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Classification and mapping of morphological features associated to soil thickenings within cultivated hillslopes – Example from SW Parisian Basin, France

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Background: soil properties (e.g. water storage capacity, carbon content) are sensitive to soil thickness variations. Recording soil thickness in agrarian landscapes, therefore, is important for soil mapping.

Soil thickness is strongly linked to landscape morphology: depends on natural factors (tectonics, lithology, climate) and human activities. Agricultural practices affect soil erodibility, and field limits can act as barriers to soil matter fluxes for both water and tillage translocations → leads to the formation of linear morphological features that relate to local soil erosion/accumulation.

Aim: to assess whether different types of linear morphological features can be discriminated by their landform attributes and soil thicknesses.

1: Material & Methods

Study area:

- In Seully, SW Parisian Basin (Fig.1)
- 16 ha hillslope in a chalky watershed
- Elevation: from 38 to 80 m; mean slope: 5.3%
- Cultivated cereals and oil-producing crops
- Important land consolidation in 1967
- Two types of linear morphological features, with decametric width:



Fig. 1: location of the study area

Lynchets (L) = slope gentling and break-in-slope separated by downslope field limit (Fig. 2a)

Undulations (U) = wide gentle convexity (Fig. 2b)

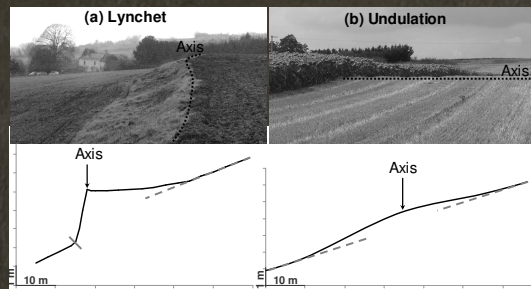


Fig. 2: view and typical cross-section of (a) a Lynchet, and (b) an undulation

Topography:

- Recording of coordinates (accuracy: few mm) and elevations (accuracy: one cm) of 1550 points
- DEM computation and calculation of slope (Fig. 3a), curvature, profile curvature and planform curvature

Soil thickness (A+B horizons):

- 734 manual soil augerings divided in two sampling schemes (Fig. 3b):
Sampling Σ : longitudinal and perpendicular sampling transects focused on the 9 more relevant features (3 Lynchets & 6 Undulations)
Sampling Δ : one point sampled randomly in each cell of a 25 m x 25 m grid over the whole study area

- Soil thickness estimation all over the study area using kriging (Fig. 3b)

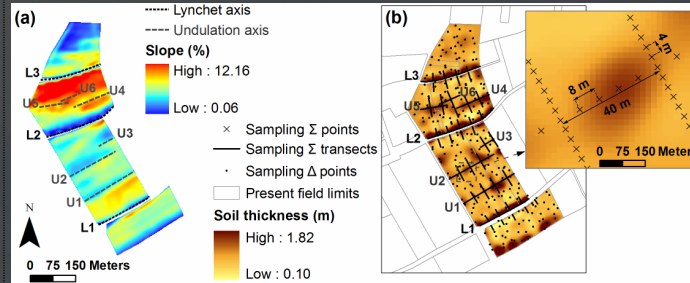


Fig. 3: data collected in the study area. (a) Slope map. (b) Soil thickness sampling schemes and estimation.

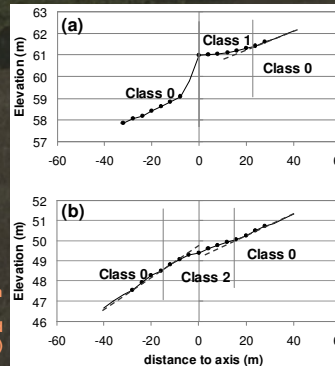
- Among the 734 points of the total dataset:
586 points = estimation dataset
148 points = validation dataset

Expert classification method:

To classify the 734 soil samples considering sample location on a specific type of morphological feature. Based on relief variation. (Fig. 4)

- Class 0: areas outside features influence
- Class 1: Lynchet
- Class 2: Undulation

Fig. 4: illustration of the expert classification method for perpendicular transects of sampling scheme Σ : (a) on a lynchet and (b) on an undulation (dot: sample location)



Statistical Analysis:

- Classification Tree (CT) = modelling approach (decision rules) to predict class belonging of a point from values of one or more predictor variables.
- CT algorithm applied to predictor variables of the estimation dataset:
 - i) landform attributes* and soil thickness (CTsoil)
 - ii) landform attributes* only (CTtopo)
- (* slope, curvature, profile curvature and planform curvature)
- Mapping of both CT results: estimation of class belonging of each raster cells (2 m x 2 m) all over the area by implementing decision rules in a GIS.
- Validation: comparison of expert classification and estimated classification of points from validation dataset.

2: Results & Discussion

- Validation results of **CTsoil** and **CTtopo** applications show model efficiencies of 83% and 67%, respectively:

→ **Both models perform well for Lynchets (Cl. 1)**
→ **Errors mainly due to difficulties in discriminating gentle Undulations (Cl. 2) and areas outside features influence (Cl. 0).**, especially when soil thickness is not accounted for

- Class 1 presents statistical differences with the two other classes for all the predictor variables (Tab. 1).
- Classes 0 and 2 appear numerically distinguishable based only on curvature, profile curvature and soil thickness (Tab. 1).

Contrast between class	Slope	Curvature	Profil curvature	Planform curvature	Soil thickness
1 vs 0	Yes	Yes	Yes	Yes	Yes
1 vs 2	Yes	Yes	Yes	Yes	Yes
2 vs 0	No	Yes	Yes	No	Yes

Table 1: Tukey's HSD (Honestly Significance Differences) test results

- Mean soil thickness is of 0.45 cm, 0.62 cm and 1.08 cm in Classes 0, 1 and 2, respectively.
- The general form of thickened soil is characteristic to each type of morphological features (Fig. 5).

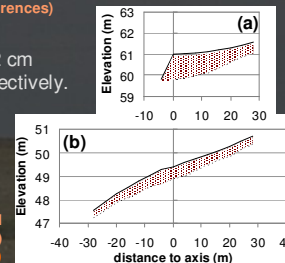


Fig. 5: illustrations of characteristic soil thickness evolution (a) in a lynchet (Cl. 1) and (b) in an undulation (Cl. 2)

- Detection of other Lynchets & Undulations by both CT result mapping
- Lynchets are associated with limits existing at least since 1836.
- Undulations are predominantly linked to field limits that disappeared during the last important land consolidation – 1967 (Fig. 6).

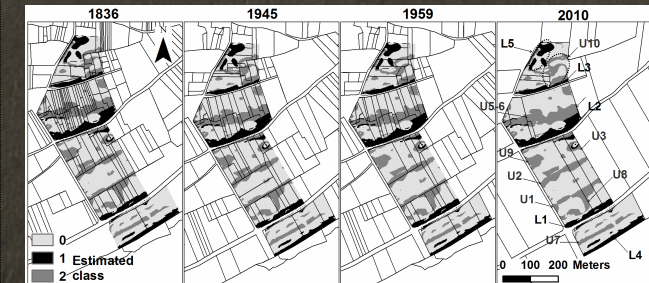


Fig. 6: maps of CTsoil model results & field limit networks of 1836, 1945, 1959 and 2010.

- Lynchets & Undulations cover more than 38% of the total study area & store about 7% and 8% of total soil of the study area, respectively.

3: Conclusion

- Development of a convenient method (usable as mapping tool).
- Efficient even if soil thickness is not known (especially for Lynchets).
- Lynchets & Undulations are indicators of human-induced soil accumulations: linked to field limits with different durations.
- Undulations are the most discrete BUT the most frequent features in W Europe due to land consolidation campaigns (1960's to 1980's).
- Perspectives in soil mapping: improvement of spatial estimation of soil thickness variations and related soil properties over large areas (association with new technologies for relief recording; e.g. LIDAR).