THE TIME-SPACE DYNAMICS OF AGRICULTURAL AREAS FROM ANTIQUITY TO MODERN TIMES

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Abstract:

This paper presents the analytical procedure developed within the Workgroup 1 of the *Archaedyn* project. It aims at studying the time-space dynamics of agrarian activities readable by the ancient field systems preserved by the forest cover, and off-site material interpreted as remains of manuring practices. Using GIS and spatial statistic tools, we studied the structuring, intensity, durability and mobility of agrarian activities at different time scales.

Key words: field systems, agrarian manurings, catchment's areas, time-space dynamics, "longue durée".

Introduction:

Workgroup 1 of the *Archaedyn* project, which focuses on "Catchment areas, terroirs and community land", aims to develop the study of time-space dynamics of agrarian activities over the long term by using two particular kinds of data: ancient field systems preserved by the forest cover and off-site material interpreted as remains of manuring practices. These two kinds of data involved a multi-scalar analysis: concerning the ancient field system, we studied the structuring and intensity of agrarian activities within a single time period (Roman period); concerning the off-site material spread in the fields since Protohistory to the present, we attempt to analyse agrarian activity dynamics over a long duration.

1. Ancient field systems

The first series of analyses carried out in the framework of Workgroup 1 deals with Gallo-Roman field systems preserved by the forest cover, which have been the object of new research for the past fifteen years in Burgundy and Lorraine. These vestiges result particularly from the stone clearing of fields and pastures, and are then considered to be evidence of agricultural exploitation. Conserved in the form of micro-reliefs, they were covered by the forest after their abandonment, which enabled preservation. Hence they are distinguished from field system patterns identified by map and/or photo-interpretation or remote sensing which are not retained here. In spite of its very imprecise chronology, this type of vestige is proof of the extension of cultivated terroirs during the Gallo-Roman period which were then definitively abandoned at an undetermined moment, at the latest during the Middle Ages, but most likely at the end of the Gallo-Roman period or at the beginning of the Early Middle Ages. The vestiges therefore show evidence of occupation dynamics. Our aim is to attempt to characterize these areas by analysing: 1) the intensity of their occupation (these field systems were the result of the regular stone clearing of cultivated parcels); and 2) the structuring of the area based on the outlines of the field system and their level of organization. The results provide elements for understanding what determines the organization of field systems preserved by the forest cover.

1.1. The study areas and the data

Eight sectors were used for this research. They are located in two regions in Northeastern France, the Lorraine and Burgundy, and cover a surface of about 10 000 ha.

The 5 sectors in Lorraine are established on the limestone plateau of the banks of the Moselle in the region of Nancy. They have been the object of research since 1998 by a pluridisciplinary team composed of archaeologists of the Regional Service of Archaeology of Lorraine (Ministry of the Arts, M. Georges-Leroy) and the National Institute of Preventive Archaeological Research (J.-D. Laffite), of researchers from the National Institute of Agronomic Research of Nancy (E. Dambrine and J.-L. Dupouey) and employees from the Forest Commission (LAFITTE *et al.* 2002; GEORGES-LEROY *et al.* 2003; GEORGES-LEROY *et al.* 2007). The Haye forest is the largest sector with more than 7700 ha (Fig. 1). The others are found in the forests of Thuilley-aux-Groseilles (40 ha), Allain (330 ha), Selaincourt (80 ha) and Saint-Amond (425 ha).

Three sectors in Burgundy, in the Yonne north of Avallon, are used: the forests of Arcis-sur-Cure (75 ha), Champlive (1000 ha), and Girolles (280 ha) (KASPRZYK, NOUVEL 2002; NOUVEL 2006; NOUVEL 2007).

The vestiges are seen either as circular piles of stones, as long stone banks (“murées”) or as terraces which sometimes extend over several hundreds of metres in length and are conserved with heights varying from a few dozen centimetres to 1.50 m. They delimit parcels of more or less regular shapes or enclosures, but they also indicate the layout of routes. Small sized settlements are generally also associated with them.

A large part of the field systems preserved by the forest cover which has been studied belongs to the Gallo-Roman period. The field systems alone are difficult to date and they are quite comparable to the same types of field systems of the modern, even contemporary era which exist nearby but outside of the forests. However, certain sections have been dated by archaeological artefacts (ceramics or Roman tiles) discovered during drillings or surface gatherings, but these are mainly indirect elements which make it possible to establish a relative chronology. Thus, many of these lineaments have a direct link with the Gallo-Roman settlements. Moreover, the forest in which they are preserved are ancient forests, which is confirmed by maps of the modern era and particularly by medieval texts, supposing that the field systems are earlier.

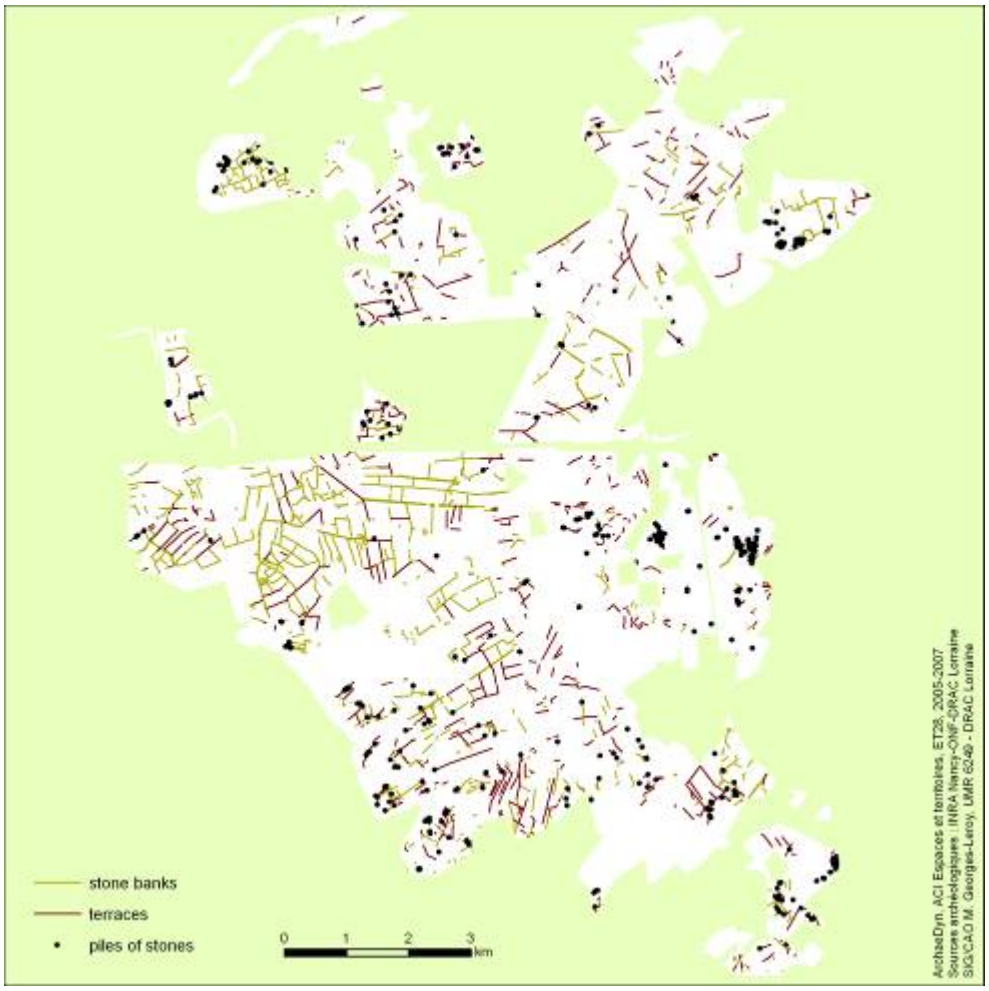


Fig. 1: Forest massif of Haye: Ancient Gallo-Roman field systems preserved by the forest cover

1.2. Characterization of the field systems

1.2.1. Analytical procedure

The analytical method consisted in developing a certain number of descriptors with which these field systems can be characterized and compared to the surrounding area. This method has seen a slow gestation and it is not totally successfully completed in the framework of the ACI because of the technical development of the descriptors, as well as the state of progress of research which differs from one study area to another. Finally, the recent Lidar survey done on the largest study area (forest massif of Haye) modified our knowledge of the area but it could not be taken into account in the framework of the ACI. In expectation of these new data, all of the tests, then, have not yet been terminated.

However, the global foundations are in place, even if they require refining. Firstly, the necessity to transform the basic information constituted of polylines (“murées”, terraces, routes) or of points (settlements) in slots or surfaces quickly became apparent, requiring a reformalization of the information by meshing in particular. Hence the need to succeed in defining the quantitative and qualitative indices which characterize the exploited areas (Fig. 2). The indices of intensity of the field system boundaries and the indices of structuring were developed in this first stage. The second stage consisted of crossing these indices with spatial analysis, thereby making it possible to determine homogeneous areas. They are then compared to the surrounding area (environmental and human data) in order to understand how these field systems were established. A certain number of descriptors of the surrounding area must also be developed in order to do this (fig.2).

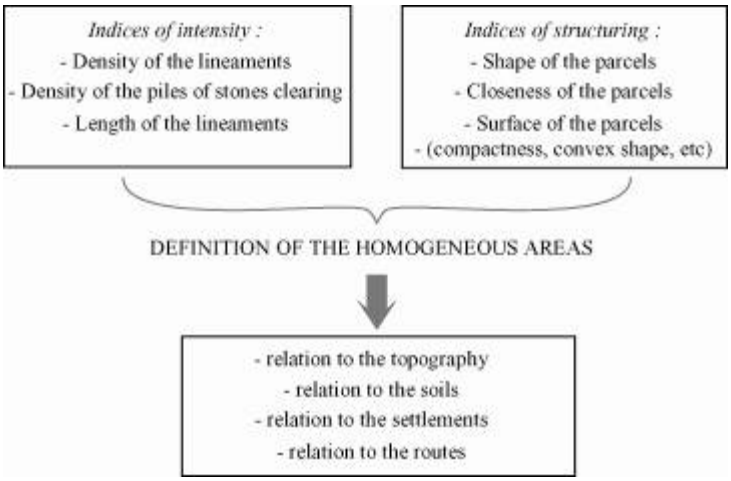


Fig. 2: Procedure for analysing ancient field systems

The validation of the indices of intensity and of structuring was carried out on all of the study areas of Lorraine. However, the combination of these indices and their comparison with the context have only been tested on the forest massif of Haye. Moreover, the indices of the environment have not yet all been finalized. The first tests show, however, that the method is promising and its first results are given here.

1.2.2. Developing indices of intensity and structuring

1.2.2.1. Indices of intensity

Three indices of intensity were retained, which were synthesized in the form of a 250 m mesh. This is the optimal resolution which makes it possible to compare all of the study areas, the surfaces of which are very variable. The first two are descriptors of density: the density of lineaments ("murées" and terraces), in other words, the total length of the "murées" and the terraces contained in a mesh, and the density of the piles of stone clearing for two areas only, in other words, the number of piles of stone clearing contained in the same mesh (Fig. 3). "Murées" and terraces were combined because they are part of the same dynamics and are sometimes confused in certain recordings (particularly when a "murée" surmounts a terrace). In order to complete the information, the third index, that of the length of the lineaments, can refine this information, for example, by making it possible to distinguish stone clearings which result from the exploitation of the field from those which have their origin in the deliberate delimitations of the field systems, or even to deal with the areas of demolished field systems. This third index was calculated by a mesh, by adding up the gross sums of the lengths of the lineaments contained in a mesh, divided by the number of lineaments. However, this must be used with caution because of the differential recording of the data: effectively, the mean length depends on the way in which the different sections were mapped in the field beforehand. Thus, for example, an important difference exists in the way in which the Allain field system was shown (each time that the "murée" was intersected by a modern disruption, the "murée" was cut into sections) and that of Haye (more schematic layout which does not take into account the slightest subsequent disruptions). This index could then only be used on all of the areas when all of the data will be homogenized.

The results allow a first quantitative approach to the phenomenon which must be validated by verifying that this intensity is not linked uniquely to the state of the field surveys. In order to do this, the map of the indices of density were compared to the map of the reliability of the information, which shows that the empty areas do not systematically correspond to the areas classed in level 2 (sector which was the object of a partial coverage).

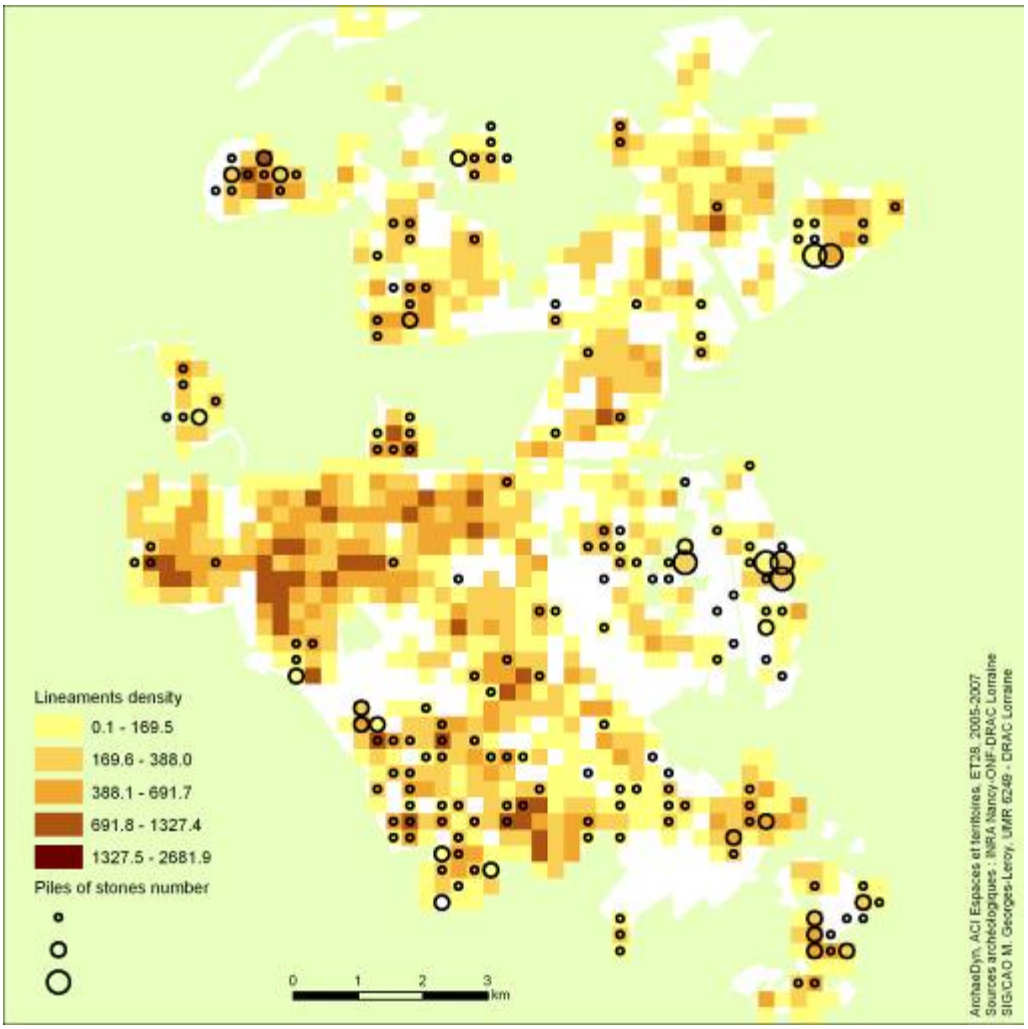


Fig. 3: Forest massif of Haye: Indices of intensity

1.2.2.2. Indices of structuring

A manual and non automatic approach prevailed earlier for the secondary category of indices which concerns structuring. Hence a layer of polygons was created by visual analysis based on the organization of the lineaments: as soon as a "space" (or a parcel) can be individualized and delimited on at least three sides, a polygon is drawn and is given characteristics. The simple visualization of this layer of polygons has already made it possible to distinguish the structured areas from the less or non structured areas.

Three indices are thus developed from this layer: the shape, the degree of closeness and the surface. The following criteria were attributed to these indices:

- shape of the parcels: square or polygonal (more than 4 sides);
- degree of closeness of the parcels: closed on 4 or on 3 sides;
- surface of the parcels: this information focuses on the boundaries which could be delimited during the visual analysis. Thus in the case of parcels identified by only 3 sides, it is possible that this surface does not represent the total surface of the original parcel.

The first combination of the indices of shapes and closeness makes it possible to differentiate homogeneous blocks, such as the existence of structured blocks which are mainly composed of closed and polygonal parcels (Fig. 4, a) or blocks of square parcels (Fig. 4, b).

Other indices are currently being developed. They originated from methodologies related to landscape ecology (BUREL, BAUDRY 1999), such as the indices of compactness (relationship between width/length) and for complex shapes, the calculation of the convex envelope. Furthermore, another index has been studied but not retained: the number of nodes contained in a mesh. It should make it possible to assess the degree of connection of the field system network, in order to distinguish in particular the sectors which show isolated segments from those which show a good

connection. However, the important amount of topological errors in entering the data in the GIS and the diversity of the ways of acquiring data does not allow a reliable calculation.

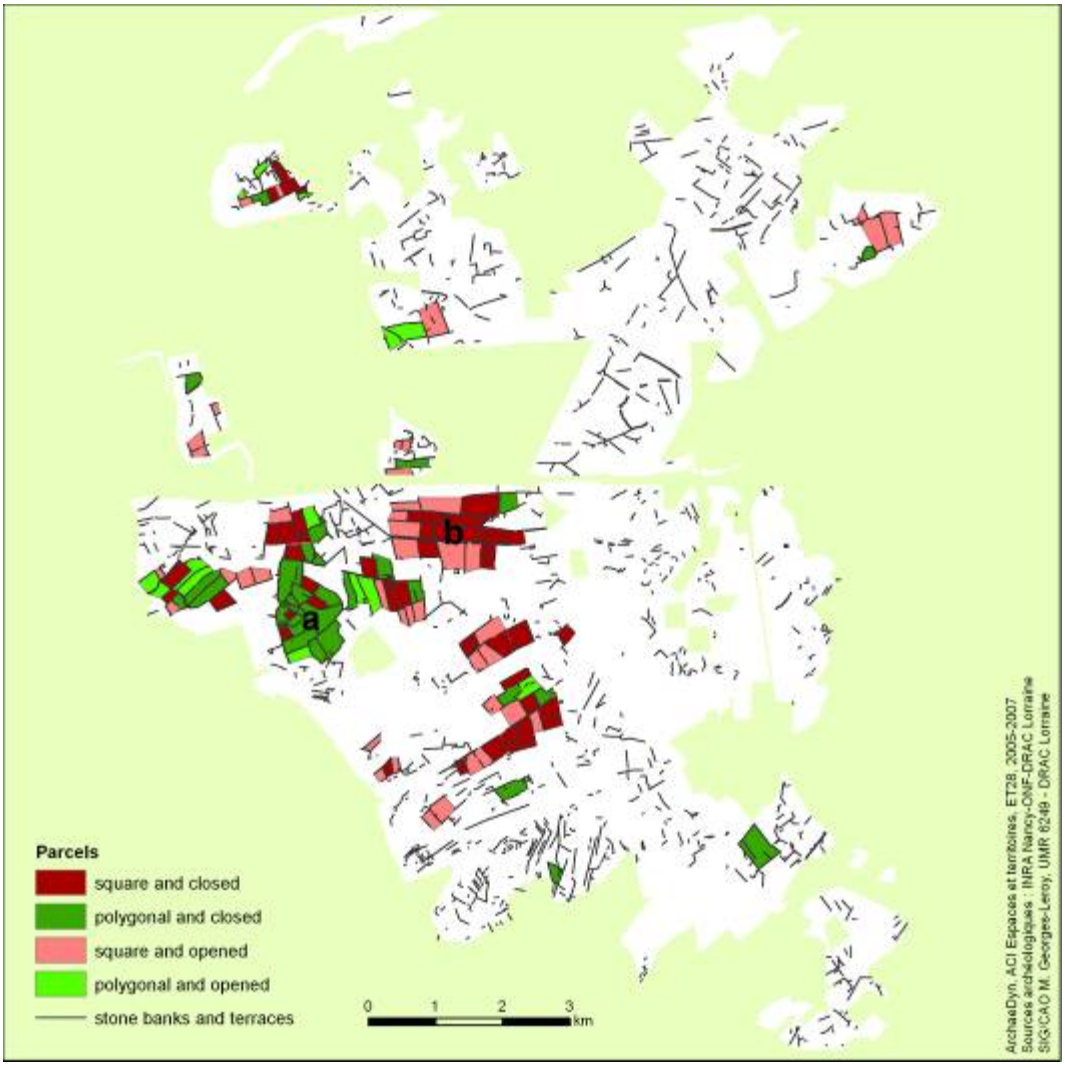
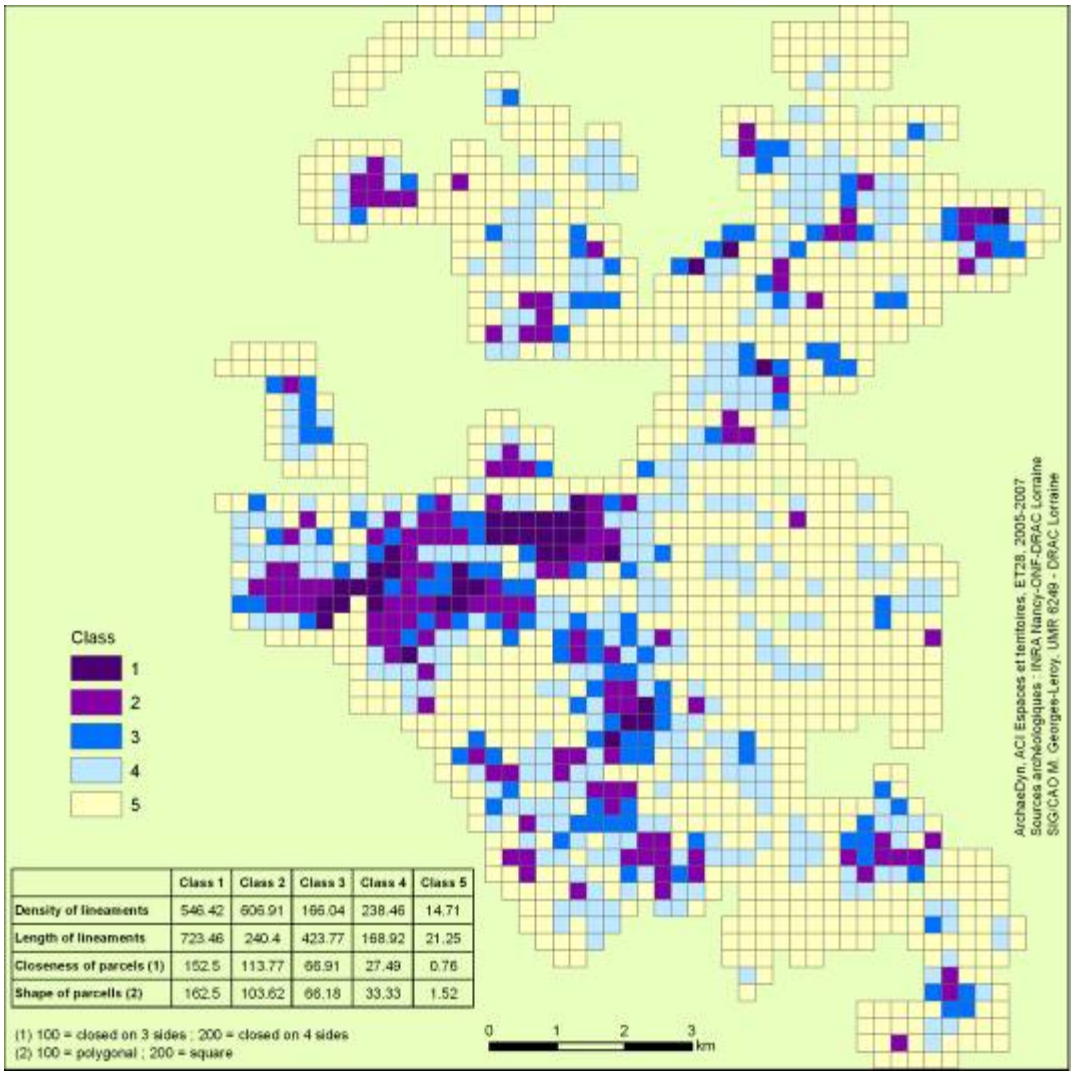


Fig. 4: Forest massif of Haye: Indices of structuring

1.2.3. Combining the indices

The first tests in which the indices of intensity and structuring were combined, were carried out on the forest massif of Haye in order to define the homogeneous areas. They were done by using the classification of the dynamic clouds method. According to this method, it was necessary to transform the indices of structuring into meshes of 250 m. Thus, for the indices of shape and closeness of the parcels, the absolute value (at the surface) in the mesh was attributed to the mesh. The surface was not used at this stage, because the new data from the Lidar survey shows a larger distribution of the parcels. Five indices (density of the lineaments, density of the piles of stone clearing, length of the lineaments, shape of the parcels, closeness of the parcels) were then retained at first, then only four, because the index of the density of the pile of stone clearing did not appear to be pertinent in this combination. The classification in 5 classes (Fig. 5) makes it possible to bring out the very structured areas, dense in vestiges and with very long lineaments (classes 1 and 2). Quite close in density, they are distinguished by a more or less high index of structuring (class 1 consists of a majority of square parcels, with a high rate of closeness) and lineaments of different lengths (very high lengths for class 1). Class 3, with average density, has an average index of structuring, but the length of the lineaments is superior to that of class 2. Class 4, with a rather similar density, is, however, much less structured and has lineaments of short length. This is an intermediary class which corresponds to either peripheral areas of the most structured sectors, or to more isolated sectors with low density. Finally, class 5, on the contrary, which has a high frequency (almost 60% of the meshes) corresponds to empty areas with a density of lineaments almost nil.



	Class 1	Class 2	Class 3	Class 4	Class 5
Density of lineaments	546.42	606.91	166.04	238.46	14.71
Length of lineaments	723.46	240.4	423.77	168.92	21.25
Closeness of parcels (1)	152.5	113.77	66.91	27.49	0.76
Shape of parcells (2)	162.5	103.62	66.18	33.33	1.52

(1) 100 = closed on 3 sides ; 200 = closed on 4 sides
(2) 100 = polygonal ; 200 = square

Fig. 5: Forest massif of Haye: Combining the indices of intensity and structuring

This combination makes it possible to complete the simple representation of the structural sectors obtained by the indices of structuring. Classes 1 to 3, and in part 4, group together the most organized areas and go beyond the boundary obtained with only these indices of structuring. Thus, certain areas in the north of the forest massif which show some layout can also be visualized, although the parcels could not be identified.

1.3. Comparing the systems with the surrounding area

These homogeneous spaces will then be analysed by comparing their localization in relation to environmental (topography, soils) and human data (routes, settlements), but developing the descriptors of the area is still largely in progress.

1.3.1. Comparison in relation to the environmental data

The influence of the topography on the set-up of these parcels, particularly the blocks of parcels, has been currently studied by using two descriptors (topographical situation and orientation). A map representing the topographical situation divided into 6 categories (depression, channel, pass, ridge, summit, flat area) was made from the DEM of the French National Geographic Institute (SALIGNY *et al.* 2008; KOKALJ, OSTIR *in* OSTIR, SALIGNY 2007). By superimposing the structured blocks on this map, it is possible to observe that the parcels were set up firstly in the flat areas in avoiding the small deep valleys, even if several ridges and small valleys are occupied (Georges-Leroy *et al.*, 2008: fig. 5). However, it must be emphasized that these ridges and small valleys play an important structuring role in the set-up of the lineaments (SALIGNY *et al.* 2008; KOKALJ, ZAKSEK, SALIGNY *in* OSTIR, SALIGNY 2007).

The second topographical descriptor which will be tested is that of orientation. Since the parcels are clearly influenced by the topography, the tools which were developed measure the importance of the latter on the set-up of the most structured parcels rather than using a general directional filtering. Moreover, this type of filtering is not adapted

since more than one-third of the study areas are classed in level 2 for the reliability of the quality of the recording (including recording errors between 10 and 70 m), which requires a certain threshold of tolerance in the automatic processing. The general orientation of the lineaments will be calculated automatically by the meshes and synthesized in the form of angle histograms, then compared to the orientation of the relief based on a methodology developed by Workgroup 4.

The other descriptors of the relief, value of the slope, exposition and sunshine (theoretical radiance) are modelled by the DEM of the French National Geographic Institute.

Since we work on agrarian structures, the second category of environmental data used concerns, of course, the agrologic characteristics of the soils. However, it must be recalled that these terrains are not perhaps the most representative of the global choices made by the ancient societies, since they were stony. Nevertheless, it is fundamental to understand why (and how) they were exploited and then definitively abandoned until the present. These soils are currently being classified by using a certain amount of descriptors (thickness, stoniness, useful water reserve, texture, structure, etc.) which make it possible to evaluate their agrologic qualities. It is interesting, however, to observe now that one of the blocks of the forest massif of Haye, composed of closed polygonal parcels, is established on very varied soils and some of them have quite poor agrologic qualities (low water reserves). It is possible that this represents a different mode of agricultural use for this block, such as grazing.

1.3.2. Comparison in relation to human data

The human elements which had an interaction with these parcels are then examined. Two of them were retained, routes and settlements, which correspond to the data that we possess. Some routes of two categories could not be distinguished in the five study areas. In light of the low number of routes and blocks of structured parcels, the interaction field system-routes has only been visually analysed (GEORGES-LEROY *et al.* 2008: fig. 6). The general orientation of the structured blocks is different from that of the main routes, except in the forest of Thuilley-aux-Groseilles. However, the blocks of parcels are clearly connected to these routes and, eventually, the orientation of the blocks is adapted to their connection. The secondary routes appear to have much better links with the structured blocks: they have very similar orientations and shapes, and they lead to these blocks.

The indices regarding the settlements are not quite yet finalized. Several avenues of research have been explored, such as the connections between the settlements and the elements of the field system (including the routes). The level of connection is very high since 80% of the settlements are directly connected to an element of a field system. Moreover, if their distribution in relation to the structured blocks is examined, it is observed that half of the settlements are linked to a structured block. The distribution of settlements in function of their types (technical quarters, farms) is another avenue which remains to be studied.

2. Agrarian manurings

2.1. Background

Interpreting off-site scatters as remains of manure practices is an idea now supported by most researchers interested in the history of landscape and settlements (WILKINSON 1982; BINTLIFF, SNODGRASS 1988). This interpretation is based on several ancient texts which offer proof of this practice from Antiquity to the present (OSCHINSKY 1971). It is also based on recent examples of excavated structures used to prepare manure (PUIG 2003) or manured zones identified by geochemical measurements, such as phosphates (NEIL RIMMINGTON 2000). Since the 2000s, many projects have been based on the study of time-space distribution of off-site material in order to approach past landscapes and territories (NUNINGER 2002; BERTONCELLO, NUNINGER 2004; JONES 2004).

Analysing scatters of artefacts over the long term enables us to study the dynamics of arable spaces with precision, in terms of spatial variability and the quantitative investment of ancient societies within these spaces.

Our purpose in the *Archaedyn* project was to identify areas which were previously and durably exploited, areas previously but less continuously occupied, and recently exploited areas. We also wanted to explain this variability in the occupation by using environmental and socio-economic variables.

2.2. Presentation of the study areas

The data from two study areas were used in the analysis of off-site material. Both are situated in the Centre of France, one in Berry (Sancergues), the other one in Touraine (Neuvy-le-Roi). They benefited from systematic fieldwork operations during the 1990s and 2000s, including site detection and off-site material collection.

Neuvy-le-Roi is located 30 km from Tours. This zone in the north of Touraine was poorly known on the archaeological level. Our aim was to verify if the density of settlement was the same as in the southern part of the Loire Valley. Fieldwalking, associated with the study of the written sources and the ancient cadastre, and aerial photos were the principal methods used in this study. More than 700 ha were covered by these campaigns of systematic collection based on a procedure which consisted of two passages in a maximal mesh of 5 meters, and resulting in the identification of 97 sites and 13 indications of sites. The synthesis of the results demonstrates a human presence in Neuvy-le-Roi since the Paleolithic. The continuity of populating is insured at least since the Gallo-Roman period. It is accompanied by a relative stability insofar as only a minor movement takes place over the long-time (POIROT 1998).

The study area of Sancergues is located 40 km from Bourges. Situated on the borders of Berry and Nivernais, this region suffered at the beginning of the study from important documentary gaps since this region was not part of the aerial survey programmes and fieldwalk operations realized during the 1970s-1980s. The purpose here was to measure the influence of the situation of margin and contact between several landscape units on settlement and landscape dynamics over a very long period (from Prehistory to the 19th century). The fieldwalking programme developed within the framework of this study was carried out between 2003 and 2006, and about 500 hectares in all of the three communes of Charentonnay, Sancergues and Saint-Martin-des-Champs were covered, representing approximately 10% of the total surface of these three communes, using the same methodology as in Neuvy-le-Roi. In this area of 500 ha, about 40 concentrations of material were tracked down and identified as indices of archaeological sites. 221 collection units of the off-site material made it possible to record more than 50 000 artefacts from divers periods, including more than 7600 shards of pottery from Protohistory to the 20th century (POIRIER 2007).

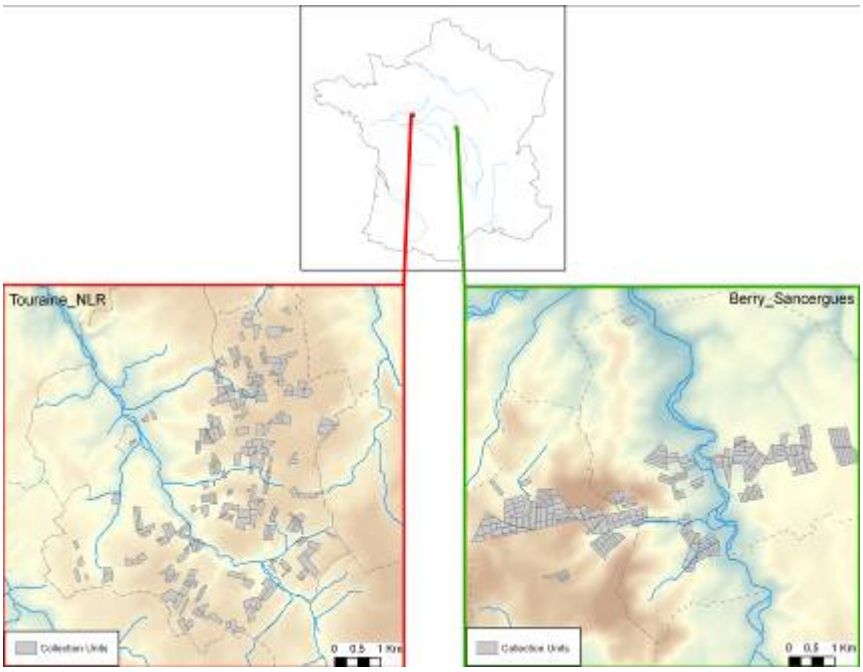


Fig. 6 : Localization of study-areas.

2.3. Analytical procedure and main results

According to the dating capabilities in each study area, it was decided to inventory the collection units of off-site shards based on the same chronological framework. The most imprecise chronological resolution was retained to integrate all the study areas which presented exploitable data. Thus, the chronological resolution of these phases is from 3 to 4 centuries.

The chronological classes for counting the material and calculating densities are as follows: 5th C B.C. – 1st C B.C.; 1st C B.C. – 4th C; 4th C – 8th C; 8th C – 11th C; 11th C – 15th C; 15th C – 18th C.

The initiative was twofold: to carry out both synchronic and diachronic analyses of the spatial and quantitative distribution of remains of agrarian manurings in each study area at the same time.

On a synchronic scale, the aim was to measure the intensity of agrarian occupation for each chronological phase. This measure was done by calculating the density of shards in each collection unit. Effectively, this density could

be considered a reflection of the investment of the ancient societies in a particular space. The higher the density of shards, the more the considered space benefited from important and/or repeated agrarian manurings.

However, it was necessary to take into account the uneven quantity of ceramic in circulation based on the historical periods: effectively, the same number of shards per hectare does not have the same value if, for example, the Roman period or the early Middle Ages is being studied. We cannot credibly adduce to putting raw densities calculated for various chronological phases on the same level. Therefore, it was decided to use a relative measure which made it possible to put all the chronological phases on the same level, that is, by calculating the proportion of the total stock of ceramic collected during the phase considered to be represented within a single collection unit. Therefore, a collection unit which supplied 8% of the total stock of collected material for the phase (5^{th} C B.C. - 1^{st} C B.C.) can be compared to another collection unit which supplied 8% of the total stock of off-site material collected for the phase (16^{th}-18^{th} C), even if the corresponding absolute number of shards is very different. The use of these relative measures not only makes it possible to put the various chronological phases on the same level, but also to compare various study areas. Effectively, we notice that the quantity of ceramic in circulation in Touraine, Berry and the Maures can vary a great deal, even within the same chronological phase. Resorting to relative values thus allows reducing these disparities.

The intensity of agrarian occupation is also estimated by the evolution of the surface manured over time. This estimation is obtained by accumulating the surfaces of all the collection units which present remains of agrarian amendment for each phase considered. Even here, the raw measures would have no meaning since the extent of the fieldwalked surfaces varies from one study area to another. It was decided to use a relative value: the proportion of the fieldwalked space which presents remains of agrarian amendment. All the study areas can then be compared.

On a diachronic scale, it is useful to estimate the global durability of human investment in each collection unit. The entire chronology is considered here with the aim of estimating the total duration of agrarian occupation within each unit as well as the stability of this occupation by identifying possible breaks (their number and their duration).

2.3.1. Indices of durability and mobility

Three indicators for measuring agrarian investment were defined. First, in order to measure the duration of agrarian occupation, the number of chronological phases occupied is computed (i.e. the number of phases which provides artefacts). A ratio is then defined between this value and the total number of potentially occupied phases (six, in this case). An index is obtained which estimates the total duration of human investment in the given area. But given our dating capabilities, some brief breaks in occupation may have occurred and are invisible within the scatters of the artefacts. Hence we decided to also compute the number of breaks detected in the occupation for each collection unit. The number of unoccupied phases which follow occupied phases are counted. We then calculated the ratio [unoccupied/occupied]. The opposite of the result (*1-[breaks/occupied phases]*) can be interpreted as an index which measures the stability of human investment.

Finally, in order to balance the global duration of occupation by the estimation of its stability, both indices were combined (multiplied) to obtain a third value which can be seen as a durability index for each collection unit. It illustrates agrarian investment over the long term, taking into account the global duration of the occupation and the breaks that occurred during this occupation.

Two indicators of spatial statistics were chosen to shed light on the spatial dynamics: the mean centre and the standard deviation ellipse methods, as shown by Workgroup 4 (SALIGNY *et al.* 2008).

2.3.2. Evolution of intensity and surface of the manured areas

- Evolution of the surface manured

A first phase of the study concerned the diachronic evolution of the surface which received agrarian manurings. The evolution of the total surface presenting remains of agrarian amendments in the study areas Touraine-NLR and Berry-Sancergues shows a general tendency towards increases in the spaces amended between Protohistory and the modern period where they reach the quasi-totality of the investigated spaces (Fig. 7).

However, these two areas show some differences in the fieldwalked area. Effectively, we notice that if the part of the surface amended during phase [5-1] is almost the same (26% at Sancergues against 29% at Neuvy-le-Roi), the Roman expansion period (phase [1-3]) is better marked at Neuvy-le-Roi than at Sancergues, because in the first case 80% of the fieldwalked surface presented remains of amendment during this period, against only 62% in Sancergues.

The decrease in phase [4-8] is also less pronounced at Neuvy-le-Roi (20% of the amended surface) than at Sancergues (40% of the amended surface).

The curve is then characterized by a continuous expansion of the agrarian spaces from the early Middle Ages (phase [8-11]) to the modern period (phase [15-18]) in Neuvy-le-Roi. The resumption of the early Middle Ages at Sancergues is necessarily much more abrupt than at Neuvy-le-Roi in view of the fact that the phase of abandonment had been equally more important.

But this resumption was short-lived at Sancergues because the amended surface is again in decline during the central Middle Ages (phase [11-15]) (-33%), while this surface remains and progresses at Neuvy-le-Roi (10%).

Finally, during the modern period (phase [16-18]), both micro-regions show manuring material on almost all the fieldwalked areas (99% at Neuvy-le-Roi, 95% at Sancergues).

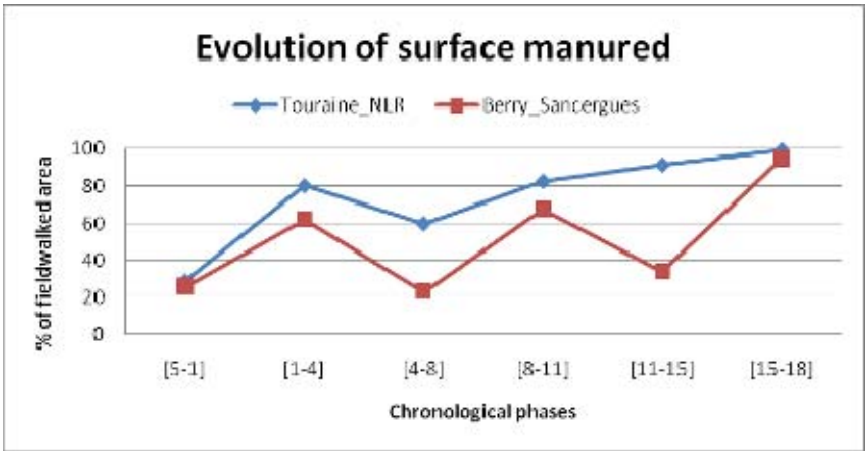


Fig. 7 : Evolution of the surface manured

- Evolution of the intensity of manurings

The evolutionary trend of the intensity of agrarian amendments in the study areas Touraine-NLR and Berry-Sancergues shows a weak growth in intensity between the protohistoric period and the Middle Ages, and a strong increase in the modern period (fig. 8).

However, these two micro-regions present a different profile: the Berry-Sancergues study area has an evolution much more irregular than that of Touraine-NLR whose evolution is almost continuous.

The intensity of manurings during phase [5-1] is more important at Sancergues (3% of the off-site material collected) than at Neuvy-le-Roi (1%). The intensification of agrarian exploitation during the Roman period ([1-3]) is clear in both micro-regions. However, it is more marked at Sancergues (14% of the total stock) than at Neuvy-le-Roi (9%).

A lower intensity of manurings is noted during phase [4-7] in both cases. This reduction is stronger at Sancergues (where this phase represents only 2.5% of the total stock) than at Neuvy-le-Roi where the level of the manurings remains constant (5% of the total stock).

The early Middle Ages (phase [8-11]) present a different facies in each of the micro-regions. In Sancergues, the intensity of manurings explodes since this phase represents 27% of the total stock of off-site material collected. In Neuvy-le-Roi, only a moderate increase of the agrarian pressure is recorded: this phase represents only 9% of the material collected.

The evolutions of both micro-regions are inversed during the central and late Middle Ages (phase [11-15]). While the region of Sancergues records a new phase of decrease (4.5% of the total stock), the region of Neuvy-le-Roi shows an increasing intensification of manuring from the early Middle Ages to the modern period. The central Middle Ages represent here 15% of the total stock of off-site material.

Finally, the modern period is marked in both cases by a strong increase in the intensity of manurings. However, this evolution is marked more at Neuvy-le-Roi (where the modern material represents 61% of the total shard assemblage) than at Sancergues (only 48%).

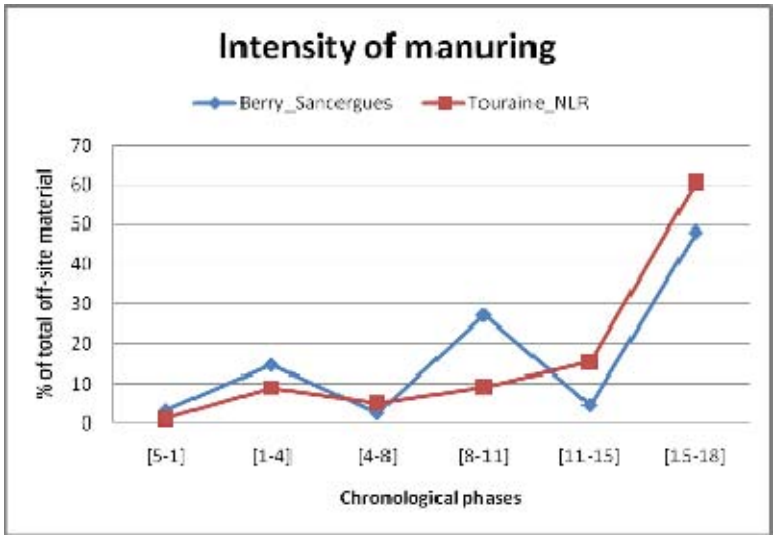


Fig. 8 : Evolution of the intensity of manurings

2.3.3. Durability of agrarian investment and spatial dynamics

- Durability of agrarian investment

The evolution of the durability index of agrarian manurings is almost inverse in the study areas Touraine-NLR and Berry-Sancergues (fig. 9). While the region of Sancergues presents a majority of collection units characterized by a very weak durability index (50.5%), the region of Neuvy-le-Roi presents a majority of collection units with a very strong durability index (47.6%).

This confrontation thus confirms the assumption originating from the examination of the other previously examined variables. It seems that the region of Neuvy-le-Roi presents a very strong stability of the agrarian spaces compared to the region of Sancergues. Spaces cultivated at each chronological phase are durably exploited, and very rarely present episodes of relative decrease (considering areas manured or intensity of manuring). A continuity of agrarian exploitation and an intensification of the cultivated spaces are observed in this region, contrary to the region of Sancergues, where episodes of conquest of new spaces for short periods and episodes of recession are alternated.

The characterization of spaces durably invested was done for the study area Berry-Sancergues and was presented at the CAA congress in 2007 (POIRIER 2008). Each collection unit was compared with its own socio-environmental characteristics, depending on its durability index. This showed that environmental constraints (such as soil quality, slope value or aspect) have almost no influence on the location of the most regularly manured spaces. Socio-economic variables seem to have more influence than the environmental ones used in this study. We noticed that the development of spaces can be durable only if the installation of several settlements insures their continued existence.

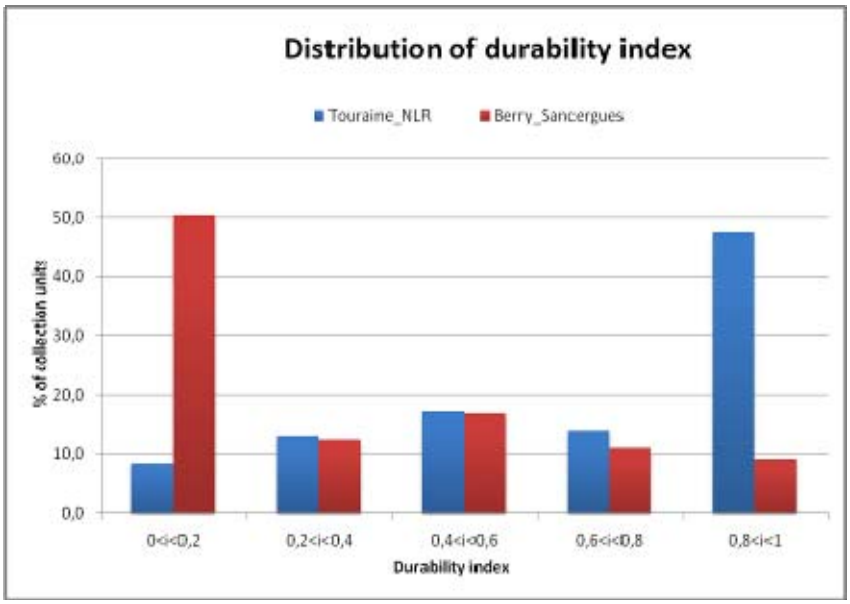


Fig. 9 : Distribution of the durability index

- Spatial dynamics of agrarian spaces.

The variations of mean centers of the agrarian manurings within every micro-region draw rather different curves for each area and confirm the highlighted tendencies by the previous indicators (fig. 10).

While the region of Sancergues presents a rather chaotic evolution, resulting from an alternation between phases of big mobility on spaces recently exploited and episodes of stabilization, the mobility curve of the agrarian spaces at Neuvy-le-Roi is much more regular.

At Neuvy-le-Roi, the phase of the greatest mobility concerns the transition between the phase [5-1] and the phase [1-3]. The mean center of manurings records then a movement of about 8 % of the biggest length of the study-area. This mobility decreases then regularly till the end of the Middle Ages (phase [11-15]). The transition between the phases [8-11 and 11-15] presents a mobility only of 2 %, equal besides in that recorded at Sancergues.

The transition between late Middle Ages and modern period presents an increase of agrarian spaces' mobility, the mean center moving of about 4 %. This mobility is however much lower than that recorded in the region of Sancergues where the value of this movement exceeds the 10 %.

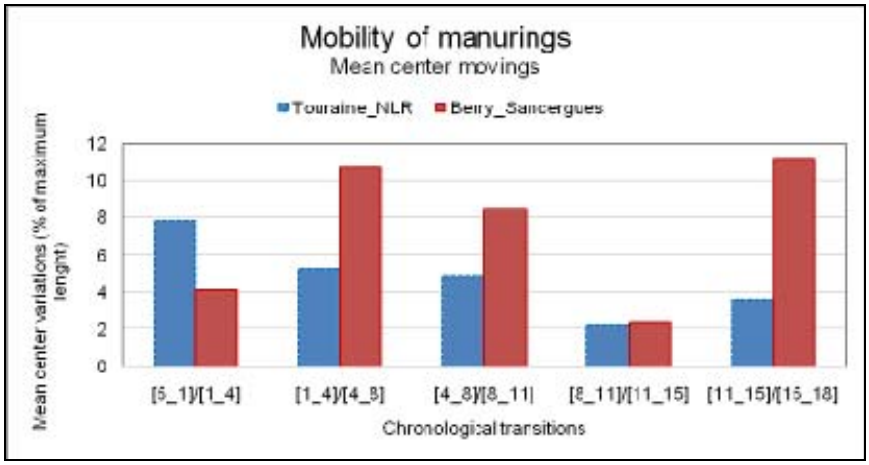


Fig. 10 : Mobility of manurings.

Conclusion and perspectives.

Work on field systems is still largely exploratory. Few studies have dealt with field systems apart from those which consider the lineaments. The aim here is to study them by taking the surface into account, hence the necessity to create surface indices with which they can be characterized. Even if all of the indices elaborated have not yet been

combined, homogeneous spaces seem to emerge which must be interpreted (different chronologies, different modes of agricultural use, etc.).

Opening new sectors would also be interesting, particularly where conserved vestiges exist over vast areas and are definitely dated to the Medieval era. Furthermore, we have not abandoned the idea of comparing these forest covered field systems with the numerous ditch field systems which have been studied in the context of preventive archaeological operations, even if the documented areas are smaller and particularly discontinuous in the area.

Concerning the study of agrarian manurings, the various indicators presented here allowed us to measure the spatial and quantitative variability of manuring over the long term. By measuring the durability of agrarian occupation in each collection unit, we can distinguish areas which benefited from a former and durable human investment, and areas recently or irregularly exploited.

The use of statistical spatial indicators such as standard deviation ellipses and mean centers made it possible to identify phases of stability and of mobility of agrarian spaces. The comparison of two different study areas sheds light on common tendencies and local particularities.

Our aim in future developments of the program is to collaborate with soil specialists in order to better describe soil properties of manured areas and ancient field systems. This would help us to better interpret the variations observed in the intensity of land occupation.

We would also include new study areas in order to compare their spatial dynamics with those already described. It would be particularly interesting to use this analysis protocol for regions concerned by the specific problem of drainage or irrigation in the south of France.

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