Soil redistribution in rural catchment: How fifty years old soil survey can help model improvement

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The Soil Map of Belgium

In 1947, a comprehensive systematic survey of the Belgian soil cover was initiated. Field observations were done every 75 meters by soil auger to a standard depth of 125cm (if possible).

Map units were delineated on cadastral field maps at scale 1:5,000 (Fig. 2.1), based on auger morphological observations and landscape context, then generalized on the 1:10,000 topographic base map for a publication at 1:20,000 scale (Fig. 2.2).

More recently, the Walloon part of this map was digitalized to produce the Digital Soil Map of Wallonia (DSMW) (PCNSW, 2004).

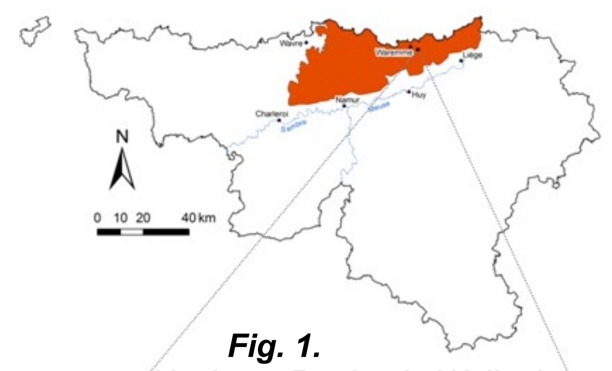

Fig. 1. *Hesbaye Region in Wallonia*

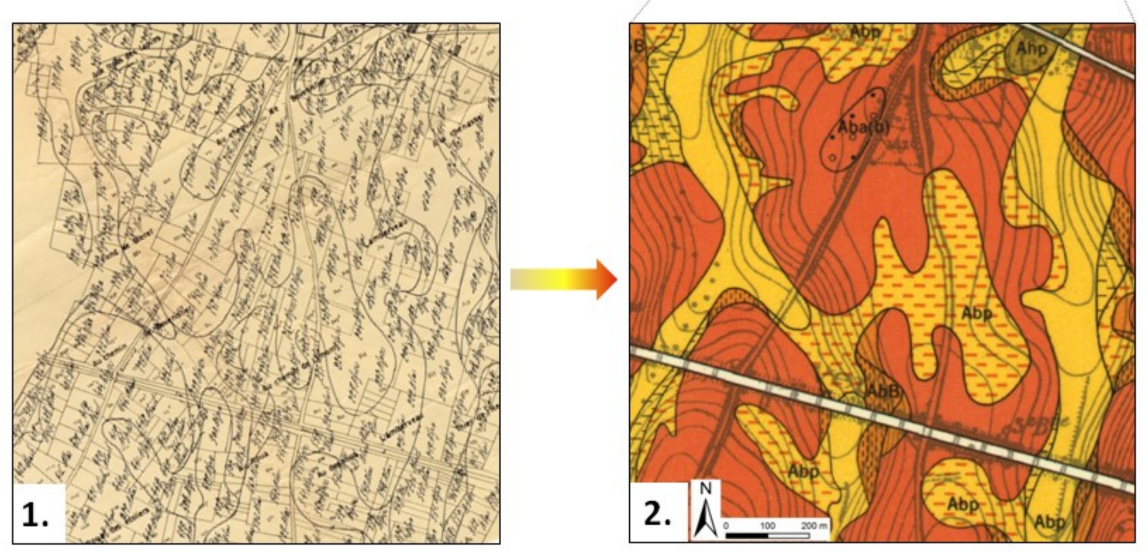

Fig. 2. *Extract from the sheet 120W—Waremme (Dudal, 1956) of the Soil Map of Belgium (the initial scale is not respected).*

1. Cadastral field map (1:5,000).
2. Printed soil map (1:20,000).

How does the soil map deliver information about erosion?

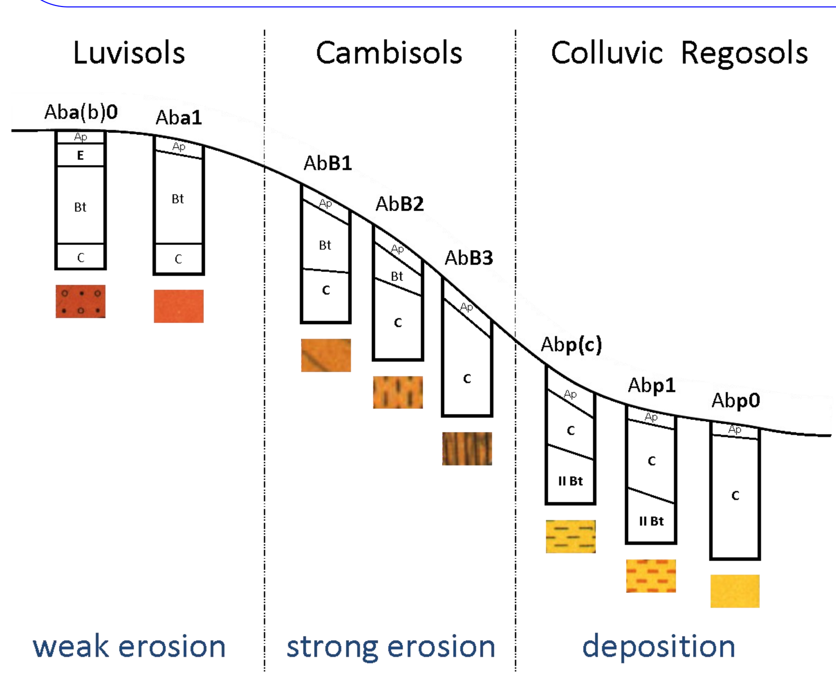

Fig. 3. *Typical soil mapping units of the Hesbaye Region, in relation with their position along a slope.*

The legend of the map includes more than 6,000 different soil types and variants. The cartographic symbols express soil morphology and properties that can be identified on the field (texture, hydromorphy, diagnostic horizon, …). Of which, some give information about erosion or deposition.

Fig. 3 illustrates this with soil mapping units representative of the studied region (Hesbaye, in the eastern part of the loamy Region (Fig. 1).

In this context, some suffixes (in bold on Fig. 3) inform about the presence of a E horizon, the depth of the lœss (parent material) or the thickness of colluviums.

Thematic revision of the soil map

Since 2010, new soil observations are carried out on different sites of the studied region, in order to :

- give spatially distributed information about erosion and deposition,
- estimate rates of erosion by comparison with historical information.

The observations are made by auger according to a catena logic and taking into account the existing limits of the map. These new observations are valuable for better understanding, localisation and quantification of net erosion, just like for validation of model results.

Nevertheless, some uncertainties remain since the old soil descriptions are based on depth classes. Moreover, the comparison with soil map need special precautions, due to the variability of soil mapping units and to the change of projection system since then. Discussion on corrections and remaining shifts is available in Lejeune (1995).

Erosion - deposition model

A 10m resolution DEM (Fig 4.3) was build up in 2009 using the best available data. Its RMSE is 0.8m on the z axis. Soil erodibility (Fig. 4.2) and rainfall erosivity (Fig. 4.1) maps were derived at the same resolution (Demarcin et al, 2009). A land use map exists at 1:10,000 scale since 2005 and is regularly updated.

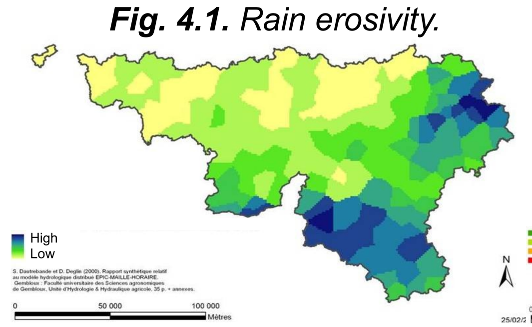

Fig. 4.1. *Rain erosivity.*

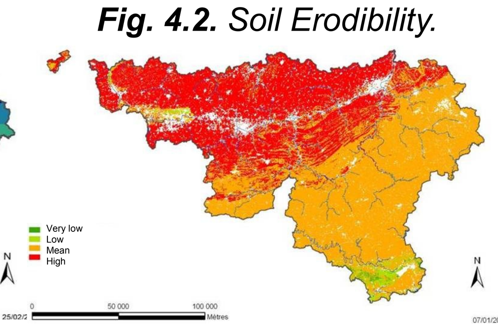

Fig. 4.2. *Soil Erodibility.*

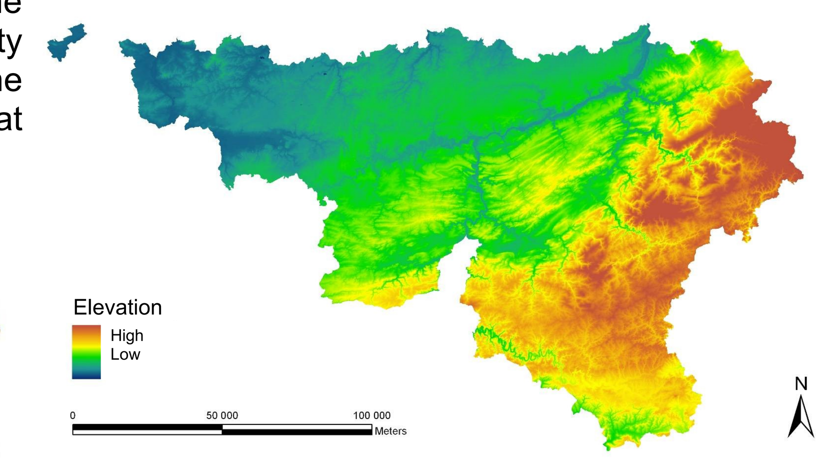

Fig. 4.3. *Digital Elevation model.*

USPED-RUSLE Model

The USPED simple model (Moore et al., 1992) predicts the spatial distribution of erosion and deposition zones in a watershed. One supposes that the sediment flow is equal to the transport capacity.

$$|q_s(r)| = T(r) = Kt(r).|q(r)|^m.\sin b(r)^n$$

Where : Kt(r) is a transportability coefficient related to the soil cover, q(r) is the water flow rate and b(r) is the slope. m and n are constant coefficient related to the soil type and the slope. Erosion and deposition rates are calculated by derivation of the flow rate along the slope.

As no experimental measurement is available, calibration of USPED equation is not available. Mitasova et al. (1996) and Mitas (1998) proposed to use the RUSLE equation in order to estimate the erosion rate (USPED-RUSLE model).

$$T = R.K.C.P.A^m.\sin[(b)]^n$$

Where R is the rain erosivity, K is the soil erodibility, C is the crop factor, P is the anti-erosive coefficient (set to 1), $A^m \sin(b)^n$ stands for LS. In this application, we modified the LS by introducing the LS computation proposed by Desmet and Govers (1996).

$$(LS)_{ij} = S_{ij}\left(\frac{1}{\lambda_{st}}\right)^m \frac{(V_{in-ij}+D^2)^{m+1} - V_{in-ij}^{m+1}}{D^{m+2}\delta_{ij}^m}$$

Where V_{in-ij} is the contributive area of the ij pixel, D is the raster resolution, δ_{ij} is the pixel's lenght factor depending on the flow direction (1 or 1,41), λ_{st} is the standard slope lenght, S_{ij} is the slope factor (Nearing, 1997).

Finally the erosion/deposition rate is obtained by derivation of the RUSLE equation :

$$ED = \frac{d(RKCLS\cos\alpha)}{dx} + \frac{d(RKCLS\sin\alpha)}{dy}$$

Sensitivity analysis : Influence of the C factor

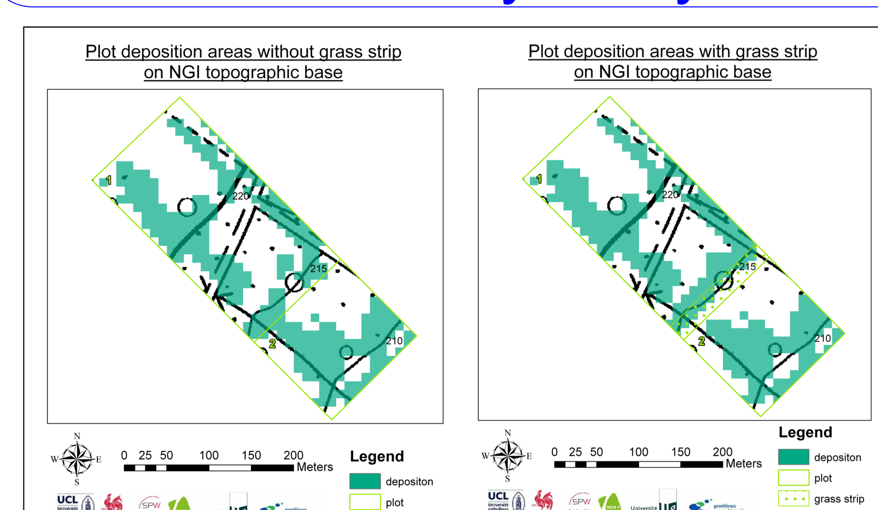

Fig. 5.1. *How a grass strip can modify the erosion/ deposition spatial distribution in a given field.*

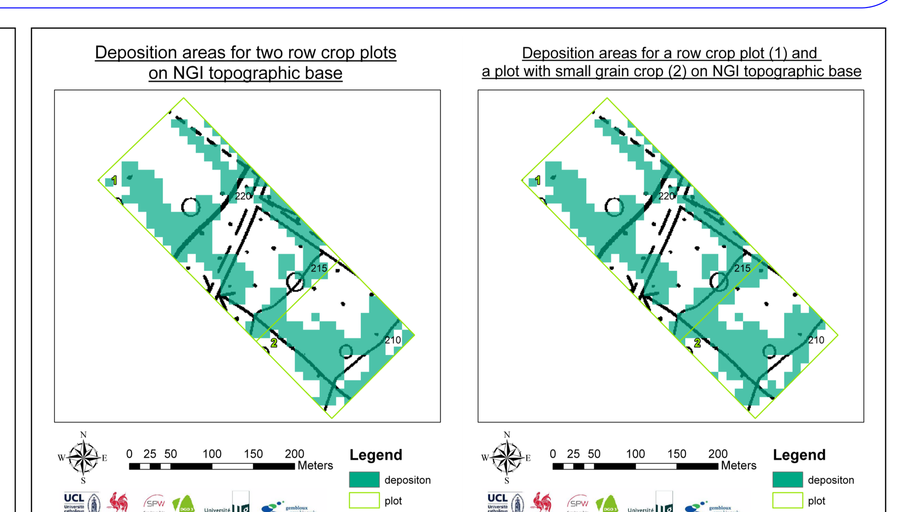

Fig. 5.2. *How a cereal instead of a row crop can modify the erosion/deposition spatial distribution in a given field.*

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Results and discussion

Spatial distribution of deposition zones

A first attempt was done to model deposition zones only based on the soil's erodibility and the MNT (C and P factors fixed to 1).

The spatial distribution of the deposition zones was compared to the observed deposition zones of the Soil Map of Belgium. One can see the quite promising results in Fig. 6. Some shifts between spatial distribution of the modelled and observed deposition zone have to be considered cautiously since the Soil Map of Belgium was partly built up on a quite old reference system. Detailed analysis still has to be achieved.

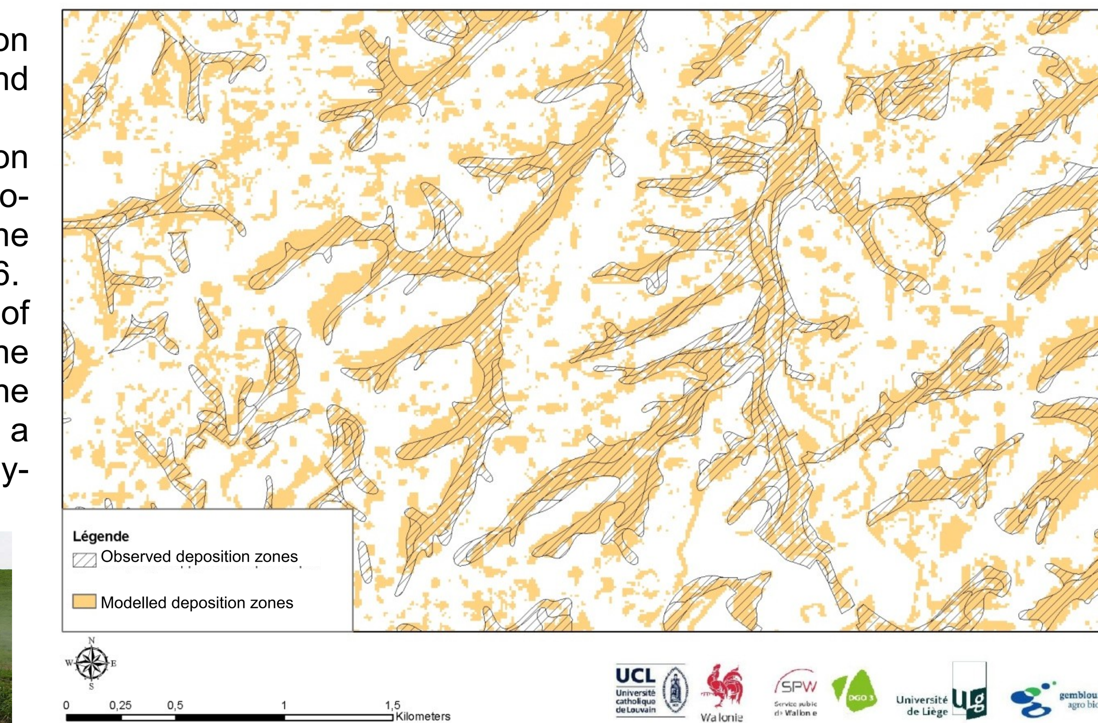

Fig. 6. *Comparison between deposition zones of the Digital Soil Map of Wallonia and deposition zones obtained by USPED-RUSLE modelling.*

Comparison between model and soil survey

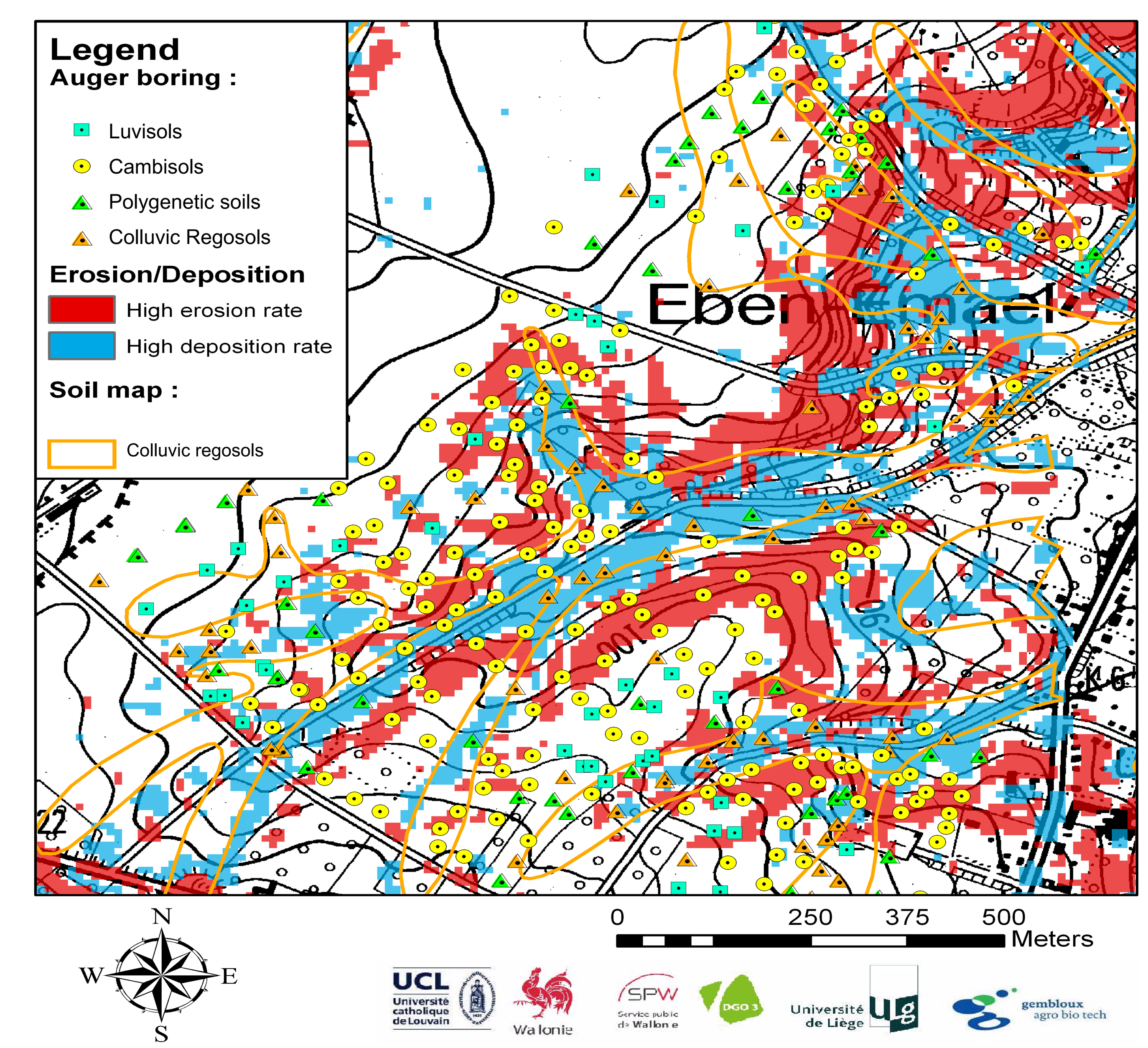

Fig 7. *Comparison between model, historical map and new observations*

The old survey (orange polylines) and the recent boring (orange triangles) show Colluvic Regosols where high deposition rates are calculated by the USPED-RUSLE model.

Few exceptions should be linked to local particularities and need further detailed analysis.

Recent auger borings highlighted polygenetic soils where colluviums are above strongly eroded soil (green triangles).

These particular zones represent key information in view to locate the transition between erosion and deposition zones and show how erosion models the relief with time.

The comparison between old and new surveys as well as the catena analysis through the landscape allow us to progress towards a calibration of the deposition model on a multidecadal basis.