Post-doctoral project

AMPLitUDe (Ab Model PastoraL UplanD)

A multi-agent based model to understand long term dynamics of pastoral upland

This study, integrated into the framework of pastoral archaeological research in the Pyrenees, focuses on pastoral high altitude areas within a long-term framework. It depends on an ethnoarchaeological approach and aims to better understand the practices in these areas by developing a corpus of high altitude pastoral sites and constructing a system of reference regarding distances travelled by herds. The aim is to look at pastoral territories, their reconstruction and, above all, to identify their present and long-term past material correlates. Huts and pens determining herd deployment are considered in relation to other sources i.e. paleoenvironmental and planimetric. Finally pastoral areas are compared to written sources preserved by valley communities since the Middle Ages.

My thesis allowed me to compile a large body of data (archaeological and ethnological) and construct a Conceptual Data Model - based on the "human-resources-herd triad". Use of a Geographic Information System resulted in a quite static approach to pastoral land use and its transformations. To overcome this, in this project I would like to develop simulation models to study the dynamic interactions between resources and pastoral societies over the long term. This is not an attempt to reconstruct the evolution of real phenomena, but to explore, through geospatial modelling, different hypotheses and advance our understanding of processes of transformation in the past.

Key-words: Landscape archaeology, mountain, geospatial analysis, hut, anthropology, environment, Pyrenees, *longue durée*, long-term, Middle Ages, simulation, agent-based model (ABM).

Research Project

1.1 Presentation of the state of research

This anthropological project is at the interface of two major fields - the archeology of pastoralism and geospatial modeling.

Although pastoralism has long been studied by archeologists (CHANG, KOSTER 1986), High Mountain areas and their pastoral exploitation have only begun to be studied recently (BARKER & GRANT 1991, RENDU 2003b). High altitude areas have long been perceived as unchanging but interdisciplinary approaches have shown they have a history. Both their landscapes and forms of exploitation have changed over time, so that we can trace pastoral transformation systems on a time scale starting 6000 years ago.

Studies conducted in Cerdagne (Eastern Pyrenees) by Christine Rendu have resulted in the locating of hundreds of pastoral structures (shepherds' huts and enclosures) over an area of 3000ha (RENDU 2003a). The excavation of 20 of these sites provides us with chronological indicators leading to the establishment of a chrono-typology. Based on hut and enclosure morphology and equipment this functional typology tells us about the different types of stockbreeding and pastoralism. Combining archeological data, the written ethnological data and information from paleoenvironmental disciplines illustrates transformations in the pastoral systems over a long period of time. This has resulted in the documentation of change from an extensive to an intensive system, and from a dairy farm to a meat or wool centered one.

Furthermore, over recent years, the development of multi-agent systems has offered new possibilities for modelling the flock's behaviour in the extension of my work described below. The multi-agent modelling allows conceptualization and simulation of an organised set of agents interacting with each other and their environment. In the Human and Social Sciences it allows formalization of complex situations involving multiple scales (spatial, temporal and organisational) and heterogeneous agents engaged in social activities (AMBLARD & PHAN 2006:19).

In recent years, simulation tools have been widely used in geography to model spatial dynamics. These tools come from the artificial intelligence research. They allow the simulation of spatial structure genesis, placing themselves at a micro level (individual or agent level) interactions amongst which create spatial organisations. The spatial structuring is therefore not introduced *a priori* in this model but, on the contrary, it is its processes of its appearance that are studied here. In a Multi Agent Systems, agents are individuals (people, animals...) mobile and autonomous, with knowledge, skills and personal objectives; they are able to interact and communicate in a given environment. It is interactions of the agents that introduce the dynamic in the model, the spatial structure evolving after each move or state change of the agents. These agents' moves or changes are conditioned by some interaction rules or transition rules, both *a priori* defined by the operator. Various experiences can be realised by adopting different rules in order to evaluate their impact on the spatial organisation of the studied phenomenon. From these simulations, it is also possible to calculate the probability of obtaining a particular structure according to the rules introduced.

The ability of multi-agent systems to model the agro-pastoral territories in their complexity has already been demonstrated (BONNEFOY, BOUSQUET & ROUCHIER 2001, ROUCHIER *et al.* 2001). These examples show that these tools are not only likely to spatialise and distribute individuals' behavior but they are especially authorize the integration of differentiated perception of space by individuals and coercion by a community. A dialectic is set between individuals, spaces and society, contributing to a territorial simulation and using

appropriate spatial techniques and clearly defined social representations to test geographical theories and hypothesis.

Little known in the French archeological community, simulation tools are tools that have already been tested by several research groups in the United States, especially in prehistory (e.g. KOHLER 1992, KOHLER & GUMERMAN 2000, KOHLER & GUMERMAN, 2005 REYNOLDS, KOHLER & VAN DER LEEUW 2007). In archeology these tools are provide real potential for urban and population dynamics for example, not to try to rebuild the evolution of a real phenomenon, but also to explore various hypotheses and advances in our understanding of the transformation process of this phenomenon. By introducing a real dynamic, this type of modelling brings thoughtful elements about the temporalities working in the transformation of a system. These are powerful exploratory analytical tools, at least taking into consideration the amount of data they can use in an interactive way. This is why it seems important to use them to consider new ways to treat and analyze our archeological data. The use of these tools and the implied methods, as well as their transferring conditions from geography to archeology, require a good understanding of their functioning and concepts.

1.2 Presentation of my research

During spatial analysis of pastoral sites from "la Montagne d'Enveig" (Pyrenees, France), I studied the distribution of huts as a function of environmental parameters using a Geographical Information System (LE COUEDIC 2004). When tackling the question of territory (area of influence) for each hut, the question of the flocks' paths appeared to be central. This interdisciplinary approach focused on one difficulty understanding the pastoral activity surrounding the excavated sites. What use and share of the space can cause various forms of flock management. Pyrenean pastures represent, most of the time, a collective resource exploited by high valley communities. On a larger scale, the territorial division of these pastures is not marked on the landscape; they are essentially defined by the practice during the livestock's pasture-ground from pastoral huts.

In order consider these activities and divisions at different times, my study relied on an ethnoarcheological approach leading to a better understanding of these spatial practices through two axes: development of a body of data on unpublished pastoral sites and the construction of a modern referential concerning the flocks' paths of movement. The aim was to consider pastoral territories, their reconstruction and especially to identify material correlates allowing approaches both present day and over the long term. It gathered the necessary knowledge to build spatial models the goal of which in time, will be the modelling and simulation of possible paths based on ancient pastoral sites. The starting hypothesis was the following: that flocks paths change according to the pastoral systems. We can then consider the

extent to which these flocks' paths define the location of shepherds' huts or the sharing of pastoral space/territory.

My thesis involved studying ethnoarcheological pastoral practices and space throughout the flocks' paths (LE COUEDIC 2005, LE COUEDIC 2010). The approach adopted yielded significant results and opened up new possibilities. Based on three fundamental components, the pastoral society, the flocks and the environment resources, I approached the pastoral system by primarily considering the material evidence. The construction of an archaeological framework about enclosure and living sites in the Anéou pastures (Ossau Valley, Pyrenees, France) allowed the creation of a functional chrono-typology of pastoral establishments associated with three main periods: Bronze Age, late Antiquity and modern era (CALASTRENC, LE COUEDIC, RENDU 2006, RENDU *et al*. 2006). In order to approach the space overlooked by the huts, I have created a modern flock-path model the goal of which was to include social, technical and environmental determinants. Two corpuses have been created. The first comprised the cartography of the Parc National des Pyrénées. Approaching the relationships between these paths and their material correlates requires us to take into account the day-to-day territories. Following this, accuracy of the Parc cartography was improved as a result of two months investigation in both the Asp and Ossau Valleys. Analyses of the results of these investigations allow us to understand the division of pastoral spaces as occupied, daily, by the shepherds, and to underline several material correlates of these paths which are useful in helping to understand the archaeological structures.

The comparison between archaeological and ethnological data with the modern and medieval writings and also palynological data has helped refine results and focus by linking the huts' distribution and the paths' territorial structuring in the valleys, for while pastoral activity is well attested by written sources which indicate that the farmhouses are assigned to villages in undivided and summering places issued at random and is supported by palynology, which reveals a growing human pressure between the 9th and 15th s, the pastoral structures of the central Middle Ages and final products are rare in the archaeological corpus. This lack of visibility could be explained by a lower investment shepherds in inappropriate places regularly redistributed.

1.3 Research project

To extend and deepen these researches, I plan to implement multi-agent simulation techniques, in order to approach the interactions between resources and society dynamic. If several models and such systems are already existing for actual agro-pastoral systems (*e.g.* BAH *et al.* 2006, BONNEFOY *et al.* 2000, BONNEFOY, BOUSQUET, ROUCHIER 2001, HILL 2006), we must now consider their application on the long term. The main goal is to apply models of

pastoral territories into archaeological data; not to attempt a reconstruction of the phenomenon real evolution, but to test various hypothesis.

I should like to be able to realize this project at the Centre for Research in the Arts, Social Sciences and Humanities (CRASSH), at the University of Cambridge, where there is an increasingly important digital humanities initiative, and thereby beneficiate from the expertise of Cambridge based researchers working on ancient societies, behavioural simulations, geospatial modelling and general digital arts, humanities and social science issues. Relevant departments within the University where high-level researchers are based include the faculty of Classics and Faculty of Archaeology and Anthropology (Department of Archaeology). CRASSH is the inter-disciplinary focus of research in these and other fields within the university. Seminars and special interest graduate and post-doctoral groups provide am interdisciplinary focus for discussions between members of different departments and my research would certainly benefit from this context. My research should be of interest to the digital humanities group and the Late Antiquity Network histed by CRASSH.

Furthermore, the Swedish Collegium for Advanced Study in Uppsala or the Institute of Advanced Studies in Bologna offer a good opportunity to develop this project and to engage fruitful exchanges with researchers at the Archaeological Institute, where the pastoral activities and landscape archaeology in other areas are experienced with and extended use of GIS.

Articulated over 10 month period, the way this study will take place can be organized in five steps. The first step would consist of an investigation of the writings made at the host institution, concerning studies in archaeological simulation. The second would be the creation of a model, using the standard modeling formalism UML (Unified Modeling Language). The third step will be the implementation of the model. The fourth will be the opportunity to get training about programming technique, such as the Java language, to translate from the formal model to the program. The model will then allow the exploration and the testing of various scenarios, changing according to social and environmental parameters (criteria given to the agents and the environment). This will be the fourth step. The last stage is the presentation of results through publications and conference presentation.

These simulation tools, because they allow the introduction of a real dynamic, seem to be particularly relevant to stimulating the genesis of spatial structure and their evolution. They could allow some progress in the understanding of the pastoral system transformation process and their translation in terms of use of space. Moreover, completion of the project will contribute to metropolitan archaeological development, by providing an experiment in multi-agent systems.

This postdoctoral research project called "**A multi-agent based model to understand long term dynamics of pastoral upland**" should help to establish a protocol for advancing our understanding of the exploitation of high altitude areas, especially mountain pastoral systems. This topic opens up a brand new field of research, gravitating around the relationship between the spatial practices of pastoralism and long term pastoral territories dynamics. Between spatial modelling and pastoral archaeology, this project is located at the intersection of various disciplines, anthropology and archaeology mainly, but also history, ethology, ecology, pastoralism, geography, processing, artificial intelligence, simulation and cognition. It is therefore a truly interdisciplinary study within the arts, humanities and social sciences.

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Bibliography

AMBLARD, PHAN 2006
Amblard F., Phan D. (dir.) - *Modélisation et simulation multi-agents : applications pour les sciences de l'homme et de la société*, Paris, Hermès, 446 p.

BAH *et al.* 2006
Bah A., Touré I., Page C. L., Ickowicz A., Diop A. T. - An agent-based model to understand the multiple uses of land and resources around drillings in Sahel, *Mathematical and Computer Modelling*, 44: 513-534.

BARKER, GRANT 1991
Barker G., Grant A. - Ancient and modern pastoralism in Central Italy: an interdisciplinary study in the Cicolano mountains, *Papers of the British School at Rome*, 59: 15-88.

BONNEFOY et al. 2000
Bonnefoy J.-L., Page C. L., Rouchier J., Bousquet F. - Modelling spatial practices and social representations of space using multi-agent systems, in: G. Ballot et G. Weisbuch (dir.), *Applications of Simulation to Social Sciences*, Paris, Hermes: 155-168.

CALASTRENC, LE COUÉDIC, RENDU 2006
Calastrenc C., Le Couédic M., Rendu C. - Archéologie pastorale en vallée d'Ossau. Problématiques, Méthodes et premiers résultats, *Archéologie des Pyrénées Occidentales et des Landes*, 25: 12-30.

CHANG, KOSTER 1986
Chang C., Koster H. A. - Beyond bones: toward an archaeology of pastoralism*, Advances in archaeological method and theory*, 9: 97-148.

HILL et al. 2000
Hill D., et al. - Modélisation de l'entretien du paysage par des herbivores en moyenne montagne : une approche multi-agents, *Ingénieries - E A T*, 21: 63-75.

KOHLER 1992
Kohler T. A. - Field houses, Villages, and the Tragedy of the Commons in the Early Northern Anasazi Southwest, *American Antiquity,* 57 617-635.

KOHLER, GUMERMAN 2000
Kohler T. A. et Gumerman G. J. (dir.) - *Dynamics in Human and Primate Societies: Agent-based Modeling of Social and Spatial Processes*, New York Oxford University Press.

KOHLER, GUMERMAN, REYNOLDS 2005

Kohler T. A., Gumerman G. J. et Reynolds R. G. - Simulating ancient societies. Computer modeling is helping unravel the archaeological mysteries of the American Southwest, *Scientific American*, july: 73-84.

KOHLER, VAN DER LEEUW 2007
Kohler T. A., Van der Leeuw S. E. (dir.) - *The Model-Based Archaeology of Socionatural Systems*, 304 p.

LE COUÉDIC 2004
Le Couédic M. - *La montagne d'Enveitg (66) : mise en œuvre des données archéologiques, environnementales et planimétriques à l'aide d'un SIG*, mémoire de maîtrise, Histoire, Université François Rabelais, Tours, 97 p.

LE COUÉDIC 2005
Le Couédic M. - *Conceptions et pratiques pastorales: modélisation de parcours actuels de troupeaux dans une perspective ethnoarchéologique. Étude de cas pyrénéens*, mémoire de master 2 recherche, Histoire, Université François Rabelais, Tours, 95 p.

LE COUÉDIC 2010
Le Couédic M. - *Les pratiques pastorales d'altitude dans une perspective ethnoarchéologique. Cabanes, troupeaux et territoires pastoraux pyrénéens dans la longue durée*, thèse de l'université de Tours, 803 p, [en ligne], http://tel.archives-ouvertes.fr/tel-00543218_v2/

RENDU 2003a
Rendu C. - *La Montagne d'Enveig, une estive pyrénéenne dans la longue durée*, Canet, Trabucaire, 606 p.

RENDU 2003b
Rendu C. - Dossier spécial. La montagne. Habitats et systèmes pastoraux d'altitude (Pyrénées, Massif-Central, Alpes). L'occupation de la montagne, premiers acquis et perspectives. Avant propos,
Archéologie du Midi Médiéval, 21: 142-145.

RENDU et al. Sous presse
Christine Rendu, Didier Galop, Carine Calastrenc, Mélanie Le Couédic, Damien Rius, Marie-Claude Bal - Montagnes et campagnes d'Oloron dans la longue durée. Premiers résultats d'un programme interdisciplinaire, *Aquitania*.