ANALYSIS OF A CULTIVATION PROFILE UNDER SUGARCANE: METHODOLOGY AND RESULTS[1]

Philippe de Blic*

Abstract

Cultivation often results in the differentiation of the arable soil into homogenous layers distinguished by their tilth. These layers can be defined by their type of structure and their consistency, the combination of these two properties serving to define the tilth. Observations on tilth are related to root distribution.

This method of examining the cultivation profile was used in Mauritius to compare two methods of preparing the soil for sugarcane.

Résumé

L'ANALYSE DU PROFIL CULTURAL SOUS CANNE A SUCRE : METHODOLOGIE ET RESULTATS

La culture résulte souvent en une différenciation au sein des terres arables d'horizons homogènes caracterisés par leurs états structuraux. Les horizons peuvent être caracterisés par leur type de structure et leur consistence, la combinaison de ces deux paramètres définissant l'état structural. Les observations sur l'état structural sont liés à la distribution des racines.

Cette méthode d'étude du profil cultural a été utilisée à l'Ile Maurice pour comparer deux méthodes de préparation du sol pour la canne à sucre.

---

[1] Translation of the original French by Peter M. Ahn. Paper presented at the workshop by R. Moreau, ORSTOM.

* ORSTOM representative at the Mauritius Sugar Industry Research Institute.

Background Information

Objectives

The Mauritius Sugar Industry Research Institute (MSIRI) established in a multi-local experiment in Mauritius in 1978 designed to compare a relatively simple soil cultivation method with normal practices, using monoculture sugarcane.

A supporting soil study was carried out in 1985 in order to observe the effects on the soil of these two methods of soil preparation, and particularly the ability of the simpler method to maintain a satisfactory cultivation profile.

Locality

The soil study concerned five trial sites with the following characteristics:
Altitude: ranging from 20 to 300 m.
Annual rainfall: between 1400 and 3150 mm.
Parent rock: basalt.
Soils: * weakly to strongly desaturated typical ferrallitic soils;
* a Vertisol, with some external drainage (one trial site).*

Cultivation methods

The normal method of soil preparation, here referred to as 'normal practice' (NP), comprises the following successive operations:

* mechanical clearing of sugarcane stumps,
* subsoiling to an average depth of 40 cm, and
* furrowing at 150 cm intervals for the planting of sugarcane cuttings.

The simplified preparation, here termed 'minimum tillage' (MT) comprises:

* chemical destruction of stumps by spraying Round-up, and
* furrowing as in the normal practice.

There are no subsequent operations apart from the application of chemical weedicides.

Methods of study

At each trial site, eight profile pits were dug at right angles to the lines of cane, sited so as to give four NP-MT pairs. Measuring 150 x 80 cm, these profile pits enabled the following operations to be carried out:

* The structural organization of the tilled topsoil did not appear to be basically different from that of the ferrallitic soils.

- o identification and plotting in the exposed pit face of soil volumes homogenized by cultivation;
- o identification of various features in the cultivation profile, such as crusts, plough pans and subsoiling lines;
- o root counting, using a 5-cm grid applied to the area of the soil face examined,
- o determination of bulk densities, in the upper 30 cm, using 500-cc cylinders or a membrane densitometer; and
- o taking of samples for physicochemical analyses.

Tilth Appraisal

Soil preparation techniques often result in a very considerable variability of tilth in the arable layer between points 1 m or even 10 cm apart. In order to compare different tillage methods, it is therefore essential to take this variability into account when describing the cultivation profile. This involves mapping the tilled horizon by noting on the vertical pit face the position and area of the 'morphological units' (Manichon, 1982) or the 'homogenous volumes' (de Blic, 1978) defined by differences in tilth. The tilth descriptions we have made are based on the separate evaluation of two parameters: type of structure, and consistency.

Type of structure

In this study we have distinguished five types of structure characterized both by the presence or absence of structural elements, and by the degree of structural development.

S1 Well-fragmented structure: well-developed structural units easily separated from each other.
S2 Moderately well fragmented structure: easily discernible structural units adhering to each other.
S3 Poorly fragmented structure: individual units coalescing and difficult to discern.
S4 Massive discontinuous structure: soil which appears massive, but easily breaking to fragments of various shapes and sizes.
S5 Massive continuous structure: continuous soil mass, resembling concrete when dry.

Consistency

Consistency is estimated at the general level of a morphological unit by the degree of ease with which a pointed object is inserted into the vertical face of the soil pit, thus testing resistance to penetration. Results are very dependent on soil humidity, and are only relative, but give a good indication of the ease or otherwise of root penetration.

Three consistency classes have been used in this study:
C1 slightly compact,
C2 moderately compact,
C3 compact and very compact.

Tilth of the morphological units

The tilth is indicated by combining the two previous properties: S3-C2, for example, indicates a "moderately compact, poorly fragmented structure".

The plotting serves to indicate the areal extent of the different tilths, and hence the structural composition of the cultivated layer, for example by using frequency histograms.

It could prove convenient to regroup the tilth classes into a smaller number of categories which are not descriptive but interpretive. Thus in this study, we have used the following three categories:
I favourable tilth
II moderately favourable tilth
III unfavourable tilth

Based on structural porosity and ease of rooting criteria, the three categories are defined as shown in Table 1.

Table 1. Classification of soil tilth.

	Type of structure				
Consistency	S1	S2	S3	S4	S5
C1	Favourable tilth				
C2		Moderately favourable tilth			
C3			Unfavourable tilth		

Average tilth

Using frequency histograms, it is also possible to obtain an average assessment for the whole of the cultivated horizon. In this way the average tilth (AT) of the horizon can be qualified as favourable, fairly favourable, moderately favourable, fairly unfavourable or unfavourable.

An AT classed as moderately favourable could be either
* contrasted, with tilths I and III dominant, or
* uncontrasted, with tilth II dominant.

The assessment of an AT is thus simply obtained by combining the basic information collected, information which can always be referred to for more precise details.

Bulk density of the cultivated horizon

Six to eight determinations of bulk density were made in each profile. Values obtained are generally in good agreement with the assessment of consistency in the field, as shown in Table 2. However, the table shows clearly that the consistency test must be interpreted with great care when making comparisons between sites.

Table 2. Consistency classes at five sites as characterized by average bulk density.

Consistency	Bel Ombre	Hewetson	Belle Vue	Olivia	Case Noyale
C1	1.05	0.87	0.94	0.97	0.98
C2	1.06	0.87	1.02	1.03	0.98
C3	1.07	0.94	1.04	1.10	1.06

Root Distribution

Root counts were made on a section of soil 140 cm wide to a depth of 50 cm. In order to compare the root distributions observed, certain simple parameters were derived from these counts.

- ***Root density***: Overall root density is the total number of roots in the surface examined, expressed as roots per square decimetre.
- ***Regularity***: The index of regularity is the ratio of the number of grid squares containing at least one root to the total number of grid squares. The index varies from 0 to 1, and the closer it is to one, the better the distribution.
- ***Vertical distribution***: The index of vertical distribution, Iv%, is the percentage of roots counted in the upper 30 cm of the profile face. This thickness generally corresponds to the cultivated horizon. Apart from calculating this index, we have prepared root frequency histograms for horizontal layers 10 cm thick.
- ***Lateral distribution*** : The index of lateral distribution, Il%, is the percentage of roots counted in a section of soil 70 cm wide, centred beneath the row of canes (centred half-width count). In the same way as for the previous index, we have drawn root frequency histograms for vertical bands 10 cm wide on each side of the cane planting line.

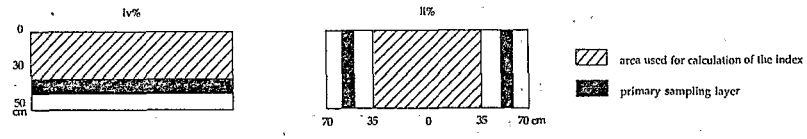


Figure 1. Diagrams indicating how the vertical and horizontal indices (Iv% and Il%) are obtained.

Example: Trial Site at Hewetson

Structural morphology summary sheets (Exhibit 1)

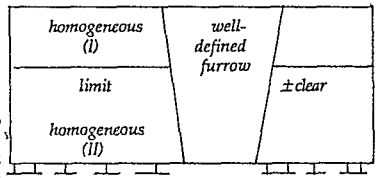
Exhibit 1. Example of a structural morphology summary sheet as prepared for the Hewetson site.

STRUCTURAL MORPHOLOGY SUMMARY SHEET: HEWETSON SITE

NP (normal practice) MT (minimum tillage)

Characteristics of the cultivated horizon

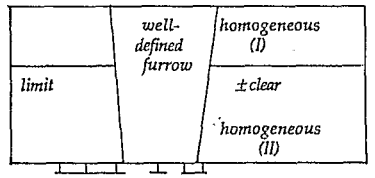
VD (vertical differentiation): *fairly high between lines*
LD (lateral differentiation): *high*



Very abrupt limit
Frequent plough pans

AT (average tilth): *moderately favourable, contrasted*

VD: *fairly high between lines*
LD: *high*



Very abrupt limit

AT: *moderately favourable, little contrast*

Rooting characteristics

Moderate density and regularity, concentrated in upper 30 cm and below the planting line. Little difference between treatments.

Principal soil constraints
- *lateral discontinuties in the plough layer*
- *horozontal discontinuity at the base of the plough layer*
- *contrasted tilth (NP)*

Principal favourable characteristics
- *high degree of uniformity in the morphological units*
- *tilth with low degree of contrast (MT)*

Comparison between NP and MT treatments

The soil characteristics are practically identical between treatments. The MT gives rise to a greater uniformity in the plough layer.

Rooting characteristics reflect the presence of well marked furrows and the abrupt discontinuity marking the lower limit of the plough layer.

These forms summarize a certain amount of soil and root information for each test site, voluntarily limited to the cultivated horizon below which no cultivation-induced changes are observed. The uncultivated subsoil is usually massive and compact, with few roots penetrating it. The information given is as follows:
- o diagrams showing lateral and vertical differentiation (LD and VD) as well as the main features of the average profile;
- o average tilth (AT) of the cultivated horizon; and
- o summary of root distribution.

From this, the main constraints and favourable characteristics can be deduced, and a comparison made of the cultivation profiles observed below each of the two treatments.

Tilth assessment

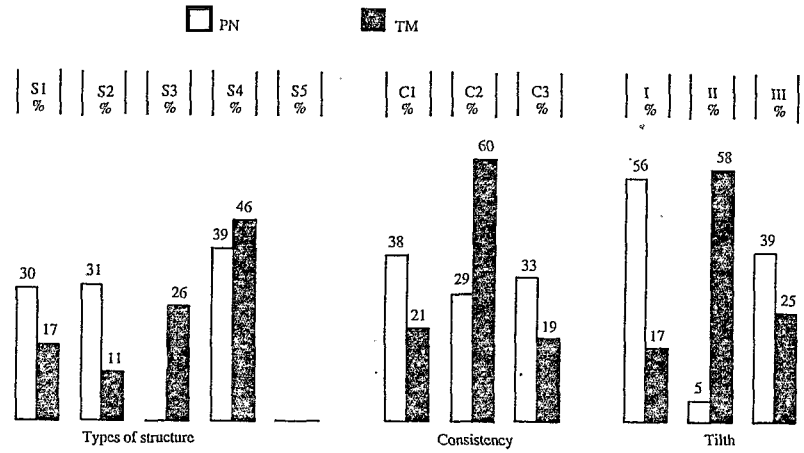


Figure 2. Distribution of structural types, consistency, and soil tilth classes, expressed as % of the cultivated horizon.

Type of structure

NP: fairly even distribution of classes S1, S2 and S4, with a slight dominance of S4.
MT: fairly clear structural decline marked by a trend away from S1 and S2 to less well differentiated structures of types S3 and S4.

Consistency

NP: fairly balanced distribution of classes, with a slight dominance of C1.

MT: C1 and C3 less important, with a clear dominance of C2, reflecting a more uniform consistency than with NP.

Tilth

NP: an almost polarized distribution of I and III, with type I representing more than half of the observations.

MT: considerably more balanced distribution, with a clear dominance of tilth II.

Root distribution parameters

For the four paired profiles examined, root density is a little higher for the MT treatment.

The index of regularity is moderate to fairly low, being slightly better for the NP treatment in three of the four pairs.

The index of vertical distribution shows a concentration of roots in the upper 30 cm independent of the two treatments.

The index of lateral distribution reflects preferential root development below the cane planting line. In three cases out of four, the NP treatment has a slightly higher index.

Root distribution and soil morphology

Table 3. **Average root distribution parameters** for paired profiles.

Parameters		Paired profiles			Average	
Root density	NP	2.1	1.5	2.3	3.0	2.2
	MT	2.2	1.7	2.5	3.1	2.4
Regularity	NP	0.37	0.28	0.40	0.43	0.37
	MT	0.32	0.33	0.38	0.40	0.35
Iv%	NP	80	87	74	86	82
	MT	95	73	80	80	82
Il%	NP	80	81	81	74	78
	MT	77	71	83	92	82

Superimposing root distribution on the cultivation profile data (Figures 3 and 4) indicates that:

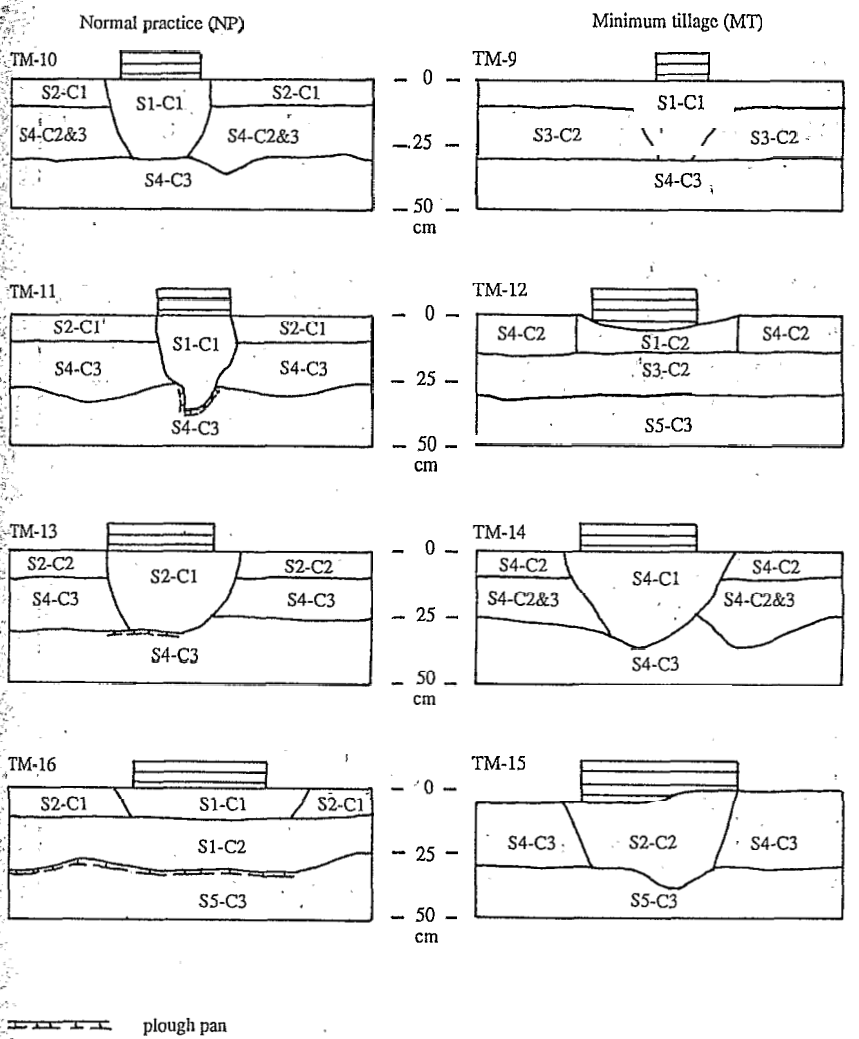


Figure 3. Morphologic schemes and soil tilth at the Hewetson site.

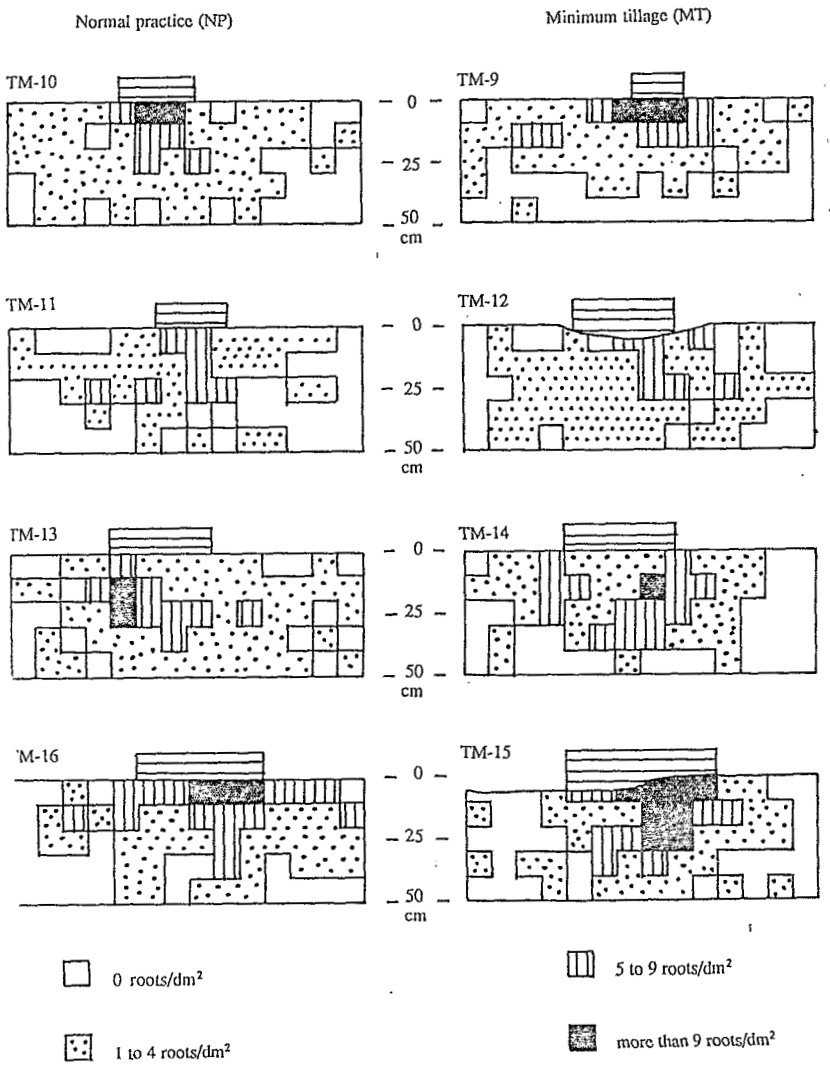


Figure 4. Root distribution at the Hewetson site.

- o vertically, roots are concentrated in the 30-cm thick cultivation horizon and penetrate with difficulty the massive and compact underlying horizon; and
- o laterally, roots tend to be concentrated in the furrow lines, which are often well marked, with better tilth.

Conclusion

This method of cultivation profile analysis was developed in the special context of Mauritius in order to help in the management of sugarcane monoculture. It showed no significant difference in soil tilth between fields prepared by NP - mechanical clearing, subsoiling, and furrowing - and fields prepared with MT - herbicide and furrowing.

This method also addresses agronomists on question relating to agricultural diversification in Mauritius, namely:

- Is the cultivation profile prepared for sugarcane also suitable for annual crops intercropped between perennials?
- If not, what technical procedure is to be recommended for crops and tilth between the rows?

The answer to the last question requires, for each soil-climate combination precise references to individual crops. In fact, soils under perennials are not frequently tilled (every 6-8 years at present), and show tilth properties comparable to those observed under natural vegetation.

In the case of annual cropping systems, interactions between soil and tillage implements are much more important than is the case with perennials. Tilth needs to be defined from other criteria adapted to each station. Reference can be made, for example, to the internal status of clods as well as to their assemblage.

Therefore characterization of the soil tilth is an efficient analytical means for carrying out diagnostic investigation and forecasting behaviour in connection with the following studies:

- o comparative trials of different cultivation techniques;
- o statistical surveys in agriculture; and
- o monitoring studies of cropping systems.

Observation of the root system also makes it possible to evaluate the consequences of the soil tilth and therefore of the cultural practices on crop behaviour. In low-input systems, the optimization of the root development is in fact a primary factor affecting yields.

References

BLIC, Ph. de. 1978. Morphologie et comportement mécanique des sols de la région Centre Côte d'Ivoire en culture semi-mécanisée. ORSTOM Adiopodoume, Côte d' Ivoire, 63p. Mimeo.

MANICHON, H. 1982. L'action des outils sur le sol : appréciation de leurs effets par la méthode du profil cultural. *Science du Sol* 3:203-209.