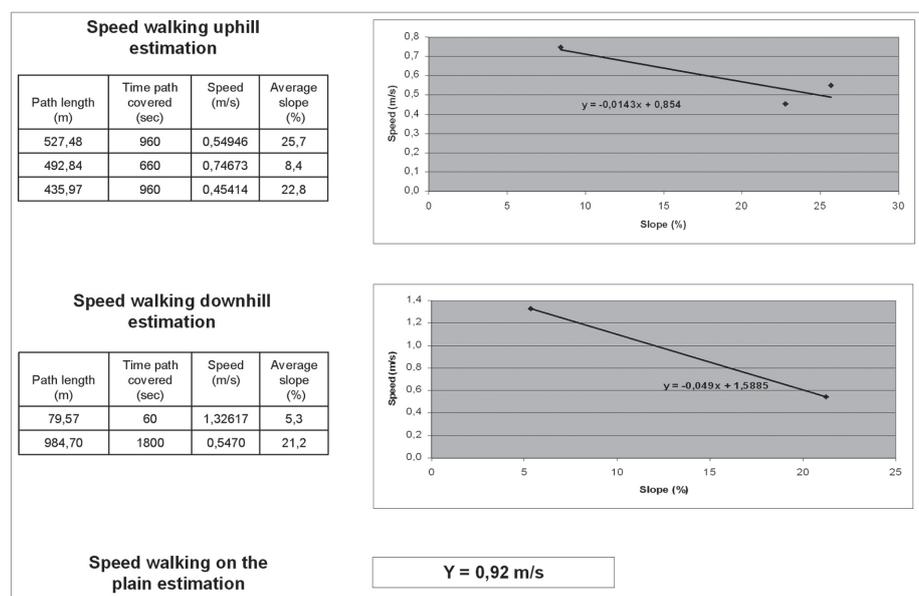


Fig. 5. Jure Vetere: relationship estimation between slope (X) and walking speed (Y) in three different terrains: uphill, downhill, plain.

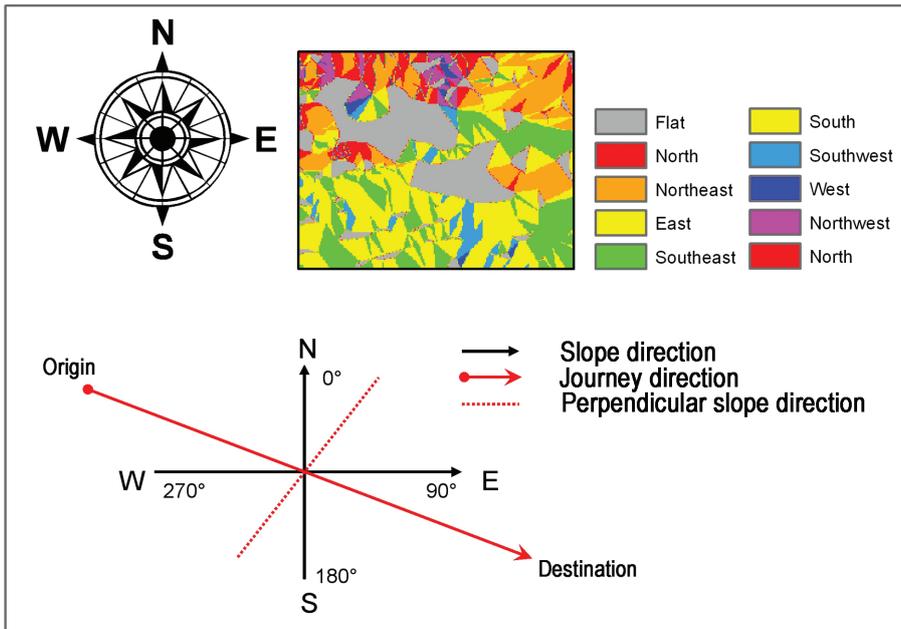


Fig. 6. Jure Vetere: method used to determine different terrains (uphill, downhill, plain), considering the aspect raster and the travel direction.

Finally, to move from walking speeds raster to time raster, the human walking speed was approximate to a uniform rectilinear motion in the individual pixels, so the cell size was divided by the speed of each cell. The second raster, used to make the analysis, was calculated with a cost weighted direction. With it we can understand which is the best direction to take to move in space, cell by cell, from a determined origin. Putting time raster and cost weighted direction raster in cost weighted distance function, and considering a walking time equal to 20 minutes and to 1 hour, it is finally possible to obtain the two areas.

## 2.2. Classification of land use

The second step (Fig. 7) was to determine the classification of the different types of potentially exploitable soils.

The GIS-based processing of the geographical and territorial information concerning the different types of soils, also made it possible to identify various potentially exploitable Environmental Units (EUs) (Fig. 8). In order to achieve this we have executed a procedure that has transformed the relative value percentages to the altitudes of the soils in a scale of the degrees of slope.

On a more detailed level, the agricultural soils (particularly those suitable for growing vegetables or cereals, EUs 1 and 2) were assumed to lie in areas where the slope of the terrain was no more than 13 degrees on average. In fact “analysis of prehistoric and historical period agricultures has usually assumed that cultivation could only occur without terracing on land of less than 10° to 15° of slope” (Bevan and Conolly 2002–2004, 126–127). This means that above these values, in order to render soils suitable for cultivation,

it is necessary to carry out terracing works. In our case study, however, during the intensive field surveys around Jure Vetere, we have not found traces of terrains with terraces at all. Regarding the other categories of soils (classified on the basis of Bevan and Conolly 2002–2004 histogram fig.4), it was observed that: a) areas with a slope of more than 13 degrees included terrain which, when free of woods and maquis or adequately deforested, could be exploited mainly for short-range grazing (EU 3); b) considering that at slopes of 30 degrees or more the possibility of practicing long-term intensive cultivation is drastically reduced, in these areas (EU 4) it was assumed that the terrain was suitable only for grazing (if not covered by forest) and/or the intensive exploitation of forest; c) steeper

Slope (°)	Slope (%)	Land use (%)
13° <	< 23.09	arable land
13° - 30°	23.09 - 57.74	land used for grazing / potentially used for cultivation (with terracing works)
30° - 42°	57.74 - 90	woods / land partially suitable for grazing
> 42°	> 90	unproductive land

Fig. 7. Jure Vetere: numerical values used to determine the classification of land use.

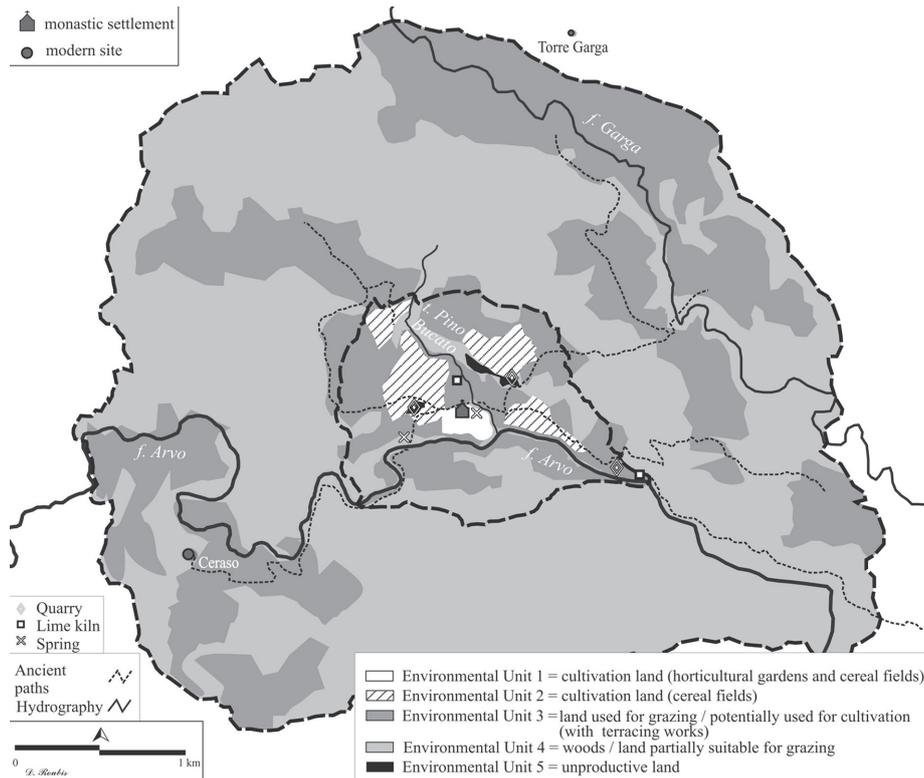


Fig. 8. Jure Vetere: the Environmental Units of the potential exploitation territory around the monastic site.

surfaces and areas of bare rock were considered to be non-productive (EU 5). We underline that the virtual reconstruction in Fig. 10 has been realized due to all these procedures and classifications.

### 2.3. Supportive capability of soils and definition of the plant landscape

In the third step of the research, we have had to evaluate the supportive capability and the behaviour of soils. So we have taken soil samples with a manual drill in different points outside the excavation area and in some other nearby terrains carried out in 2002 and successively, between 2004 and 2005. The laboratory analyses concerning the quality of available soils for crop cultivation around the site allowed us to verify the low fertility of the soils (Lazzari *et al.* 2007, 49). In effect the chemical and physical analysis demonstrated that soils derived from granitic bed rock with sandy and limy texture, are chemically acidic and contain few nutritional elements. We also have to consider the rocky feature of the soils, which requires a good deal of work to be exploited.

From these analyses, and from the spatial distribution of the soils in the GIS, it emerges that in Jure Vetere the terrain suitable for grazing was more abundant than soils suitable for agriculture,

thus indicating a monastic economy based mainly on livestock rearing. The site of Jure Vetere, during its very short medieval life, made available an exploitable territory of limited extension, but it was able to provide subsistence for a small monastic community.

Finally, the last phase of the research, particularly important for the processing of the data via the GIS, was the study of the ancient environment which surrounded the monastery at the time of its foundation and during its brief life. The archaeo-botanical analyses and the palynological study made it possible to reconstruct the environment, and the vegetal landscape

of the tableland where the proto-monastery was founded, providing the data necessary for interpreting the dynamics of exploitation of the surrounding land by the monastic community (Fiorentino *et al.* 2007; Mercuri *et al.* 2007). The aims of these studies were both the knowledge of the exploitation of plant resources by monks in the short period of occupation of the site and the reconstruction of the plant landscape of the site where the monastery was founded.

### 3. The virtual reconstruction

The methodological basis of the virtualisation is partly technical, due to the extensive use of Computer Graphics techniques, and partly analogical, i.e. based on the comparison of data originating from other sites dating back to the same period and located in the same region (Gabellone 2007).

The image in Fig. 9 shows a moment of daily life in the site of Jure Vetere, viewed through a virtual camera which shows the remains visible today in their unfinished state, *in fieri*, given that the building was abandoned before it was completed. We know from the documentary sources and the archaeological excavations that the monastic complex was almost totally destroyed by a fire, and that a new church was



Fig. 9. Jure Vetere: virtual reconstruction of the monastic church from the south-west.



Fig. 10. Jure Vetere: virtual reconstruction of the medieval landscape from the south. 1) ecclesiastical building; 2) spring; 3) lime kiln; 4) quarry; 5) Environmental Unit 1 (arable land – horticultural gardens and cereal fields); 6) Environmental Unit 2 (arable land – cereal fields); 7) Environmental Unit 3 (land used for grazing / potentially used for cultivation); 8) Environmental Unit 4 (woods / land partially suitable for grazing); 9) stream Pino Bucato; 10) river Arvo.

built on the site, differing slightly from the previous one. The elements necessary for the rebuilding were partly recovered from materials not damaged by the fire and partly extracted from nearby quarries, located in the same valley. Construction continued incessantly until the exact moment when it was decided to abandon the building work and not to continue with rebuilding any further. Blocks lying on the ground in a curve, ready to be placed in their final position, probably as part of an arch; a space inside the side nave used to prepare the lime; holes for scaffolding poles near the apse and along the side nave; everything in and around the building testifies to its sudden abandonment. What remains on the ground today is the starting point for us and the *stimulus* to tell the whole story of this site, not just the moment when it was abandoned, but it is also interesting to represent visually the organisation of the building site, with scaffolding still in use, the tools, the walls built above the levels marked by fire and the monks patiently engaged in their work.

The reconstruction of the ancient landscape (Fig. 10) sought to take account of every element that might help recreate the scene. The detailed study of spatial analysis based on GIS (defined above), the archaeobotanical analysis and the study of pollen samples taken from different points of the excavation area, has given information on the existence of horticultural gardens and open sown cereal fields (EUs 1, 2), land used for grazing (EU 3), woodlands (EU 4), together with the existence in the surrounding area, found during the field surveys, of several springs, quarries, lime kilns and ancient paths. Even the flora and fauna were derived from the painstaking and detailed study of the bioarchaeological samples taken from various points identified inside the area of excavation. The recovery of seeds, particles of charcoal and other charred material was achieved by means of micro-excavation and made it possible to determine not only the types of *species* present, but also their concentration.

Light simulation techniques using radiance maps or HDRI, sub-polygonal displacement for the creation of the walls, the generation of filaments for the patches of grass, advanced rigging and subdivision surfaces for the poses and modelling of the human figures, are just some of the many features applied to the reconstructive study of Jure Vetere.

The case study described here enables us, thanks to the use of technology, to open a window on our past and (we think is the time to point it out) on

our past landscapes, but the real objective is and remains historical and archaeological research, which, thanks to Virtual Reality can be narrated and represented as never before. The archaeological data in our possession were used to perform the virtual reconstruction of the ecclesiastical complex in its landscape context in order to emphasize the first evidence of “medieval monasticism” investigated archaeologically in south Italy, in the Sila mountain region of Calabria.

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Figures 1, 4, 7–8: Dimitris Roubis (graphical elaboration); figure 2: Dimitris Roubis and Francesca Sogliani; figure 3: Dimitris Roubis (diagram with the archaeological research method) and Francesco Gabellone (virtual reconstruction of the church); figures 5–6: Maria Danese (graphical elaboration); figures 9–10: Francesco Gabellone (virtual reconstruction).

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