Tiber Valley Virtual Museum: 3D landscape reconstruction in the Orientalising period, North of Rome.

A methodological approach proposal

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***Abstract*—This paper discusses a multidisciplinary methodology for the 3D reconstruction of the hypothesized ancient landscape along the Tiber Valley North of Rome in the 8th century AD. As part of the CNR-ITABC Tiber Valley Virtual Museum project, we used quantitative evaluation of geological and ecological data, historical, archaeological and demographic information. Moving from theory and literature on spatial archeology, the project is implemented through advanced raster algebra operations in GRASS-GIS, output to maps which are then imported in the VUE terrain engine for photorealistic 3D landscape generation.**

Keywords—Virtual Museums; 3D reconstruction of the potential past landscape; multidisciplinary approach; spatial archaeology

I. The Project: Definition, Goals and General Approach to the Theme of Tiber Valley

Since middle 2011 CNR ITABC is developing a new Virtual Museums, supported by Arcus s.p.a., dedicated to the Medium Tiber Valley. The project, that will be concluded in 2014, is quite original and ambitious for its multidisciplinary approach to the study of the landscape considered in its several cultural components: geological, natural, historical, archaeological, evocative and symbolic. The Virtual Museum has been conceived in order to increment and disseminate the knowledge of the territory and its cultural heritage and to encourage people to visit some important and beautiful places that are still marginal in relation with the main tourist itineraries, too much focused on the Capital. The area North of Rome, between Monte Soratte (North) and Fidene (South), Palombara Sabina (East) and Sacrofano (West) and crossed by the ancient consular road via Salaria, has been taken in consideration.

We are working on a central VR application characterized by natural interaction and by an artistic and evocative style that will be accessible as permanent installation in Villa Poniatowky (Villa Giulia Museum). It will constitute a sort of "portal" to the theme of Tiber river considered in its several aspects, especially the symbolic values and meanings, rather than the descriptive ones, which it represents for the Roman and Italian history. Beside, we are developing a multimedia web site, multimedia and VR applications for the museums of the territory (the River Museum in Nazzano, the archaeological Museum of *Lucus Feroniae*) and for mobile devices with the goal to support the public before and during the visit of the real sites through the access to cultural contents while attending places, museums, archaeological sites, naturalistic itineraries. The different applications will derive from a common dataset, with some adjustments according to the specific communicative formats required by the different conditions of fruition. A key concept of the project is the approach to the landscape in its different interpretative and emotional dimensions; from macro-scale (the landscape in its holistic vision) to micro-scale (specific sites: the ancient roman city of Lucus Feroniae, Volusii's roman villa, Natural Park of Tevere-Farfa, Monte Soratte) and also in its geological, anthropological and cultural evolution through the time, (prehistorical, pre-roman/orientalising, roman, medieval and actual ages). The project involves a multidisciplinary team composed by CNR and University researchers, private companies (archaeologists, art historians, geologists, computer scientists, surveyors, computer graphics) but also by artists, musicians and public stakeholders.

II. Methodological Approach

A. An historical perspective

One of the priorities of the project was to find a convincing method to simulate the ecosystems and the soil

use in the past, finalized to the 3D reconstruction of the potential ancient landscape of the Tiber Valley in different ages. In this paper we focus on the orientalising period (end of the VIII century -VII century BC), which was particularly important for the growth of the first urban centers.
Although such process of virtual reconstruction is crucial for the digital heritage domain, the different approach have not reached a common agreement.
The earliest focusing on ecological aspects in archaeology's history date back to Gordon Childe's studies [13]. Despite the various kinds of methodologies for spatial analysis developed during the '60s (Hodder and Orton 1976), the earliest attempts to turn such an approach into a concrete, numerical methodology to define landscape potential is the definition of the *Site Catchment Analysis* model by Higgs and Vita Finzi [14]. Despite the criticisms to such an approach [11], it has then been applied in different contexts, often varying distance parameters for site buffer definition. At the same time, spatial analysis models have been used for experiments of territorial simulation. Among these, interesting and remarkable works have been carried on for the Tiber valley area (the same object of the present work) in the last decades [8], [16]. The earliest organic implementations of the model in a GIS date back to the early '90s [12] leading to interesting results although certainly facilitated by the isolated context of an Isle. Nevertheless, such an approach in traditional archaeological perspective, tend to emphasize the definition of *positive* areas: the *buffers*, the places where productive or interesting features are located, leaving apart the definition of *remaining* parts of the territory, a crucial point faced by Landscape Archaeology (Cambi and Terrenato 1994). Virtual reality approach, on the contrary, needs an organic approach to landscape definition, where no part may be left undefined. An attempt in this sense has been performed for the definition of Ancient Via Flaminia virtual landscape reconstruction [7] and formalized by Pescarin [15]. The present work represent – through the concrete case study of the Tiber Valley Project – a proposal of generalizable formalized model for the landscape reconstruction through time, taking into account the various economic and social models of different civilizations, following one another on the same geographic space.

B. Methodological approach in the reconstruction of the ancient landscape of the medium Tiber valley North of Rome in the orientalising period

Following a multidisciplinary approach, we combined several kinds of information, quantitative evaluation of geological and ecological data, historical, archaeological and demographical studies. We propose a complete pipeline procedure, from GIS data elaboration up to final realistic 3D renderings.
As first step we realized a digital Elevation Model (DEM) of the actual landscape with a resolution of 10 mt, obtained thanks to the collaboration of the National Institute of Geophysics and Vulcanology, which was textured with a satellite image (IRS) with a resolution of 5mt.
In parallel we elaborated a digital elevation model of the area with a resolution of 5 mt, starting from aerial photogrammetry[1]. A set of 12 aerial IGM analog photos has been used, taken in 1954, before the construction of the two major modern infrastructures: the dig of Nazzano (1955) and the highway (1961). This DEM has been realized in collaboration with Bruno Kessler Foundation and constituted the base for the 3d model of the terrain in the past ages, that, successively, has been colored in a realistic way through 3D and 2D graphic libraries.
Basically, for the creation of the ecosystems the archaeological map and the land unit map were our starting points. The latter was useful to define the soils composition and their attitude to host specific ecosystems, both natural and cultivated by the man (in collaboration with Digiter srl).
From the original 75 land units, 6 main macro-ecosystems have been obtained after a process of simplification:
-volcanic
- sedimentary eco-landscape (sandy-conglomeratic- clayish)
- calcareous eco-landscape of low-medium height (Soratte mountain)
- calcareous eco-landscape of considerable height
- valley eco-landscape (Tevere, lower terraces included)
- Tiber banks eco-landscape.

We also analyzed the geomorphology and geology of the territory, the slopes, the orography, the accessibility of the river and we elaborated an hypothesis of ancient courses for the Tiber and of possible presence of ancient harbors or crossing points/structures on the river (fig.1). The results were compared with the archaeological remains and we found good correspondences.

Regarding the definition of the potential natural vegetation to associate to each macro-ecosystem of the landscape, we took in consideration the existing thematic cartography elaborated by Regione Lazio and Provincia di Roma. We can assume that the potential natural vegetation has not changed in a substantial way. These data have been combined with the archaeological map and demographic analyses for the orientalising period (the roman period in in progress) in order to define the areas influenced by the presence of human settlements and activities ("buffers").

A specific methodology has been followed for the buffer creation, considering several factors in relation with the geography and geomorphology of the territory, the distance of the lands from the infrastructures (the roads for instance), the economic model, the technological level and the movement potential of the population in the daily conduction of their work (fig.5).

[1]Aerial photos set of 12 analog images IGM (1954), digitized at 20 micron (ca 2600 dpi). Camera Fairchild KF246 with 152 mm lens. Height of flight: ca 5600 m. Ground Sampling Distance: ca 40 cm. Ca 30 GCP for geo-referencing

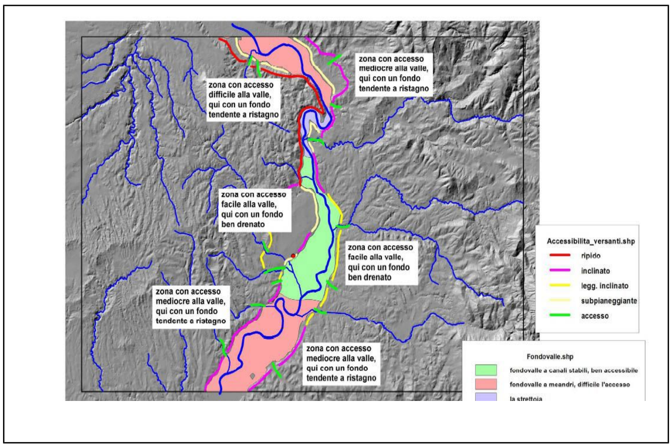

Fig. 1. Geological study related to the accessibility of the medium Tiber Valley and hypothesis of the ancient Tiber course

Each of these factor has a certain level/proportion of importance in relation to the others, and this relation can change through the different historical ages. For the characterization of the cultivations and vegetal species we were supported by the studies about alimentation and food in the past ages existing in bibliography and by other information from pollen analyses or archaeology.

The final result of this work is the elaboration of a color map that describes the past landscape, including natural and anthropic areas. Each color of this map represents a specific ecosystem (fig.6).

The methodological process followed for this period can be easily replicated for other chronological phases, changing the weight of the single parameters, as we will explain in detail in the next paragraphs.

An ecosystem consists in a specific mixed set of plants that adapt to that soil, climate, orientation and so on. The combination and disposal of the plants in each ecosystem is natural or linked to the cultivation techniques existing in that specific age.

The final step has been the conversion of this symbolic description of the landscape (GIS) in a realistic 3D representation, through powerful tools for landscape generation and design, as described in the following paragraph. The final representation, aimed also at cultural transmission to the public, is of two types: a real time application developed in Unity 3D and a movie realized in Vue, so data have been processed and optimized differently for the two outputs.

III. A GEOLOGICAL BASE FOR THE RECONSTRUCTION OF THE POTENTIAL ANCIENT LANDSCAPE

Several million years ago (Upper Pliocene, Lower Pleistocene) the area of the middle Tiber course was located in a sea arm, where the current mountains formed the surrounding mainland (belonging to the Apennine mountain chain) or islands: Monte Soratte, Fara Sabina, the Cornicolani mountains. Successively this sea was filled up by sediments, whose grain size decreased from pebbly through sandy to clayey in function of the distance to the mainland stretches. This differentiation is still reflected in the granular composition of the hills. Due to the ongoing formation of the Apennine chain, the whole landscape was uplifted to form the current morphological structure.

Hundreds of thousands years ago, (between 600.000 and 300.000 years ago, Middle Pleistocene), the explosive volcanoes of the Colli Albani and Sabatino have created a discontinuous coverage of the sedimentary hills and mountains with ash and lapilli. During and after the volcanic activity, the stream network has gradually carved this landscape, saving only the hill summits, which for this reason are now covered by the scattered remains of volcanic sediments. In that period, and even before, the Tiber course has undergone various shifts, due to tectonic movements and the deposition of volcanic products.

After the main volcanic activity, several travertine plateaus were formed in tectonically subsided areas. In the northern part of the area, various levels of river terraces are present, the older ones being covered with volcanic deposits. The current level of the Tiber valley floor was achieved less than 10.000 years ago, with the completion of its alluvial infill after the sea level low stand of the last glacial age (Wurm III, 20.000 years ago).

Which morphological elements of this area may have changed substantially over the last 3000 years? This is a short period from the earth-sciences viewpoint. So one may state that during this time span the hills, slopes and valley floors have not changed much, apart from the hills being lowered in height a few meters due to erosion and the valley floor levels having grown with a similar value due to natural accumulation. The latter is proven by the burial of the Roman age surface in the lower Tiber valley at a depth of about 1-2 meters [1]. What has certainly changed substantially is the course of the Tiber river, though not in all stretches to the same degree. Proof of these variations is provided by some historical maps of the area [5], by aerial photographs and by the partly known evolution of the lower Tiber since Roman times (ibidem). In other areas of central Italy, in this time span the landscape changes have been stronger, but those were mainly limited to the coastal areas and the surroundings of the Colli Albani Volcano [2],[3].

For this area, a Land Units map at scale 1:50.000 was drafted. Such a map depicts the spatial distribution of the soils in their lithological, morphological and drainage context. These data were used to evaluate the suitability of the territory for cereals (eventually with rows of vines) and grassland, and for olive groves and orchards (fig.2).

The Land Units map was then combined with the Phytoclimatic map of Latium at scale 1:250.000 [4], to create a map of the “Eco-Landscape” (fig.3). For each legend unit were described: the dominant phytoclimate, the main soil characteristics (depth, stoniness, water retention, fertility, acidity) and the expected vegetation. Both maps were used as input for the landscape model of the orientalising age (VIII-VII century BC).

Moreover, an hypothesis was developed of the river course of 2000-3000 years ago (see also fig. 1). Essential in reconstructing the past hydraulic regime of the Tiber is the presence of the narrow passage of Nazzano, probably of tectonic origin. To the north of that point there must always (at least in the Holocene) have been a meandering and actively shifting river course (which in detail of course is impossible to reconstruct), bordered by fluvial terraces. In the narrow passage there must have been a curved but constrained stream path, not much variable over time. And to the south of the passage a linear river course, more downstream passing into an actively meandering system, and without terraces along the valley.

Simplified legend of the Eco-Landscape map in figure 3:

1) undulating volcanic reliefs (**VO**)
2) volcanic reliefs with steep slopes (**VR**)
3) undulating sedimentary sandy-conglomeratic reliefs (**SO**)
4) sedimentary sandy-conglomeratic reliefs with steep slopes (**SR**)
5) depressions (**SC**)
6) sedimentary clayey reliefs (**SA**)
7) limestone reliefs at lower and medium altitudes with steep slopes (**L**)
8) undulating limestone reliefs at higher altitudes (**CO**)
9) limestone reliefs at higher altitudes with steep slopes (**CR**)
10) undulating limestone reliefs at the highest altitudes (**HO**)
11) limestone reliefs at the highest altitudes with steep slopes (**HR**)
12) Tiber valley floor (**FF**)
13) other valley floors (**FA**)
14) lower fluvial terraces (**FT**)

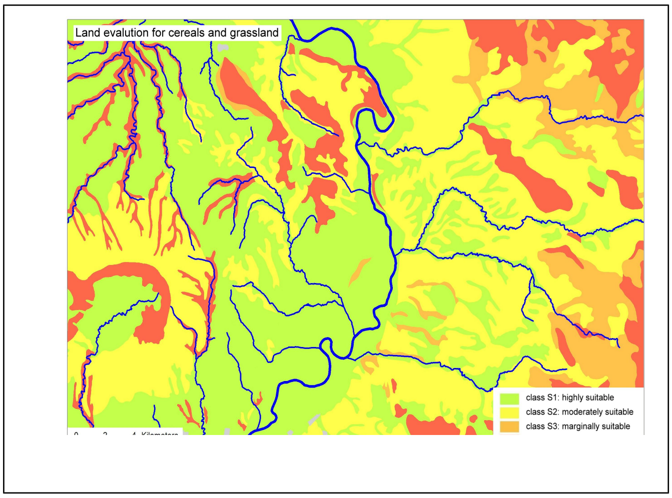

Fig. 2. Evaluation for cereals/ meadows-grazing (possibly with vine rows).

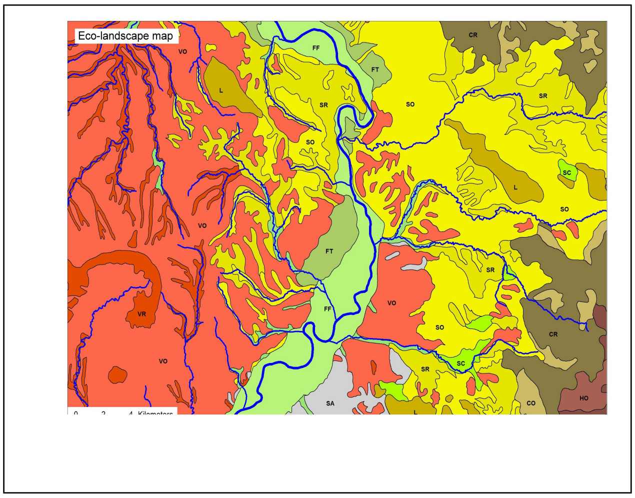

Fig. 3 Eco-Landscape map

IV. THE MEDIUM TIBER VALLEY NORTH OF ROME IN THE IRON AND ORIENTALISING PERIOD

The population of the Tiber area during the Iron Age results extremely variegated as the Tiber river is going to shape the proto-urban scenery of such territory, becoming the main trade route with its own harbors and river ports. Tiber is also becoming an important political "frontier"[20] between the Etruscan lands, with the Capenate enclave to the left, and the area under Latini e Sabini influence to the right [16].

The substantial presence of man in Sabina area is probably due to the displacement of people from the Velina valley towards the Tiber river, as historical sources revealed. Next to this important political-commercial fluvial route, a new terrestrial one develops, similar to the ancient segment of Via Cecilia [19]- which today becomes the famous Via Salaria - around which various traces of human presence have been found. Sabina people of the VIII century B.C. lived in small villages located in strategic points along the Tiber river, directly distributed near the riverbed or near its tributaries like the Farfa river. These villages, with an extension of about 8 up to 10 ha, consisted of huts with roofs of reeds and branches.

There were not extended lands with mono-cultures, on the contrary men were used to cultivate vegetable gardens within, or just beside, their villages, where activities related to subsistence economy and the proto-historical production were carried out, such as: growing vegetables, raising animals in small enclosures, pottery manufacture, bread baking etc. Cultivated species of plant, which have been archaeologically attested, are: lens esculenta (lentils), peas, broad beans, grains spelled, barley, millet, panic, grass pea and vetch, some for human uses and others for animal employments. The vines was cultivated not in rows but climbing on the trees staying on the wood's border (fig. 4).

Fig. 4. Sketches of a village and of its land organization in the VIII cent. BC

Starting from the end of the VIII-beginning of the VII century. B.C., (Early Orientalising age), the situation changed with the accentuation of the proto-urban phenomenon that will definitely emerge by the VII century. B. C. Villages evolve, some get together until reaching a total dimension of more than 20 ha; others disappear. Major centers develop on leveled hilltops, as Eretum and Cures, extending their area to 25-30 hectares [20]. Other centers of Nomentum (15-20 ha) Ficulea (22.5 ha) and Poggio Sommavilla belong to the same category as Cures and Eretum.

In the Orientalising phase, the proto-urban centers are about 10 km far from each other. They control territories of about 100 square kilometers, due to the long-distance commercial traffic promoted by the emerging elites, principal characters of the new political organization. People of the VII century BC lived in houses made of bricks with foundations and tiled roof, sometimes decorated with painted terracotta. Necropolis appear in this period, with chamber tombs, such as those of Colle del Forno and Poggio Sommavilla. Thanks to a more favorable climate, drier and with lower temperature range, some plant species appear, like dogwood, elderberry, blackberry and rowan, used for the production of fermented beverages, together with various types of fruit, grown in the areas surrounding the villages. Furthermore, vineyards and olives are attested, both for domestic production and exchange, as showed by specialized pruning tools found in Etruscan villages.

Sabina centers developed their own handmade ceramics production too, although strongly influenced by neighborhood people such as Etruscans, Latins and from Praeneste and Tivoli.

Sabines, unlike Etruscans and Latins, are going to remain anchored to a pastoral culture, populated by gods related to nature as "Lucus Feroniae" to which sacred woods and a temple were dedicated. Other sacred temples like Trebula Mutuesca, still dedicated to Feronia, and the one of Forum Novum, arose at crossroads, exchange points and market places, rather than in towns.

V. Determination of the Cultivated Land in Relation with Demographic Studies

The landscape reconstruction process was performed in 4 steps:

- Definition of the natural terrain attitude (see above): *What would probably be natural soil cover without human action?*

- Definition of natural terrain attitude (see above) to different cultivations: *Which kind of culture is any area more suitable for?*

- Definition (in consideration of a large amount of data) of a range of land suitability values for agriculture: *How good would be any area for being cultivated?*

- Determination, for the whole study area, of the quantity of land cultivated land in relation of nutritional, commercial, working cost needs: *How much land was needed to cultivate?*

From such steps, the final color map for landscape reconstruction is reached. The first two were described in the previous paragraphs. This paragraph deals with the latter two passages.

Once created a GIS and the ecological attitude (eco-landscape) map of the whole territory, the next step is to define a gradient of attitude for the cultivation of different areas. Such a process is a complex one, as it is connected to different aspects and each of them may have different relevance according to the social context we are dealing with. Closeness to settlements, to rivers, to roads may have influenced an area in different ways through time. Following such observation we defined a polynomial approach:

$$\mathbf{aX+bY+cZ....}$$

Where X,Y,Z are the different thematic aspects formalized in the GIS layers, aand a,b,c their relevance, on the basis of social and technological features of the context.

Thus, to define Orientalizing Iron Age cultivation attitude map, we reached the formula:

$$\mathbf{M=(X+0.5Y+0.5Z+3K+W)\ [if\ J<40\%]}$$

Where (fig.5):

M= area agricultural potentiality

X= map of distance from settlements (round buffers at 2,4,6,10 km)

Y= map of distance from roads (buffer at 1,2 km)

Z= map of distance from rivers and waterstreams (buffers at 300,1000 m)

K= simplified eco-landscape map (5 categories of ecological potential)

J= slope map (only values < 40% are considered)

W= cost map (cost analysis): quantifies the effort needed to reach any point from the settlements.

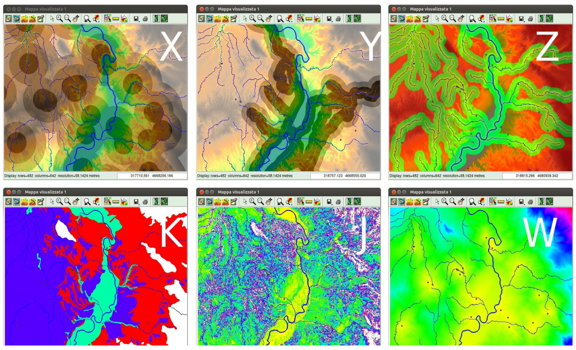

Fig.5. Buffer maps

For instance, in Roman Age, the same formula may be used just changing relevance parameters:

M=(0.5X+Y+0.5Z+3K+W) [if J<40%]

giving less relevance to the closeness to settlements (X) and more to the closeness to roads (Y), in a social context with a well organized transport net.

Such a method allowed a simpler managing of the whole process of landscape map creation through time, as some GIS softwares (for instance GRASS-GIS) allow to use the polynomial formula directly in the raster processing tools.

The resulting map will show a gradient of the area suitablle for agriculture. The next step is, then, to choose a *cutting point* to limit the cultivated area on the basis of agricultural needs (set by working availability, nutrition need, demography, etc.). Both etnoarchaeological and documentary data may be used for such a purpose.

In our case, for the Orientalising Iron Age we considered a wheat yield of about 6-700 Kg per hectare: Columella and Varro's texts refer of about 1300 Kg, but it seems too large (Arnoldus & Pozzuto 2009: 36) and one third must be subtracted for fallow fields and for seeds to be preserved in order to be planted. Besides, on the basis of literature, we considered a ratio wheat/flour of 100%, a supply of 300 kcal/100 grams and a need of 2500 Kcal/day half of which provided by cereals (in the frame of a balanced diet).

The famous *bina iugera* tradition tells us that Romulus gave each family (4 people) two *iugera* of land (4 iugera= about 1 hectare), and would lead us to an estimation of 0,125 hectares and 87 kg per year per person, corresponding to 700 kcal per day: a too low budget. We decided to adopt an estimation of about 0,2 ha p.p., still compatible both with the bina iugera tradition and the hypothesis by Arnoldus & Pozzuto (2009: 39), reaching a final value of 1150 kcal/day.

For the demographic estimation we choose to follow Di Gennaro and Guidi's approach (Di Gennaro and Guidi 2009), considering an extension of 25 hectares for larger settlements (Cures, Eretum) and 8 for the others, with alimited number of smaller ones (2 ha). The estimated density of 100 persons per ha (Di Gennaro and Guidi 2010), and the hypothesis of 12000 inhabitants for the whole studied area led to a result of some 2400 hectares cultivated for cereals, shifted to 3000 considering land managing features.

The final color map corresponding to cultivated areas, was then drawn considering an extension of 3000 ha of cereal/pasture-prevailing land and about 400 fruit orchard-prevailing land (at that time, plantations were not exclusive, oil and vineyards are included also in cereals-prevailing ecosystems, as classical authors refer).

The resulting map was then superimposed to the Soil ecolandscape one, reaching the final basis for the global landscape reconstruction (fig.6).

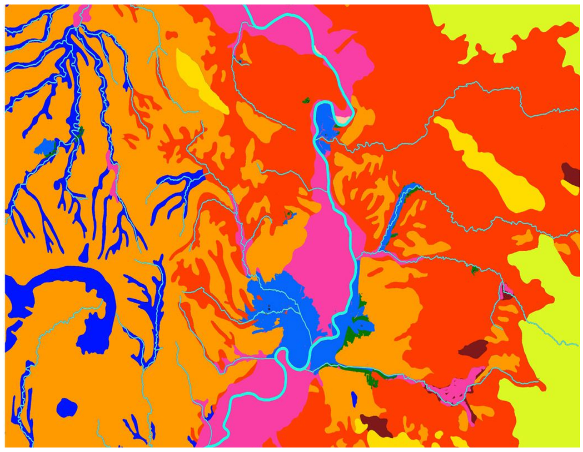

Fig. 6. Final color map with natural landscape and cultivated areas (VIII-VII sec.a.C.), Each colour refers to a specific ecosystem.

VI. Final rendering: generation of the 3D ecosystems in Vue and in Unity 3D

In our approach the final 3d representation of the landscape plays a key rule both at scientific level and for public dissemination. In a 3D environment we have multiple possibilities of analyses and interpretation, because this simulated space offers a perceptive and cognitive dimension similar to the one we experience in the real life. 3D is fundamental in the knowledge process based on the experience, because it creates a difference and dynamic relations between who is interacting and the environment. Inside a 3d environment user feels spatially embodied in the system; this embodiment constitutes a new frontier of the communication and learning processes. For this reason it is fundamental to define a good protocol to preserve the original scientific reliability of data and translate the 2D representation to a 3D simulated environment, useful both for experts and especially for the museum audience.

The terrain generation in Vue for the 3D reconstruction of the potential Tiber valley ancient landscape had two orders of magnitude: the first one is a model for a general overview, and

the second one, with a smaller size and a higher level of detail, is positioned around the villages where we need a more detailed representation. Both models are later confluent into a single macro model, in order to give the villages a realistic background from the geomorphological point of view.
In the 3D reconstruction of an ancient village this type of approach produces scenes with a huge number of polygons: in fact on the hi-poly terrain models the 3d ecosystems have been placed, including 3D models of the plants of the Iron Age, of animals, men, objects of daily life and housing of the time. The scene has about 1.5 billion polygons, extremely difficult to handle, which fortunately are used by Vue only in the final rendering process. In fact, the software provides the ability to adjust the level of detail of the objects represented in the canvas according to the video card performance, starting from polygonal model at full resolution, up to a billboard or a simple point, which are extremely light for the scene management..
The data resulting from the GIS are of two types: 1) the shape of the land, imported in VUE as heightmap (geotiff) or USGS/SDTS DEM (. dem o. ddf), 2) the colormap, used to place the vegetation on the territory: this image is created together with a legend that assigns an ecosystem for every single color and with a corresponding excel file with the description of the plants present in each ecosystem, the percentage of presence, the dimensional data of the individual essences.
All these information are used for the 3D generation of ecosystems in Vue, where they can be distributed according to a procedural programming approach, (for instance the density and the presence of plants is calculated on the base of the terrain slope, the fog on the base of the altitude, etc.). The population can also be positioned manually with editable paintbrushes, with a total control on the location of the present species. The models of the plants of the Iron Age have been processed with the Vue Plant Editor, which allows to create or modify a plant and to replicate it as instances always different, based on the set of algorithms named SolidGrowth.
In addition to the plants, a set of animals, people or objects, modeled and texturized in 3D Studio Max, ZBrush and Mudbox. have been imported in VUE for the final composition of the scene.
Regarding the human settlement, we found some bibliography about the space division and the aspect of villages but with very few drawings and sketches. So we tried to design and create in 3d a typical village of the end of the iron age (VIII century BC) with an additional support by the experts (in partic. Paola Santoro, CNR ISMA). We modeled a hut in detail, the interior and the exterior, basing on the model of the well know hut found in Cures Sabini. We also propose a 3D model of built house, in order to show this transformation process (fig. 7,8).
The second terrain model, with lower resolution, is visualized from a greater distance: in this case the colormap was filled up with several 2d textures instead of polygonal models of vegetation. These textures were created with top view renderings of plants generated in VUE, which were later saved as custom patterns in Photoshop, and subsequently applied on the general texture of the DEM through the use of customized paintbrushes.
There is a second strand of terrain modeling that is addressed to the real-time applications, and it is focused on the reconstruction of the actual landscape. It is implemented through the Unity Terrain Engine. In this case the macro-model of the territory has been divided into tiles to obtain a paged terrain, a dynamic geometry that increase the number of polygons and the LOD (Levels of Detail) in relation with the distance of the camera from the terrain. The tiles are generated through the use of height maps, that are imported in Unity 3d in RAW format. Once generated the terrain, a diffuse map can be added, further implemented with the splat map, applied directly on the surface of the terrain through the 3d painting tool. The Unity Terrain Engine is an extremely powerful tool: in fact it allows to "paint" also 3d optimized models of vegetation, directly on the terrain: these geometries of vegetation switches dynamically from a quite complex polygonal object into a simple billboard, according to the camera distance. The image used by the billboard is the rendering of the same polygonal plant, prospectively coincident with the position of the plant 3d model seen by the camera. Increasing the distance of the camera from the plant also the billboard disappears, leaving only the terrain diffuse texture visible.

Fig. 7. 3D reconstruction in Vue of Eretum in the VIII cent. BC

Fig. 8. on the left: 3D reconstruction of a typical hut of the VIII cent. BC (exterior and interior), on the example of the hut of Cures Sabini. On the right: 3D model of typical house of the VII century BC.

The plants can be obtained modifying existing models, or can be created from scratch, using the Unity Tree Creator, a powerful engine that can procedurally handle all the plants characteristics, starting from the thickness of the trunk and of the branches, density, length and linearity, up to the orientation, density and size of the individual leaves. Once these parameters are set as "characteristics of species" it is possible to generate an infinite number of different plants.

All the geometries of plants can also dynamically respond to physical entities and forces, eg. wind, particle systems or collisions with characters.

VII. Conclusions

In this paper we described, within the framework of the Tiber Valley Virtual Museum), the process of creating a valid methodology for the 3D reconstruction of the potential ancient landscape along the Tiber Valley North of Rome in the Orientalizing period (VIII century AD). This chronological phase has great importance for the development of civilization in this area because settlements that were previously scattered on the territory began to integrate and to define new urban environments.

Following a multidisciplinary approach, we crossed several kinds of data, quantitative evaluation of geological and ecological data, historical, archaeological and demographic information. We propose a complete pipeline procedure, from GIS data processing up to final realistic 3D renderings.

In order to define the areas of influence of human activities in the landscape, we considered the natural attitude of the territory in terms of geomorphology, soils composition, vegetation, climate, accessibility, distance from the river, daily movement capability, technological skills etc. and we considered these data in relation with the map of the archaeological sites and findings. We interrelated all the data according to a polinomial approach where variables represent a set of thematic maps, each of which has a customizable relevance parameter that may change for different cultures (in proto-historic society, the closeness to the countryside is certainly more relevant for cultivation than the proximity to roads, whereas during the roman empire the whole territorial net of routes may have the same weight, etc.).

Starting from the literature on spatial archeology, the paper defines a solid theoretical approach, which is implemented through advanced raster algebra operations in GRASS-GIS, generating the maps which are then imported in the VUE and Unity3D terrain engine for photorealistic landscape generation.

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