Characterization of agrarian resources for archaeological applications

Elise Fovet, Nicolas Poirier

ACI "Spaces and territories" 2005-2007
Final conference - Dijon, 23-25 june 2008

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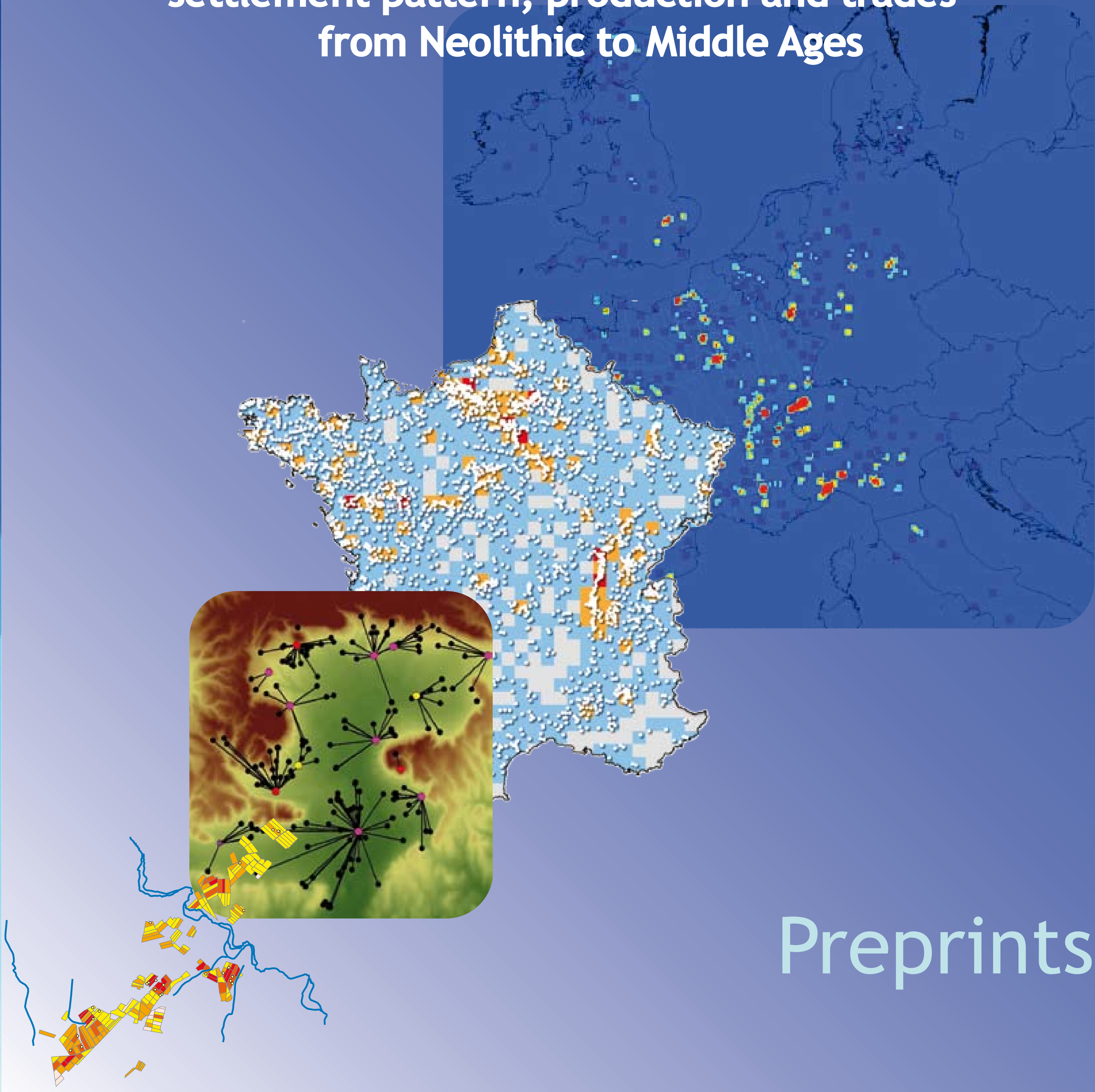
7 millennia of territorial dynamics

settlement pattern, production and trades from Neolithic to Middle Ages



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Spatial dynamics of settlement and natural ressources : toward an integrated analysis over the long term from Prehistory to Middle Ages

Final Conference – University of Burgundy, Dijon, 23-25 june 2008

ARCHÆDYN

7 millennia of territorial dynamics

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Sylvie COSTILLE-VAREY, Nathalie PUILLET *UMR 6249, Besançon*
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SOMMAIRE CONTENTS

CHARACTERIZATION OF AGRARIAN RESOURCES FOR ARCHAEOLOGICAL APPLICATIONS

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Abstract:

This poster presents a methodology set up to define agronomical areas and to offer hypotheses regarding possible past land uses. Instead of classifying study areas as "good" or "bad" land, a precise description of the soils was used. The description of the physical characteristics of soils also helps to compare different soil classifications. This poster also shows initial attempts for practical application through two case studies in which appropriate geographical data (i.e. soil maps) are lacking. We propose to deal with this problem by using ancillary data (geological map and Landsat images).

Résumé :

Ce poster présente une méthode de définition des terroirs permettant de proposer des hypothèses quant aux possibilités de leurs utilisations par les sociétés anciennes. Au lieu de classer les espaces étudiés en "bonne" ou "mauvaise" terre, les sols sont précisément décrits. La description des caractéristiques physiques des sols aide également à comparer différentes classifications des sols. Ce poster présente également les essais d'application pratique dans deux zones d'études présentant des problèmes de manque de données appropriées (carte des sols) ; par l'utilisation de données ancillaires (carte géologique et images Landsat).

1. Introduction

This poster presents an exploratory work developed within one of the ArchaeDyn program's workshops, called *Catchment Area, "Terroirs" and Community Lands*. The general purpose of this workshop is study of the ancient management of agro-pastoral resources at a large scale and in the long term (from Iron Age to Middle Age). During the program, the workgroup mostly worked on archaeological indicators of agro-pastoral exploitation (eg. manuring), so as to distinguish several levels of ancient uses around ancient settlements. The logical continuation of this work is to take into account of agronomical potentialities in the analysis of these past land uses. We chose not to classify study areas in "good" or "bad" land, but to use a precise description of the geographical environment using soil and topography. Here we present the initial attempts regarding soil quality, which causes several problems, for instance: the comparability of soil typologies in different regions or the lack of geographical data (i.e. soil maps).

2. Characterization of agrarian resources for inter-regional studies

2.1. Comparability of soil classifications

In order to compare ancient management of agro-pastoral resources at a large scale and in different areas, a common soil typology must be used. However, we often have to deal with different soil maps elaborated at different dates, for different purposes, or even from different "pedological schools"; these facts involve different soil classification schemes. In the presented case, we had to deal with one map based on soil genesis (lithosol, calcosol, fersialsol...), and another mostly based on soil texture classification (clay, clay loams, sandy loams...).
For a non-specialist it is very difficult to collate directly these different soil classes.

2.2. Methodology to define agronomical areas

The first step of the proposed methodology is to **specify a set of criteria to assess agronomical soil quality** (Fig. 1). The adopted soil quality criteria have been proposed and explained by F. Favory[1] and A. Ferdière[2] after a work group discussion for this purpose. These criteria are the most important regarding restrictions for agriculture. Therefore, they help to group soil classes which are different from a pedological point of view, but similar from an agronomical point of view.

The second step is to **describe soils of the study areas according to these criteria.** As it is not always possible to fulfil all the chosen criteria, the next step is to **select common available soil criteria**. Then, **similar original soil classes are grouped** (Fig. 3). Thus, the proposed methodology enables comparison between different soil classifications; although some groups of soil are not present in all study areas: for instance, the category I exists only in the study area located in Languedoc and has been divided regarding the bedrock (because it has strong influence on the available water capacity), conversely hydric soils exists only in the study area situated in Berry region.

The resulted typology allows the analysis of ancient land uses regarding the environmental constraints. It simplifies soil information and, at the same time, enables us to match up any particular agronomical property with the types of past land use, their intensity and evolution. This point interests us particularly since present technical approaches to soil classification are probably not relevant for ancient societies because of old techniques, as showed by previous studies (eg. BERGER ET AL. 1997). This typology is not a 'soil classification'; nevertheless it allows further hypothesises regarding the soil quality for ancient societies using available soil information.

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Fig. 1. Soil characteristics (adapted from FAVORY ET FERDIÈRE 2006); common available criteria for the 2 study cases are in black type.

Criteria	Constraints
Available Depth	Limits plant growth by restricting the rooting zone
Fragments in the soil	Influence the porosity and hydraulic conductivity of the soil.
Surface Fragments	Can destroy the equipment. In some cases, soil fertility can be affected by the weathering of the fragments. However, surface fragments slow down evaporation and protect the soil from the impact of rainfall.
Water Saturation	Permanent water saturation has a strong effect on plant growth and mortality since anaerobic conditions affect the respiration of plant roots.
Available Water Capacity	Small quantities of water available for plants are critical in regions prone to drought. Furthermore, it affects the efficiency of irrigation systems (also drainage).
Texture & Structure	I Influence the porosity of the soil, thereby the amount of air and water moving freely through the soil, as well as the plant's ability to propagate roots through the soil. It also affects the workability of the soil (ease in tillage).
Soil reaction (pH)	The relative acidity or alkalinity of a soil can determine the type of cultivated plant.
Parent material	Many soil properties relate to parent material: chemical content, texture, structure, the kinds and amounts of fragments…
Age of soil	Indicates if the present soil conditions can correspond to past conditions.

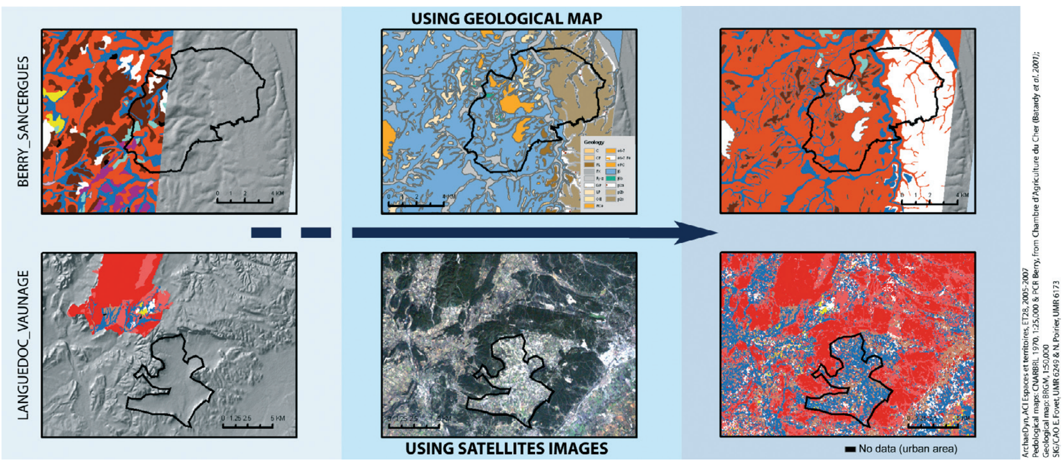

Fig. 2. Extrapolation of soils information

3. Dealing with a lack of soil data using ancillary data

3.1. Methodologies to extrapolate soil information

As available soil maps do not (or not completely) cover our study areas, two tests have been performed to extrapolate soil information from ancillary data (Fig. 2, left): Geological map and Landsat images.
Geological data were considered as relevant to extrapolate soil information because many soil properties relate to parent material. The most represented soil category per geological map unit was found using a zonal statistic function. Then major soil categories were allocated to each geological map units (Fig. 2, at the top).

We also used Landsat images composition to extrapolate soil information because remote sensing techniques record variations in the surface ecosystem which is strongly related to edaphic conditions. The spectral signatures of each category of soil were computed on a combination of 5 Landsat images (Landsat 7 ETM+) acquired in different weather and seasonal conditions (summer and winter). The training areas were chosen regarding the land cover types: fields or vegetation areas (forests and grasslands). Then a soil category was assigned to each pixel in the study area with the maximum likelihood classification technique -it is based on similar spectral response (Fig.2, down).

3.2. Discussion

To assess the accuracy of the classification of the Landsat images, the correspondence between the resulting classified data and the existing soil map was computed (Fig. 4). This accuracy assessment shows that soil categories are globally well identified; although soil category VII is over-represented.

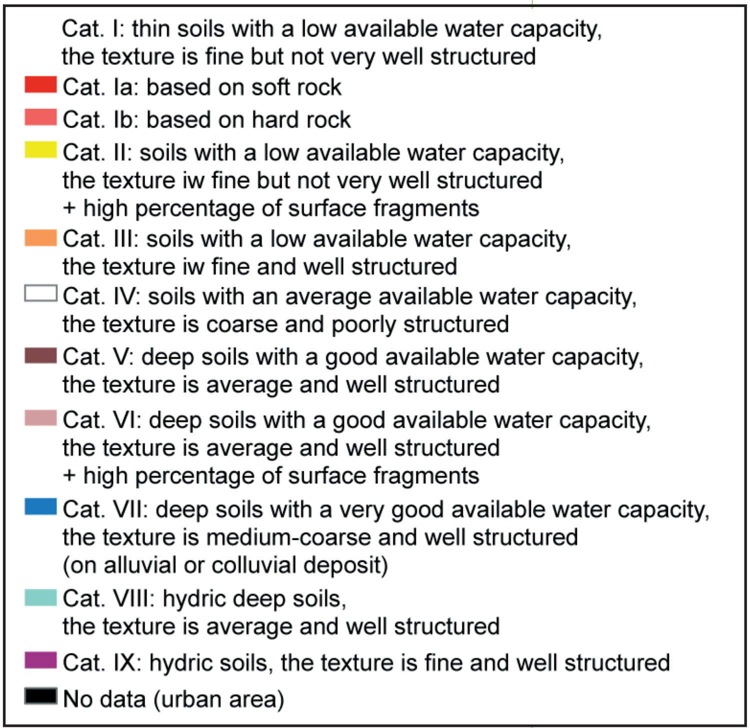

Fig. 3. Soil categories (adapted from CNARBRL 1970 and Batardy *et al.* 2001)

In re-examining the original classes of category VII, it was observed that these soils can locally contain high amounts of surface fragments. This fact probably produces a wide spectral signature which overlaps other soils (notably with "rocky" soil such as the soils of category VI).
In conformity with the authors of the soil map, small areas containing surface fragments within soil classes were not differentiated at first. However, a high percentage of surface fragments seems to have a strong influence on spectral reflectance and should be taken into account to extrapolate soil information from satellite images.

		Reference Data (soil map)					
		Category Ia	Category Ib	Category VI	Category VII	Category IV	Category II
Classified data	Class Ia	**63**	12	8	13	8	2
	Class Ib	13	**83**	3	2	2	
	Class VI	3	1	**56**	7	1	2
	Class VII	17	3	30	**65**	22	15
	Class IV	4		2	8	**63**	10
	Class II	1		1	4	5	**70**
		100	100	100	100	100	100

Fig. 4. Correspondence between classified image and soil map (% per soil map category)

To compare the two methods proposed for soil information extrapolation, the correspondence between the geological map units and the existing soil map in the same study area (i.e. in the oriental Languedoc region) were computed. This zonal statistic shows that the geological map does not give better results in this study area since the geological map units usually correspond to several soil categories (Fig. 5). Likewise, one soil category can appear on various geological map units. This fact is probably due to the scale of the geological map (1:50,000) and therefore to the uncertainty of the drawing of the map units. Furthermore, the geological map unit is not always the parent material: some thin layers, such as recent alluvium or scree (mass of fallen material), are too thin to be indicated on a geological map, but can constitute the real parent material for the soils.

4. Conclusion and prospects

Regarding the comparability of soil quality in different regions, the proposed approach (comparing soil properties instead of collating original soil classes) can be very useful when archaeologists do not have possibility to work with soil scientists. Nevertheless, this initial attempt could be improved by collaboration with pedologists, notably for a better understanding of correlation between present agronomical properties and ancient agrarian practices (eg. manuring).

The tests performed to extrapolate soil information using ancillary data showed that soil information extraction is possible; although, some improvement must be done. If direct allocation of soil information from geological data can be efficient at large scale, it presents problems for the studies at community land scale. Remote sensing extraction gives finer results, although some misclassifications happen (mainly due to small differences between original classification criteria and phenomena influencing the spectral responses). We think that these methods can be improved by using additional parameters: topographic variables and solar radiation. These parameters are also very important for the elaboration of a more comprehensive typology of agrarian resources.

Fig. 5. Correspondence between geological and soil maps in the study area situated in the Languedoc region (% per soil map category)

Cat. Ia	Cat. Ib	Cat. VI	Cat. VII	Cat. IV	Cat. II	Geol type
0.6	35	5	1			calcaires cristallin (faciès Urgonien) (Barrémien supérieur)
	3					calcaires (faciès Urgonien) (Barrémien inférieur)
2	3	3	3			calcaires durs (Hauterivien supérieur)
10	11	4	8			calcaires lacustres (Ludien)
3	0.2	13	3			calcaires lacustres (Lutétien)
16	52	26	14			HARD LIMESTONES (SUM)
	1	1	0.1			calcaires argileux (Barrémien inférieur)
0.1	6		1			calcaires à interlits de marnes (Hauterivien inférieur)
4	8		2			calcaires argileux et marnes (Hauterivien inférieur)
5	8	1	2			calcaires et marnes (Hauterivien inférieur)
	5	2				marno-calcaires beiges (Hauterivien supérieur)
	15					marno-calcaires gris (Hauterivien supérieur)
2	2					marnes et calcaires argileux (Valanginien)
0.2			0.1			marnes et calcaires argileux (Barrémien inférieur)
11	44	4	5			SOFT LIMESTONES (SUM)
27	1	49	31			marnes (Bartonien)
8	1		2			marnes (Oligocène supérieur)
	0.4					niveau de marnes sableuses (Ludien)
5						marnes et poudingues calcaires (Oligocène supérieur)
16	0.3	9	24	22	1	grès de Célas (Oligocène inférieur)
8			1			grès et conglomérats (Bartonien)
3	0.2	1	8	78	99	molasse calcaréo-gréseuse (Burdigalien inférieur)
4	1	2	3			sables rouges, grès (Paléocène et Eocène inférieur)
72	3	61	69	100	100	CONGLOMERATE, SHALE, SANDSTONE, MOLASSES (SUM)
0.6		4	10			Alluvions récentes:limons, sables, graviers et galets
0.5		5	1			Colluvions:sables et limons
1		10	12			ALLUVIUM & COLLUVIUM (SUM)

Spatial dynamics of settlements and natural resources: towards a long-term integrated analysis, from prehistory to the Middle Ages

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Characterization of Agrarian Resources for Archaeological Applications

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This exploratory work was developed within one of the ArchaeDyn program's workshops, called **Catchment Area, "Terroirs" and Community Lands**. During the program we worked on archaeological indicators of agro-pastoral exploitation (eg. manuring), so as to distinguish several levels of ancient uses around ancient settlements. **The logical continuation of this work is to take into account of agronomical potentialities in the analysis of these past land uses. Here we present the initial attemtps for practical applications:**

Characterization of agrarian resources for inter-regional studies

Comparability of soil classifications

In order to compare ancient management of agro-pastoral resources at a large scale and in different areas, a common soil typology must be used. However, we often have to deal with different soil maps elaborated at different dates, for different purposes, or even from different "pedological schools"; these facts involve different soil classification schemes. In the presented case, we had to deal with one map based on soil genesis (lithosol, calcosol, fersialsol…), and another mostly based on soil texture classification (clay, clay loams, sandy loams…).

For a non-specialist it is very difficult to collate directly these different soil classes.

THE PROPOSED METHODOLOGY:

▷▷▷ Enables comparison between different soil classifications .

▷▷▷ Helps to group soil classes which are different from a pedological point of view, but similar from an agronomical point of view.

▷▷▷ Allows the analysis of ancient land uses regarding the environmental constraints. The resulted typology enables us to observe possible correlations between agronomical potentialities and the types of past land use, their intensity and evolution.

Methodology to define agronomical areas:

1. Specify a set of criteria to assess agronomical soil quality (see fig. 1)

Criteria	Constraints
Available depth	Limits plant growth by restricting the rooting zone
Fragments in the soil	Influence the porosity and hydraulic conductivity of the soil.
Surface Fragments	Can destroy the equipment. In some cases, soil fertility can be affected by the weathering of the fragments. However, surface fragments slow down evaporation and protect the soil from the impact of rainfall.
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Texture & Structure	Influence the porosity of the soil, thereby the amount of air and water moving freely through the soil, as well as the plant's ability to propagate roots through the soil. It also affects the workability of the soil (ease in tillage).
Soil (pH)	The relative acidity or alkalinity of a soil can determine the type of cultivated plant.
Parent material	Many soil properties relate to parent material: chemical content, texture, structure, the kinds and amounts of fragments…
Age of soil	Indicates if the present soil conditions can correspond to past conditions.

Fig. 1. Soil characteristics

2. Describe soils present in the study areas according to these criteria, using soil handbooks.

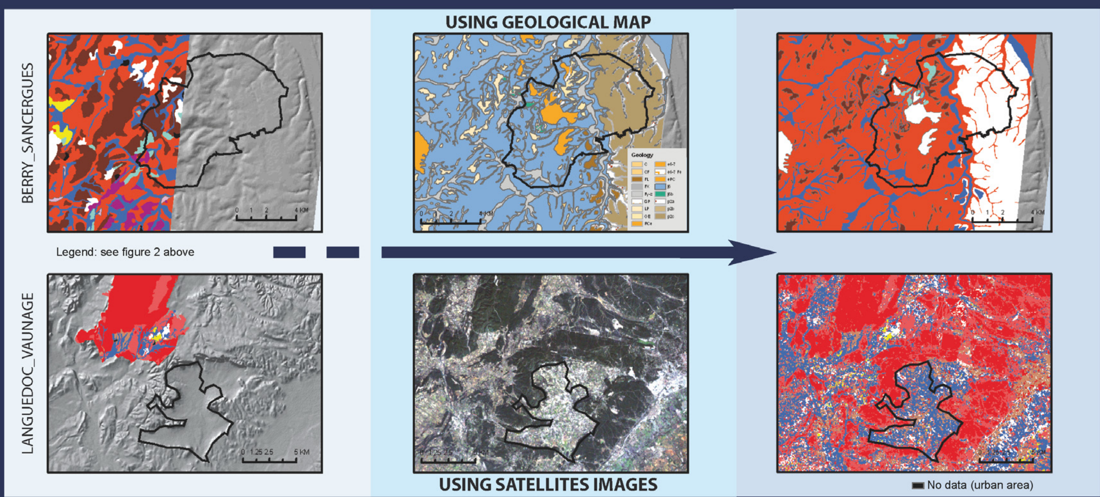
3. Select common available soil descriptors (in white type in the presented case)

4. Group similar soil classes (see fig. 2)

- Cat. I: thin soils with low available water capacity, the texture is fine but not very well structured:
- Cat. Ia: based on soft rock
- Cat. Ib: based on hard rock
- Cat. II: soils with low available water capacity, the texture is fine but not very well structured + high percentage of surface fragments
- Cat. III: soils with low available water capacity, the texture is fine and well structured
- Cat. IV: soils with an average available water capacity, the texture is coarse and poorly structured
- Cat. V: deep soils with good available water capacity, the texture is average and well structured
- Cat. VI: deep soils with good available water capacity, the texture is average and well structured + high percentage of surface fragments
- Cat. VII: deep soils with very good available water capacity, the texture is medium-coarse and well structured (on alluvial or colluvial deposit)
- Cat. VIII: hydric deep soils, the texture is average and well structured
- Cat. IX: hydric soils, the texture is fine and well structured

Fig. 2. Soil categories (adapted from CNARBRL 1970, 1:25,000 & Batardy et al. 2001, Le Berry antique: Atlas 2000)

Dealing with a lack of soil data using ancillary data



Unavailable or incomplete soil data

Available soil maps do not (or not completely) cover the study areas

Choose a comprehensive repository

▷ Geological data: many soil properties relate to parent material.

▷ Landsat images composition: remote sensing techniques record variations in the surface ecosystem which is strongly related to edaphic conditions.

Extrapolate soil information

▷ The most represented soil category per geological map unit is found using zonal statistic function. Then major soil categories are allocated to each geological map units

▷ The spectral signatures of each category of soil are computed . Then a soil category is assigned to each pixel in the study area with the maximum likelihood classification technique -it is based on similar spectral response.

Discussion:

If direct allocation of soil information from geological data can be efficient at large scale, it presents problems for the studies at community land scale (one geological map unit can correspond to several soil categories, one soil category can appear on different geological map units, geological unit is not always the parent material…).

Remote sensing extraction gives finer results and soil categories are globally well identified with this method, although some misclassifications happen (mainly due to small differences between original classification criteria and phenomena influencing the spectral responses).

THESE TESTS SHOW THAT:

▷▷▷ It is possible to extrapolate, from ancillary data, some soil information based on the proposed characterization of agrarian resources. The extrapolation can be improved by using additional parameters: topographic variables and solar radiation. These parameters are also very important for the elaboration of a more comprehensive typology of agrarian resources.

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