SOIL VERTICAL AND LATERAL DIFFERENTIATION

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ABSTRACT

Three scales of organization - the basic assemblage, the horizons, and the soil mantle - are taken as a starting point for the study of vertical and lateral differentiation. The morphological characters, or basic combinations, are mainly colour, aggregates, porosity, and concentration features. They have a significance not only in terms of pedogenesis, but also in terms of soil management. They may vary according to seasons or as a continuous trend on a longer-term evolution, and are specially organized in horizons and in catenas. The limits between soil features and horizons are important both vertically and laterally. Catenas can be lithosequences, toposequences or chronosequences. An understanding of these organizations and of their dynamics is very important in choosing the site for an experiment station.

INTRODUCTION:

MORPHOLOGICAL ORGANIZATION OF THE SOIL

Soil, as is the case with all natural bodies, is an organized, structured entity - that is, the organic and mineral constituents of the soil are arranged with specific relationships between them.

The morphological organization of the soil exists at all scales of observation:

- from the basic assemblage of the particles, that we can observe with the microscope,
- up to the arrangement of the pedological systems at a regional scale.

In fact, when we want to know how to use soils, it is important to study and interpret three scales of organization:

1. The scale of the basic combinations of the constituents. These basic combinations are expressed in terms of:
   - colour
   - aggregates
   - porosities
   - nodular and linear concentrations.
2. The scale of the horizons:
   - each horizon is characterized by one or several types of basic assemblages.
3. The scale of the pedological mantle:
   - this is made up of the vertical superposition and the lateral succession of several horizons.

The morphological organization of the soil is equivalent to the anatomy of a plant or of an animal. This morphological organization is, at one and the same time, the result and the driving force of the dynamics of the soil. Hence we know that the morphological organization of the soil is:

- the evidence of the past history of the soil, and also
- the expression of the actual dynamics (mainly the hydric and the biological dynamics) of the soil.

This means that when we want to evaluate, to understand, and to use the fertility of a soil, we have to study in detail the morphological organization of the soil - at the different scales of its organization.

THE MAIN MORPHOLOGICAL CHARACTERS

The description and the interpretation of the vertical and lateral variations of soils can be made by studying four groups of morphological characters:

- the colours;
- the aggregates;
- the porosities;
- the concentration features.

A detailed study of these morphological characters enables us to make certain deductions with regard to the morphological composition, dynamics and fertility of a soil, and these are briefly reviewed below.

1. The colours can be interpreted in terms of:

* the presence of determined constituents:
  - organic matter
  - iron
  - carbonates

* the state of some constituents:
  - reduced iron
  - goethite
  - hematite

* the dynamic processes:
  - biological activities
  - hydric evolution
  - migration of clay
  - carbonation
  - salinization

By studying these different aspects of the soil, we can deduce some information about several chemical and physical features: the absorption complex, the pH, the texture, and so on.

2. The presence and the morphology of the aggregates (rounded, angular, laminar), and the dimension and stability of these aggregates, can be interpreted in terms of:

* texture
* clay mineralogy and dynamic (swelling)
* presence of organic matter
* absorption complex and pH
* biological activity
* hydric dynamic

So the aggregation gives good indications about:

* chemical fertility
* accessibility of this fertility to the roots

3. To be well understood and well interpreted, the porosity has to be:

* first: described in terms of the morphology and origins of the soil:

- alteration
- particle assemblages
- biological activities
- fissuration
- assemblage of rounded aggregates

* second: measured in terms of:

- total porosity
- porosity of the aggregates
- porosity of the micro-aggregates: textural porosity
- structural porosity, i.e. the porosity between the aggregates

In terms of fertility, it is most important not only to have data about the macro- and microporosity that influence the dynamic of the water, but also to have detailed observations about the space and time variations of the porosity: abrupt variations of the porosity are never good for the fertility.

4. The concentration features are organizations which result from mechanisms involved in the transfer of the constituents in the soils:

- cutans
- nodules
- sand capping
- band
- pedotubules

In terms of fertility, these concentration figures give good indications regarding:

- the mechanisms of leaching and of accumulation in the different horizons of the soil, and
- the biological activity.

TIME AND SPACE VARIATIONS OF THE MORPHOLOGICAL CHARACTERS

Colours, aggregates, porosity and concentration figures are characters which express the basic assemblages of the soil, and which vary in relation to the time factor and in relation to the space factor.

A. In relation to the time factor, there are two types of variations:

1. <u>Seasonal variations</u>: the morlphology of the soil varies at each moment in relation to the variations of humidity, temperature, and biological activities (vegetal and animal). These variations have a big influence on the physical and chemical fertility.

2. <u>Progressive modifications, year after year</u>: this concerns the more or less rapid evolution of the pedological mantle. This

evolution can be greatly accelerated by the way in which the soil is used, notably with regard to:

- compaction
- disaggregation
- leaching of clay
- erosion

It is absolutely necessary, if we want to protect the fertility of the soils, to observe and to measure with precision the morphological evolution of the soils.

B. In relation to the space factor, it can be seen that the morphological characters of soils are organized in horizons, in which vertical superposition and lateral succession define the morphology of the pedological mantle.

At these smaller scales, the scale of the profile and the scale of the catena, it is very important to observe in detail where and how the morphological changes take place - that is, where and how the appearance, the disappearance, the aggregates, the porosities and the concentration figures occur (see Figure 1).

Each one of these vertical and lateral changes is meaningful in terms of physico-chemical properties and in terms of the dynamics (the water dynamic for example), as well as in terms of the potentiality and vulnerability of the soils. It is these morphological changes that we have to represent on detailed soil maps (see Figure 2).

CONCLUSION:

STUDY OF THE MORPHOLOGICAL LIMITS

It is important to emphasize the importance of studies which examine the limits that mark the vertical and the lateral variations of one or several morphological characters of the pedological mantle: it is as important to know about the limits as what exists between the limits.

We know that in terms of the lateral distribution of the soil characteristics we have three main types of catena or sequences:

1. <u>The lithosequences</u>: The lateral variations are concerned with the variations of the rocks. In these sequences:

   - the vertical differentiation limits are dynamic limits, i.e. they vary as a consequence of the evolution of the soil; but

   - the lateral differentiation limits are fixed: they correspond to the rock limits.

2. <u>The toposequences</u>: The lateral variations are determined by the topography. We know that in general in these types of sequence all the limits are dynamic, and it is very important to know how, and at what speed, the vertical and lateral differentiation limits evolve.

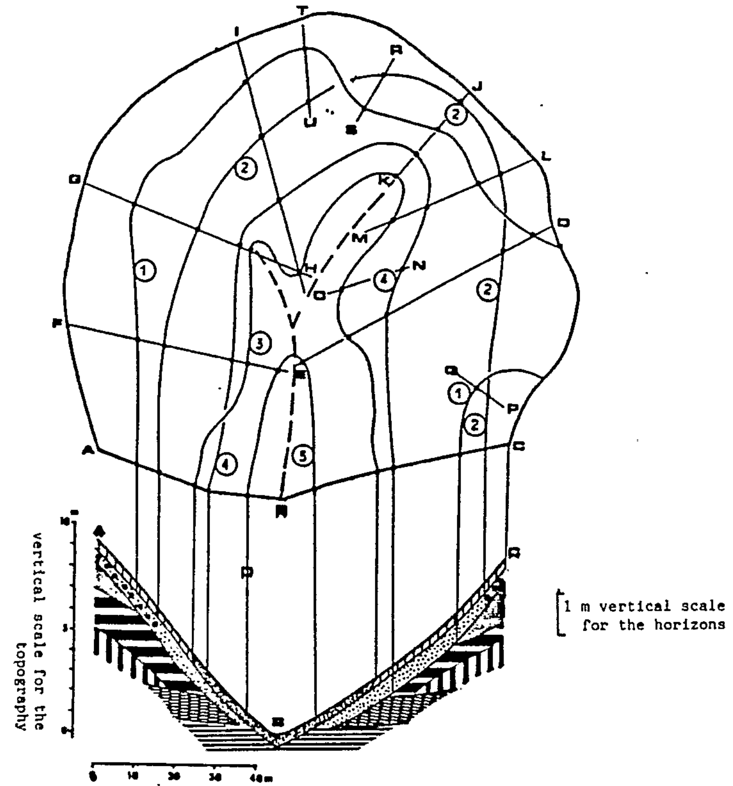
3. <u>The chronosequences</u>: The lateral variations are determined by the age of the soils, i.e. the age of the material on which the soil rests.

   - chronosequence along a slope, i.e. the evolution of carbonate accumulation as a factor of the age of the surfaces (see Figure 3), or

   - chronosequence of landscapes, i.e. the chronosequence of the transformation of an Oxisol to a Spodosol (see Figure 4).

It is, then, by studying and mapping the chronosequence that we can partially answer the question concerning how and at what speed the vertical and lateral differentiation limits evolve (see Figure 5).

Finally, it is in relation to all these morphological data - vertical, lateral, and dynamic morphological data - that we can situate, with considerable precision, an experiment station which aims to test the use of the pedological mantle in relation to the anatomy and physiology of the pedological mantle concerned (see Figure 6).



Isodifferentiation curves

Note: The characterization of each curve is drawn for an observer crossing the curve from the side where the number is placed:

(1) where the compact red horizon disappears (d)
(2) where the nodules disappear (c)
(3) where the hydromorphic characteristics of the humus horizon appear (g)
(4) where the purplish-red sericitous horizon disappears (e)
(5) where the white horizon reaches the base of the humus horizon
/ where the isodifferentiation curve has been located

Figure 1. Analytical phase: cross section and plan (after Boulet, Humbel and Lucas, 1982).

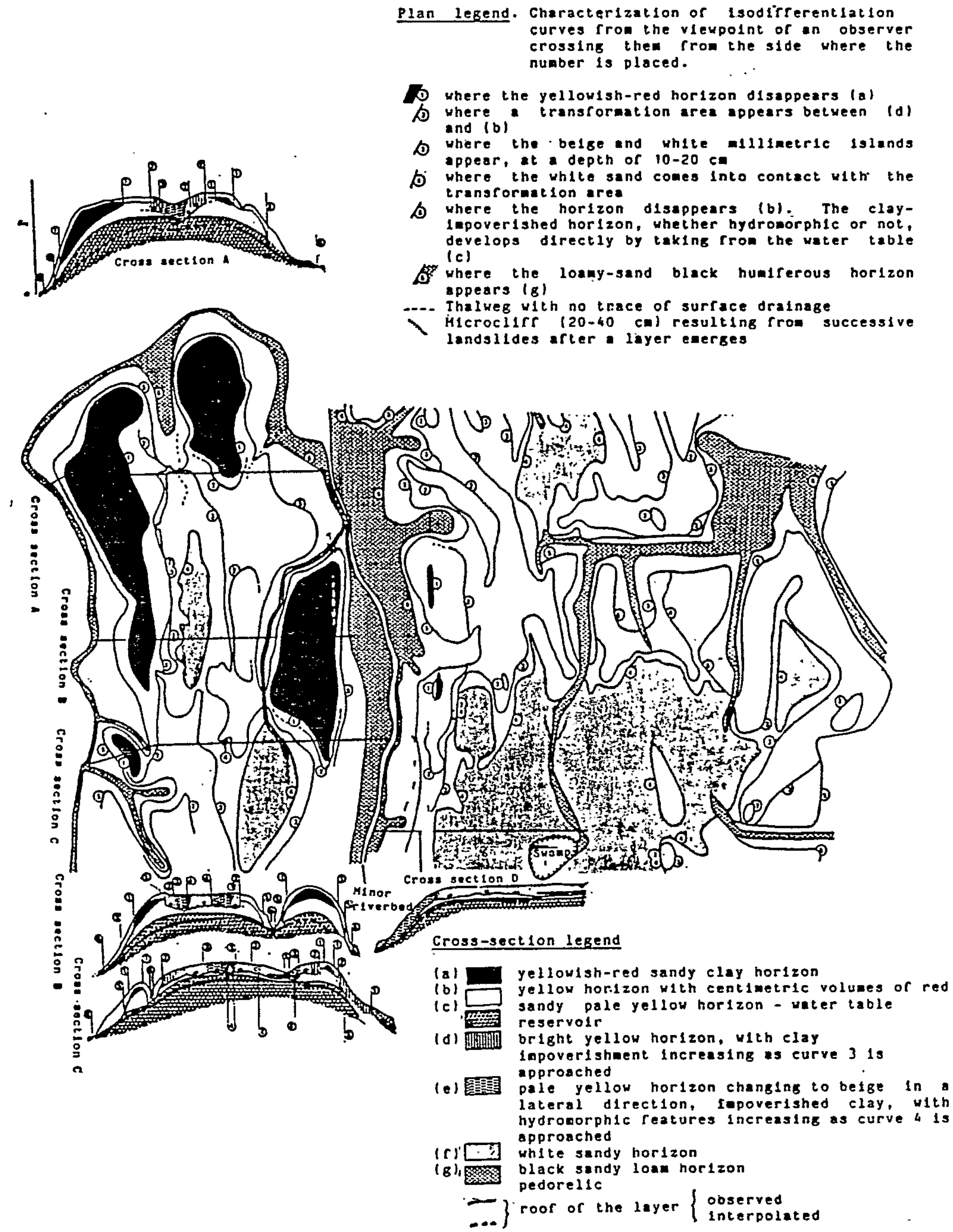


Figure 2. Diagram of the cross sections and prelittoral bars.

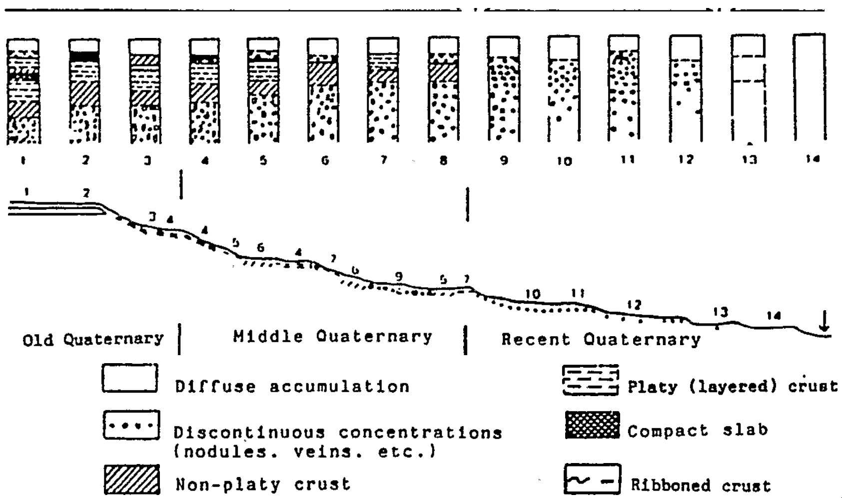


Figure 3. Distribution of the main types of calcium carbonate accumulation as determined by the ages of the surfaces and of the soils (the length of the sequence varies between tens of metres to a hundred metres and more; the difference in altitude between and Old and Recent Quaternary is in the order to tens of metres (Zebra, Morocco).

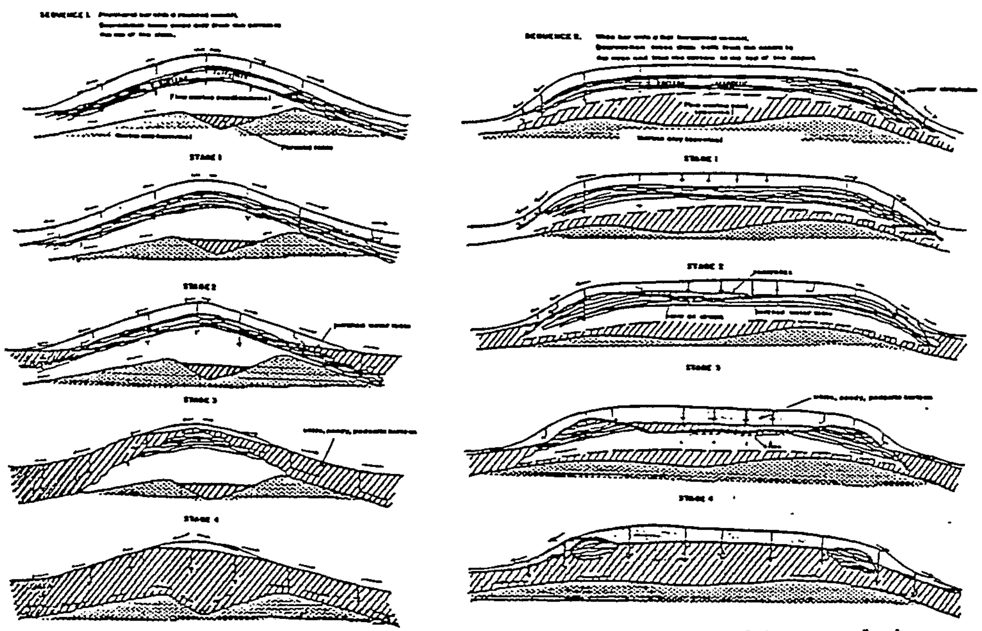


Figure 4. Stages in the evolution of prelittoral bars (after Boulet, Humbel and Lucas, 1982).

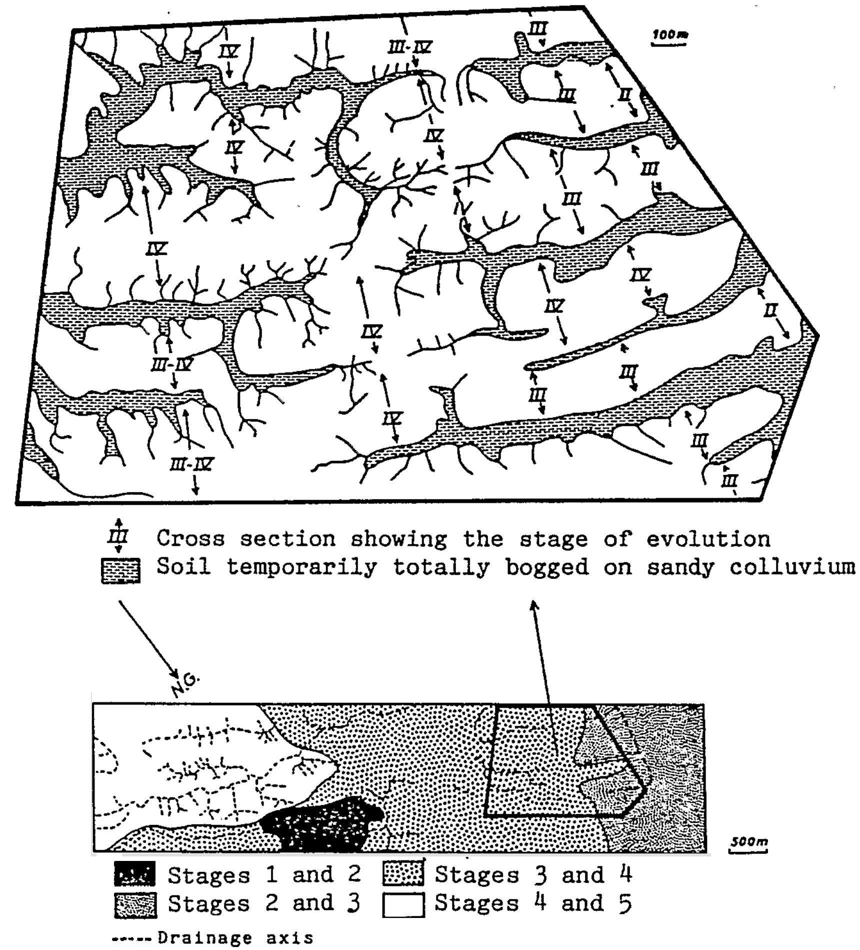


Figure 5. Synthetic map of prelittoral bars.

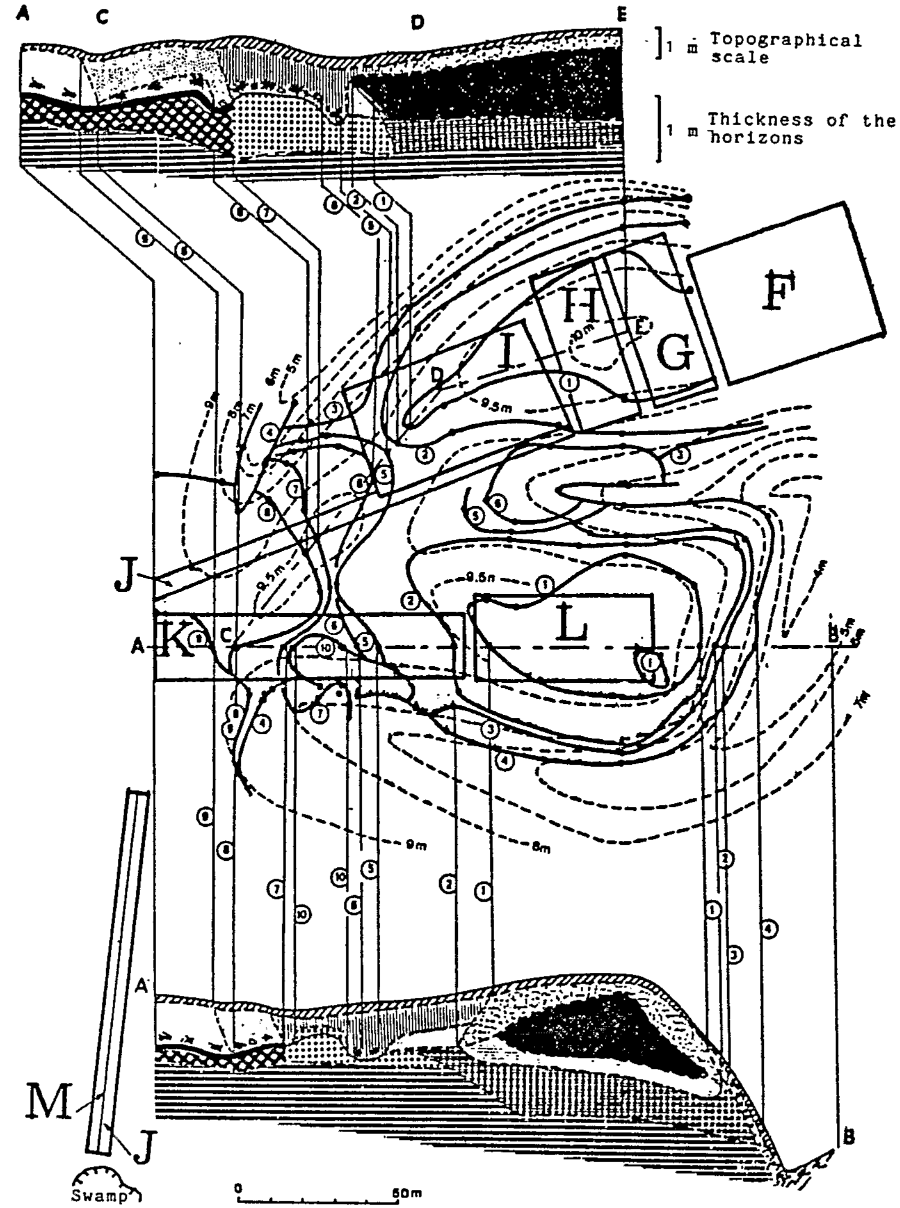


Figure 6. An example of agropedological experimentation on prelittoral bar.

PEDOLOGICAL LEGEND (SUMMARY)

Cross Section Legend

Horizon limits: progressive; rapid; planic floor of perched table

(a) humiferous horizon, sandy;
(b) strong brown sand to sandy clay;
(c) yellowish red sandy clay;
(d) strong brown sandy to sandy clay;
(e) strong brown with cm volumes of red, clay decreasing downwards;
(f) light yellow with cm volumes of red, sandy, water-table reservoir;
(g) dark brownish yellow sandy to sandy clay;
(h) brownish yellow deeply impregnated with organic matter: the impregnation depth of organic matter and the clay impoverishment increases from curve 1 towards curve 7
(i) strong brownish yellow sand to sandy clay;
(j) yellow with volumes of red main less indurated sand to sandy clay;
(k) transition between (h) and (j) by interpenetration and relicts (from j into h)
(l) dark brownish yellow, getting gradually lighter with depth, sandy;
(m) light grey to white, sandy;
(n) ochre, organic brownish black streaks, sandy clay:
(o) red pedorelics more or less indurated;
(p) pedoreilcs;
(q) grey humiferous volumes;
(r) ochre spots along the pores.

Legend for the Isodifferentiation Curves

Centifugal differentiation

(1) change from 7.5YR to 10YR in 18-20 cm (b)→(h);
(2) where (b) disappears;
(3) where pedorelictual volumes appear (o);
(4) where ochre spots appear in 18-25 cm.

Centripetal differentiation

(1) (2) as given above;
(5) where pedorelictual volumes appear (p) at the bottom of (h);
(6) where humiferous volumes appear (q);
(7) where a planic limit appears;
(8) where white sand appears (m);
(9) where the brownish-yellow material disappears (m);
(10) where the clay-impoverished material gets thinner (<40 cm) (h), and where the characteristics which appeared with curves 5 and 6 disappear;
where the isodifferentiation curve can be seen.

AGRONOMIC EXPERIMENTATION (Philippe Godon, IRAT)

Manioc
- F: collection (42 varieties)
- G: fertilization trial
- H: herbicide trial
- I: behaviour trial (5 varieties)
- J: behaviour trial (6th variety)

Soybean
- K: behaviour trial, with and without ridges, and with and without liming
- L: diversification trial (5 varieties, 6 repetitions)
- M: behaviour trial, only one treatment

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SOIL AND SITE CHARACTERIZATION FOR SOIL-BASED RESEARCH NETWORKS

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ABSTRACT

Soil and site characterization are crucial elements in any kind of soil-based research. The characterization process takes on a new dimension when research networks are considered, as compared to experimentation at a single site. Reproductibility of site characteristics at other locations is the single important constraint in a network, and since this is not always feasible, the alternative is good characterization and documentation of site characteristics.

The paper provides some guidelines on aspects to be considered in soil and site characterization. The IBSNAT approach is used as an example, and some of the minimum data sets are used as illustrations. The need for a data base management system is empahsized and some aspects are elaborated to show the complexity of establishing a network.