ModeLTER : modelling of landscapes and territories over the long term, the members of an European Associated Laboratory (EAL) in CAENTI.

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MODELTER: MODELLING OF LANDSCAPES AND TERRITORIES OVER THE LONG TERM, THE MEMBERS OF AN EUROPEAN ASSOCIATED LABORATORY (EAL) IN CAENTI

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INTRODUCTION

The aim of this new project is the modelisation of landscapes and territories over the long term. This has been a topic that engaged the proposed research team for several years, particularly in the frame of two European projects, Archeomedes I & II, during the 1990s (Van der Leeuw S., Favory F., Fiches J.-L. (eds.) 2003, Favory F., Girardot J.-J., van der Leeuw S. 2004). Both French and Slovenian teams were involved in the project by Professors S. Van der Leeuw and Z. Stančič. Since this period, the collaboration of French and Slovenian researchers increased in activity, and it finds now a new organization in an European Associated Laboratory, linking archaeologists, anthropologists, geodesists and geographers in a small and trained team.

An European Associated Laboratory is an out wall structure, linking researchers from several European countries, during four years. Depending upon the cases, it can be a federative association of overall laboratories, or it can be a small group with a particular competence involved in a specific research. ModeLTER corresponds to the second profile. It starts in 2007. The following lines give a simplified overview of the program.

In ModeLTER, our purpose is to develop concepts and methods regarding the relationships between societies and their environment over the long term, meaning from Iron Age (8 centuries before JC) to nowadays. The team will study the territorial strategies – i.e. how societies did change in their way to occupy their land - and their links with the system of landscape production – i.e. how societies did produce new organization of their environment. ModeLTER will have a dual purpose: to model conceivable explanations of changes, and to understand resilience phenomena in order to provide useful indicators for sustainable development studies.

The ModeLTER's scientific program consists of a fourfold activity:

1) ***Detection*** of features related to past landscapes: this is the basic level required to produce and to process original data, such as archaeological maps, land-use, and terrain models depicting relief (DEM/DTM).
2) ***Contexts*** of the past societies in their natural, social and historical aspects: this is the analytical level, where original data will be overlaid and combined to create indicators of changes, to understand decision strategies regarding settlement pattern and territory.
3) ***Prediction*** of what could have happen, when or where we cannot get information through detection: the purpose is to produce interpolation models and to predict spatial information using indicators defined within the framework of previous steps.
4) "**Tools and databases**", in order to integrate the group within the framework of different cooperation platforms, such as Archaeores, Arkas, ZRCGIS or CAENTI. This work package aims to build, diffuse and transfer tools and databases produced by the LEA.

Several cases of study will be followed-up in different areas, in Europe and overseas (Albania, Croatia, France, Hungary, Italia, Mexico, Romania, and Slovenia).

1. DETECTION

Detection is the basic level required to efficiently produce and process high quality and high resolution original data. The main aim of detection is to reveal past features, to design them in GIS entities, and to provide data for modelling of landscapes over the long term. Remote sensing – airborne and satellite, optical, radar, and lidar – will be used and complemented with advanced data processing.

1.1. Satellite images and aerial photography

With optical image processing we will continue the work already performed by the members of the group in different areas in France, Slovenia, Mexico, and Croatia. Medium (Landsat, SPOT) and high resolution (QuickBird and IKONOS) satellite images will be processed to expose features related to archaeological remains and paleorelief (Oštir et al. 1999, Nuninger and Oštir 2005). Information about "anomalies" manifested through changes in vegetation, for example, can be obtained by computing different indices (vegetation, mineral, etc.) from multispectral data (Kvamme 2005, Rothaus and De Morett 2001, Saturno et al. 2006). The proposed methodology will use multitemporal datasets, to include changes during the growth season, and the seasonal humidity changes (floods, droughts). Spectrally rich data from medium resolution satellites (e.g. Landsat) will be supplemented with information from high resolution satellites (Švab and Oštir 2006). Optical data will be combined with radar images to detect humidity changes, and to produce digital elevation data. According to our experience this will enable the detection and characterization of features of interest with more detail, as presented through fig 1. Satellite images will be complemented with aerial photography, specially archives, to provide the necessary information for photo interpretation of

both recent and past landscape, i.e. historical photo analysis (Kvamme 2005).

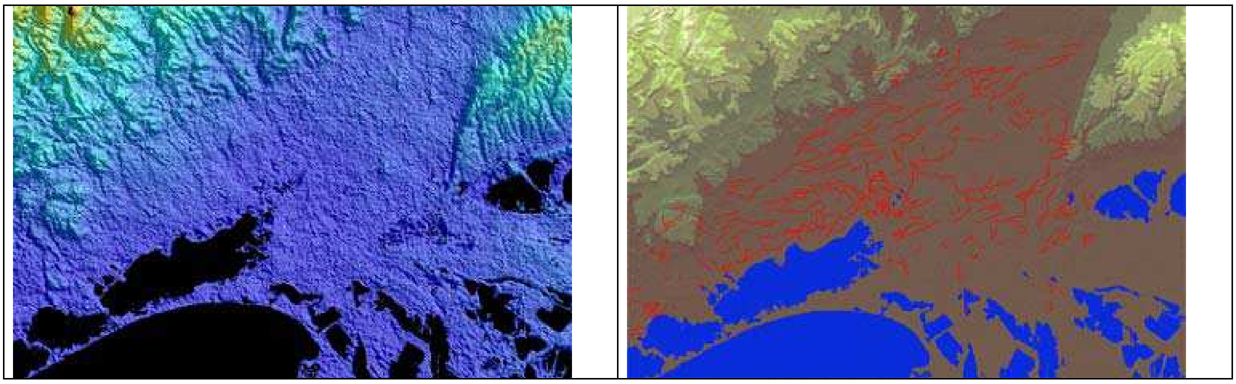

fig.1. DEM derived from radar images (InSAR) on left part, and extraction of suspected paleo features (red lines) on right part. LANGUEDOC area, Southern FRANCE. Source : K. OSTIR & L. NUNINGER.

1.2. Lidar

One of the most important remote sensing data sources for detection will be lidar. Lidar (light detection and ranging) technology is similar to radar, as it measures the time delay between transmission of a pulse and detection of the reflected signal. Due to the spectral characteristics of lasers used (ultraviolet, visible, or near infrared parts of spectra) its signals are reflected both from vegetation and from the ground. This enables the production of very accurate digital elevation models, and vegetation maps (Kvamme 2005, Kobler et al. 2006). The proposed laboratory will develop processing methods for the application of lidar in archaeology and geomorphology. The Slovenian part of the group is already active in the development of lidar point cloud filtering algorithms to produce better DEMs, and obtain vegetation parameters, i.e. canopy profiles etc. (Kobler et al. 2006). Results obtained allow automatic or semiautomatic feature detection even under dense canopy, as shown on fig. 2. River channels, terraces and building footprints have been observed under forest canopies by the members of the group, while other authors report similar or even better accuracy, e.g. detection of ploughing under forest. The studies performed in the future will be focused on detection and mapping of geomorphological features such as palaeochannels, river terraces, and floodplains, in order to identify areas of potential for preservation and erosion. Variations in micro topography are likely to indicate favourable locations for past activities and investigate potential to identify cultural, archaeological, and landscape features.

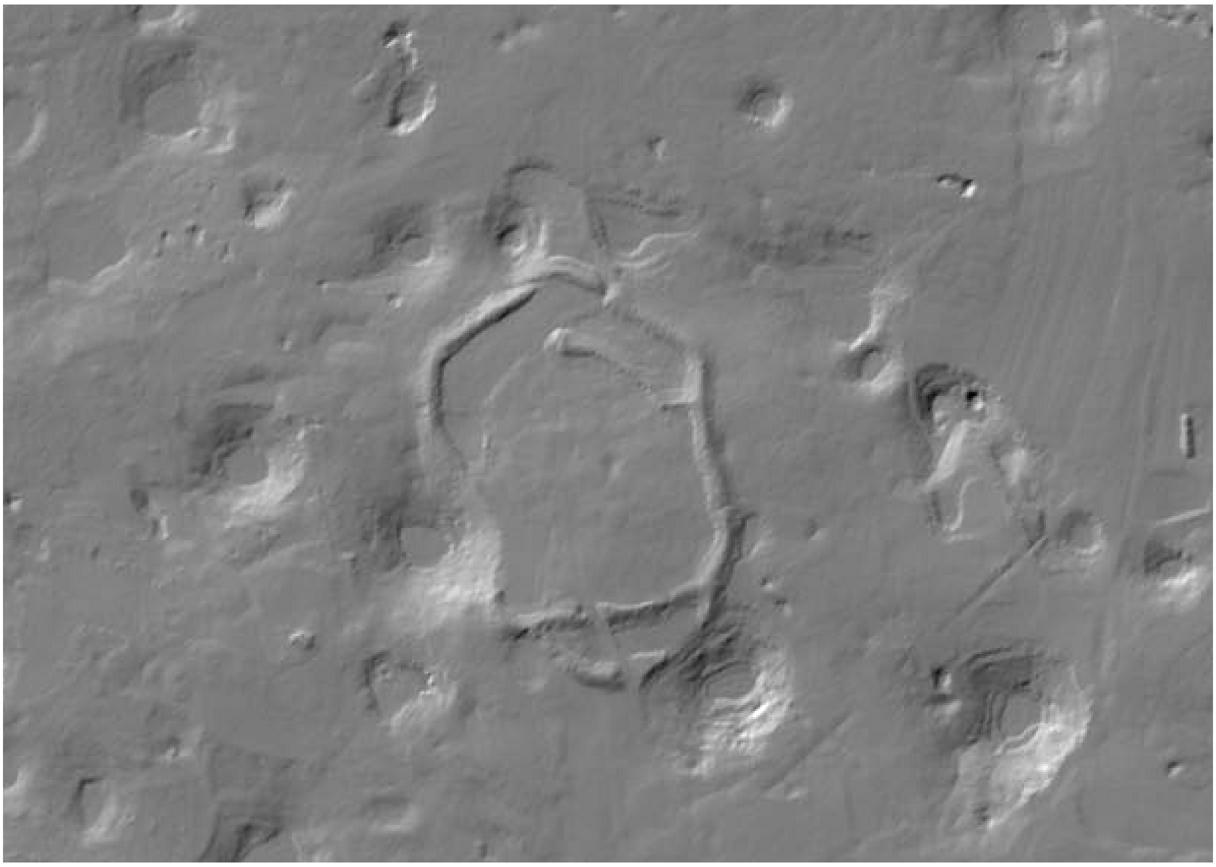

fig. 2. Feature detection using LIDAR under forest canopy : DTM showing dolines and fortification footprints in KRAS area, Wertern SLOVENIA. Source K. OSTIR.

1.3. Terrain modelling

Lidar will be only one of the sources of elevation data (digital elevation model, DEM). Members of the group have developed a methodology that uses best properties of all existing datasets, e.g. different raster DEMs, contour lines, hydrology, land cadastre, geodetic point, etc., and integrates them into an output DEM that is overall better than particular datasets. Weighting sum with geomorphological corrections can be used to obtain a visually and morphologically homogenous model. While lidar can be used in local or micro-local scale, advanced interpolation will be applied in regional or supra-regional scale (Podobnikar 2005). The DEM will be further be processed to compute derivatives, such as slope, aspect, curvature, roughness, texture, and solar illumination (Brossard, Joly 1996, Brossard & al. 2002, Zakšek & al. 2005).

1.4. Data integration

A considerable part of image processing will be devoted to structure detection. In the beginning simple methods like edge enhancement and detection filters will be used, and later the object recognition will be involved (Nuninger and Oštir 2005). Simple filtering enables visual interpretation and detection of paleo-features and remains of human activities. Automatic feature extraction techniques in digital remote sensing usually rely on the varying spectral properties of ground surface materials (i.e. the parts of the electromagnetic spectrum that they absorb and reflect to a varying degree). Lidar imagery provides only variations in elevation (or in reflected laser intensity) as a means of identifying features. Automatic feature identification with such data requires the recognition of patterns in a single variable, for example to locate the edges of discrete features through rapid changes in elevation or to identify areas of contiguous higher or lower elevation. A variety of techniques, like subtraction of interpolated data from surface model, might be employed to achieve this and to extract features of interest (Fowler 2002).

The object oriented approach will be used for several reasons. The first one is the fact that features representing objects, for example fossil channels, building footprints, walls, terraces, drainages, ways, etc., have to bee detected. Additionally, high resolution optical data (imagery with the resolution in the order of 1 m) obtained from aircraft and satellite cannot be efficiently processed with general methods developed for mid and low resolutions. DEMs produced from lidar can also clearly show elevation changes in the range of

decimetre, enabling the detection of objects in the relief, especially if supported by multispectral data and lidar response intensity.
The laboratory will develop methods to integrate different datasets and include them in to common analyses. We will include multi sensor, multi temporal, multi resolution, and multi modal data.

2. CONTEXTS

'Contexts' correspond to the analytical level, where original data will be overlaid and combined to create new indicators. Landscape and territory are the result of many interactions and processes. Their understanding requires, on one hand, systematic observations of land use and practices over times, and on the other hand, it needs an anthropological approach to focus on interactions between territories, and to identify land development strategies. The expected indicators are a matter for social and economical value and choices, according to cultural and geographical context. They have to contribute to a better overview of landscape and territories co-evolution over times.

2.1. Land use and practices of spaces over time

One can study land use in historical view (past times) as well as in present days. Land use characterization is usually based on remote sensing image processing which classifies, with more or less details, every part of space. Thus, land use distinguishes urban areas from forest or cultivated areas for example. Similarly, archaeological remains such as manuring traces (as proposed in fig.3) , field system features, settlements, and burial activities ... allow to produce land use maps for several periods (Bertoncello and Nuninger 2006).

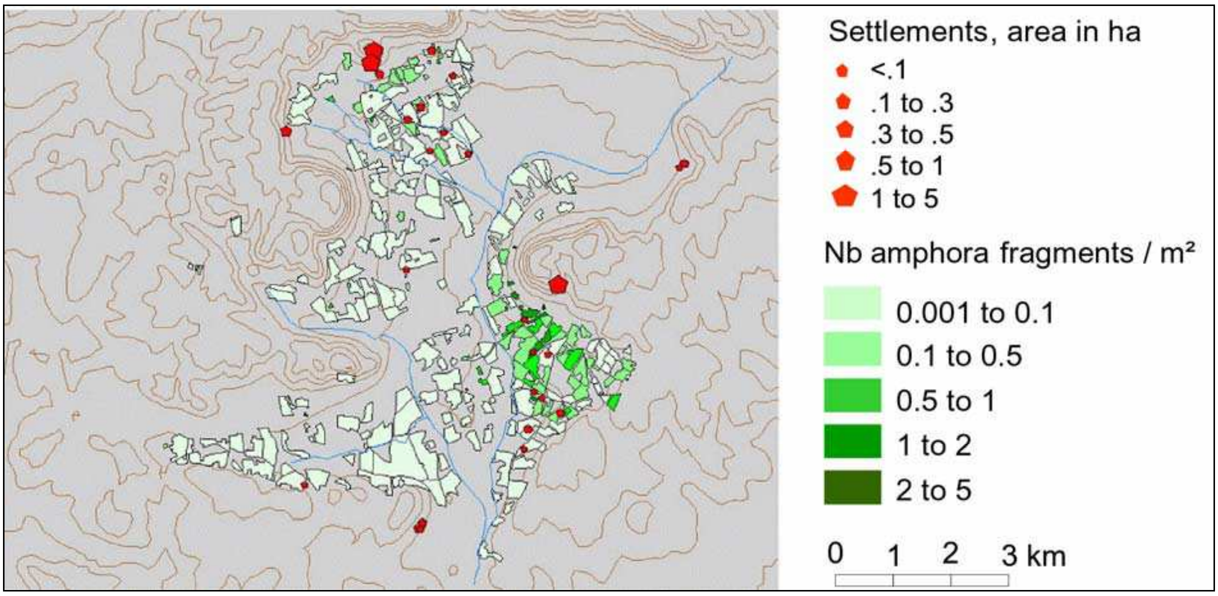

fig.3. Densities of manure scattering in fields, locations and areas of settlements (-200 to –100 BC), VAUNAGE area, Southern FRANCE. Source : L. NUNINGER

Focusing on differences between periods, whatever their duration, ModeLTER will provide quantitative indicators of change in terms of intensity and rhythms. In other words, each part of space studied can be qualified by its progressive or fast development and, similarly, by its decrease (Tourneux 2000). In addition, some qualitative indicators will be produced to characterise the types of change so as to evaluate its impact on landscape and on territorial structure or position.

The second approach will focus on the environment of settlements, using descriptors of composition and configuration in the style of landscape ecology, including scalar aspects. Rather than land cover, the input will mainly be relief, described in terms of homogeneity, variety, diversity, fragmentation and so on. These variables are well described in literature, but still encounter the problem of the size of the environment to be taken in account, which is directly linked to scale-effects. Following the work developed in our team (e.g. for bird inhabitation or epidemiological modelling), we will process local variability minimisation through radial analysis to identify variables and scale levels where inhabited localisations show a maximized difference with other places (Wharton 1982). The first output should be knowledge of space scale determinants, the second expected result should show a follow up of environment preferences in time. This will be used in the third work package to provide some basis for prediction models.

Within the first two approaches, ModeLTER's team will be able to provide an accurate description of changes regarding land use and settlement pattern

for several areas and periods within a long term framework. Even if one can observe changes and infer some strategy, the question remains: why people made particular choices? Actually, what was the issue and what kind of reply have they developed according their own context? To be active and to clarify decision making, GIS tools offer an opportunity to include "cognitive" criteria in modelling, as visibility or pathway algorithms for example (Zakšek et al. submitted). Nevertheless, these tools are usually formatted for present economic applications, and the cognitive criteria are particularly unlooked-for. We intend to improve these two points, on one hand processing algorithms, and on the other hand integrating well-known cognitive criteria from anthropological studies. This work favours a better understanding of human perception and action, especially for past societies, regarding territory and landscape production. The main goal is to define assumptions and models of strategies which can be used for prediction.

2.2. Territorial strategies

Beyond the relationships between human and natural components of space, the team will focus on anthropogenic environment to characterize models of territorial and land development in times.

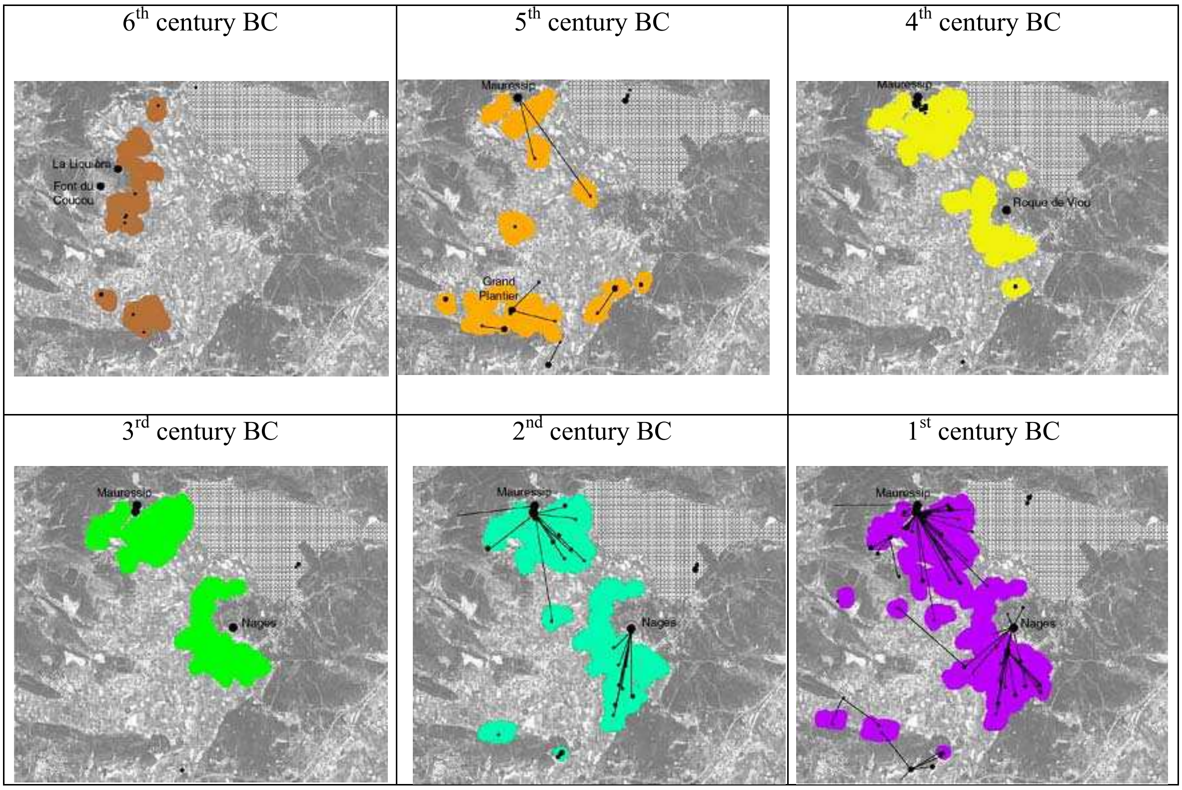

fig 4. Linking settlements in networks, giving « infields » to each network following different criteria, and preparing for analysis of time series. VAUNAGE area, Southern FRANCE. Source : L. NUNINGER

First, it is important to understand different kinds of settlement patterns and type of territories defined over times. Relationships between settlements will be considered in terms of distances, accessibility or visibility from one settlement to each others. These inter-sites variables are mainly derived from settlement localization and DEM analysis (produced in first step). A well-experienced approach based on classical gravity models takes in account these inter-sites variables to build hierarchical networks of settlement, as shown on fig. 4 (Durand-Dastes et al. 1998; Nuninger 2004; Nuninger and Sanders coord., 2006). This model does not take into account of temporal aspects, however. The temporal dimension of relationships will be approached thought the heritage process from period to period. Whole information featuring connectivity relations could be summarized in contiguity matrices encapsulating time and space links. Then, each settlement, described by this matrix, can be considered as a statistical record, belonging to a single general matrix featuring all the connections in space and time. This general matrix can be analysed using multivariate analysis algorithms to produce synthetic typology of site connections, in space on one hand, and in time on the other hand. The basic idea is to bring to the fore settlement networks as a kind of skeleton of territories.

The second level of analysis aims to study landscape production, which could be defined as

the "skin" of territories. The French part of the group studied techniques and processes of land development from prehistory to nowadays. These studies are based on field system objects, shape of parcels or parcel boundaries for example. At this level, the aim is to understand processes of land development around the network of inhabitation, i.e. to understand how communities built their environment to define their own space (Klopatek and Gardner 1999). The landscape will be systematically described according to a grid of analysis based on experiences and competences of the geographical team, and then processed for multivariate analysis (Tourneux 2000, Tolle 2005). The challenge will be to adapt the grid to historical and archaeological criteria as we did it for settlement pattern, to get a large overview of landscape production over times based on the same methodology.

At last, with approaches and facts observed within the first work package, we should be able to point out anomalies, like unusually fast changes or extraordinary behaviours (Nuninger 2004). Regarding our historical, ethnographical or geographical background, focusing on anomalies should give a better understanding of trajectory followed by the communities of each study area. At this step, it is important to point out that the interpretation or explanation of phenomena will be based on references elaborated at each level according to the same methodology for each area. The definition of anomalies, and their explanation, will be helpful to introduce uncertainty in the prediction processes.

3. PREDICTION

Using references from environmental features and from human behaviour produced in the work packages 1 and 2, the team will be able to develop prediction modelling (Van Leusen and Kamermans (eds.) 2005, Kamermans 2006, Stančič & al. 2000, Stančič and Veljanovski 2000).

Two main approaches will be followed: first, an explicative method at local level, predicting settlements positions using relief characteristics, scale effects, and territorial strategies; and second, a geostatistical method at regional level, taking in account the spatial structures of settlement densities and co-explicative variables.

3.1. Prediction with explicative methods

The purpose of explicative methods is to draw a theoretical map of settlement dispersion over poorly known areas, using the data and knowledge acquired in the previous steps. As far as environmental preferences have been highlighted, including their scale components and interactions between settlements, it can be possible to build explanatory statistical models, giving for each period the probability to find a settlement in each place. Typically, binary logistic regression with Logit model can be used in this way, helped with algorithms for evaluations of model performance (Stančič and Kvamme 1999, Tomlin 1990). One major interest of this kind of prediction is to give for each place a value between 0 and 1 (where 0 means no settlement, and 1 means settlement), and to maintain local scale, while other methods need continuous variables, implying scale reduction.

Binary logistic regression has already been employed in archaeological prediction modelling (Verhagen et al. 2005). Here, the innovating aspect of the research is demonstrated in several ways. First is the use of high quality archaeological and environmental data, transformed in occupation variables including territorial strategies. Next is the large time depth series covering different land use practices, and last is the evaluation of model performance through statistics indicators and field comparisons. In this way, such a model is at the same time inductive (facts based) and deductive (strategies oriented), and maintained between safety guides.

3.2. Prediction with geostatistical methods

Rather than estimating local probabilities, this approach produces predictive maps of settlement densities at regional scales. Taking in account, for a given period, the localizations of known settlements and the areas of archaeological survey, a cellular model can be derived, representing the densities of settlement trough a regular grid. This means that the information goes from Boolean level to true quantitative level, offering the opportunity to process various interpolation models. Among them, geostatistical methods such as co-kriging allow to base the prediction both on the spatial structure of the observed phenomenon (settlement density dispersion), and on explicative phenomenon (environmental and anthropogenic context, heritage). The expected output is a temporal stack of predictive spatial models at regional scale, which could become a new basis for temporal observation of land occupation dynamics, summarizing stability times, crisis and reorganizations.

4. TOOLS AND DATABASES

At present, individual existing groups use various data processing and analysis tools, both commercial and developed by themselves. The fourth activity in LEA ModelTER focuses on three axes : optimisation in the use of tools, increasing of their availability, and preventing their duplication (even

multiplication). This will decrease costs, and organize the entire group with common software and hardware.

The individual groups in the laboratory already manage a significant number of archaeological databases and other spatial data layers. It is anticipated that in the next years these will be updated and supplemented with new ones. Common technical team will therefore work intensively on database management, maintenance and storage, involving intensive application of internet database technologies. The GIS systems will be used both locally within the group, and through networks for the scientific community, plus, with some limitations, to the general public. A Web mapping system – based on existing knowledge and expertise – will be developed with tools available for basic and advanced analyses, processed in the laboratories or in the field (for mobile devices, equipped with GPS receivers).

Up-to-date technical equipment will be deployed to enable the collaboration between the members of the out walls laboratory. An Access Grid node will be established with a set of resources, including multimedia large-format displays, presentation and interactive environments to support group-to-group interactions. Additionally, a multi user document repository (knowledgebase) system for publishing files/documents onto the web will be used. All the tools and documents developed or produced in the laboratory will be published and made available for interested users.

Both scientific results and tools will be promoted on the ModeLTER's website, that will be built within the Archaeores platform to provide a scalable and a self updating framework for coordinators and researchers. This site will be partly in open access, partly reserved to the research group, and linked to the e-collaboration tools mentioned above.

CONCLUSION

The proposed ModeLTER teams have proven with recent projects that the laboratory is able to achieve the envisioned goals. At the European level, apart from individual programs of research, a unit associating, so tightly, archaeological, geographical and geodetic skills, working on territorial and landscape issues where human strategies are at the heart of research, does not exist yet. We believe that ModeLTER can become an incubator of ideas and methods.

ModelTER projects are at the core of methods for the understanding of territories. They link acquisition, structure, analysis and dissemination of spatial and temporal information, at various scales, regarding natural and anthropogenic phenomena and processes. The team is designed through several partnerships, established between different laboratories in France and Slovenia. This places ModelTER in the canvas of territorial intelligence.

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