Application of the Landsoil model to simulate water and tillage erosion in an intensively farmed landscape submitted to land consolidation with contrasting soil types

Sébastien Salvador-Blanes, E. Halais, Benjamin Gaudubert, Joël J. Daroussin, Florent Hinschberger, Rossano Ciampalini, Alain A. Couturier, Caroline Chartin

Application of the Landsoil model to simulate water and tillage erosion in an intensively farmed landscape submitted to land consolidation with contrasting soil types

Salvador-Blanes, S.[1], Halais, E.[1], Gandubert, B.[1], Daroussin, J.[2], Hinschberger, F.[1], Ciampalini, R.[3], Couturier, A.[2], Chartin, C.[1]

[1] EA 6293 GéHCo – GéoHydrosystèmes Continentaux, Université François Rabelais de Tours, Faculté des Sciences et Techniques, Parc de Grandmont, 37200 Tours – France – salvador@univ-tours.fr
[2] INRA – Unité de Science du Sol, 2163 avenue de la Pomme de Pin, CS 40001 Ardon, 45075 Orléans Cedex 22 – France
[3] INRA – UMR LISAH - 2, place Pierre Viala, 34060 Montpellier Cedex 1 – France

INTRODUCTION AND AIMS

Soil erosion processes have increased through the last decades in particular through land consolidation. Water and tillage erosion processes have been extensively studied and modeled at various time and space scales. The recently developed Landsoil model (Ciampalini *et al.*, in press), partly based on the STREAM model (Cerdan *et al.*, 2002) is the first expert model to spatially simulate both water and tillage erosion at the event scale.

We apply it here for the period 2010-2100 to an intensively farmed area in temperate climate, where two contrasting soil types are observed. The aim is to quantify the effect of water and tillage erosion on morphogenesis over a century.

STUDY AREA

Seuilly (Loire valley), NW France
- 240 ha, elev. 30-100 m, SE facing slope 0-25%.
- Climate: oceanic, 615 mm rain evenly distributed throughout the year.
- Geology: quaternary loess on the plateau, cretaceous chalks on the slopes and fluvial deposits.
- Soil types: clayey Calcaric Cambisols on the slopes, loamy Cambisols on the plateau.
- Landuse (Fig. 1): winter and spring crops (85%, cereals and oilseeds). Land consolidation in 1967, 1982.

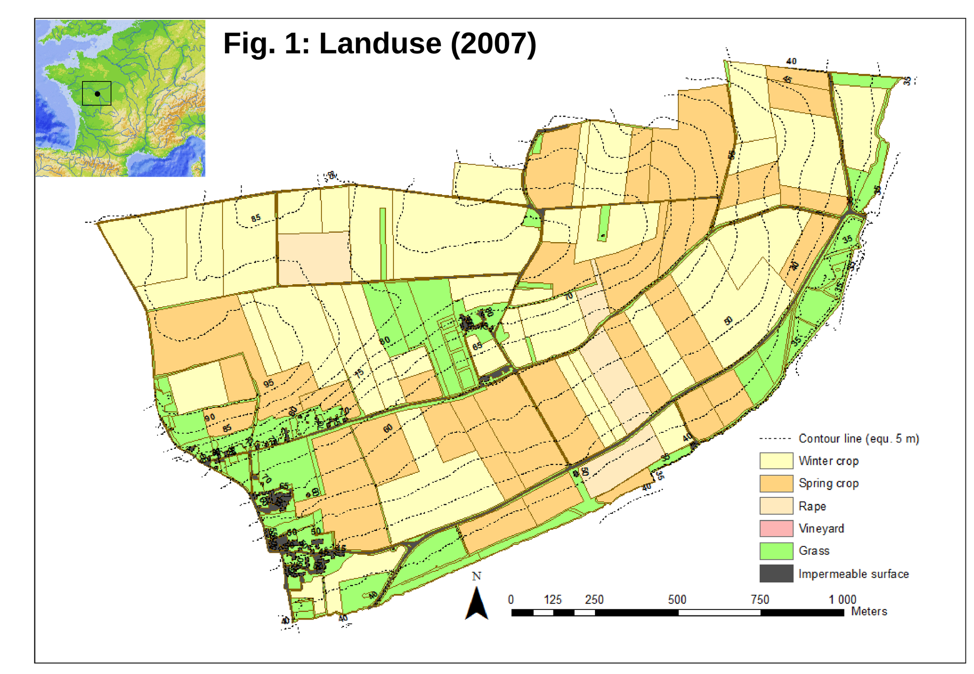


Fig. 1: Landuse (2007)

STRUCTURE OF THE MODEL

Each year between 2010-2100: water and tillage erosion processes simulated successively according to Figure 2. After each rainfall event or tillage operation, a new topography is calculated.

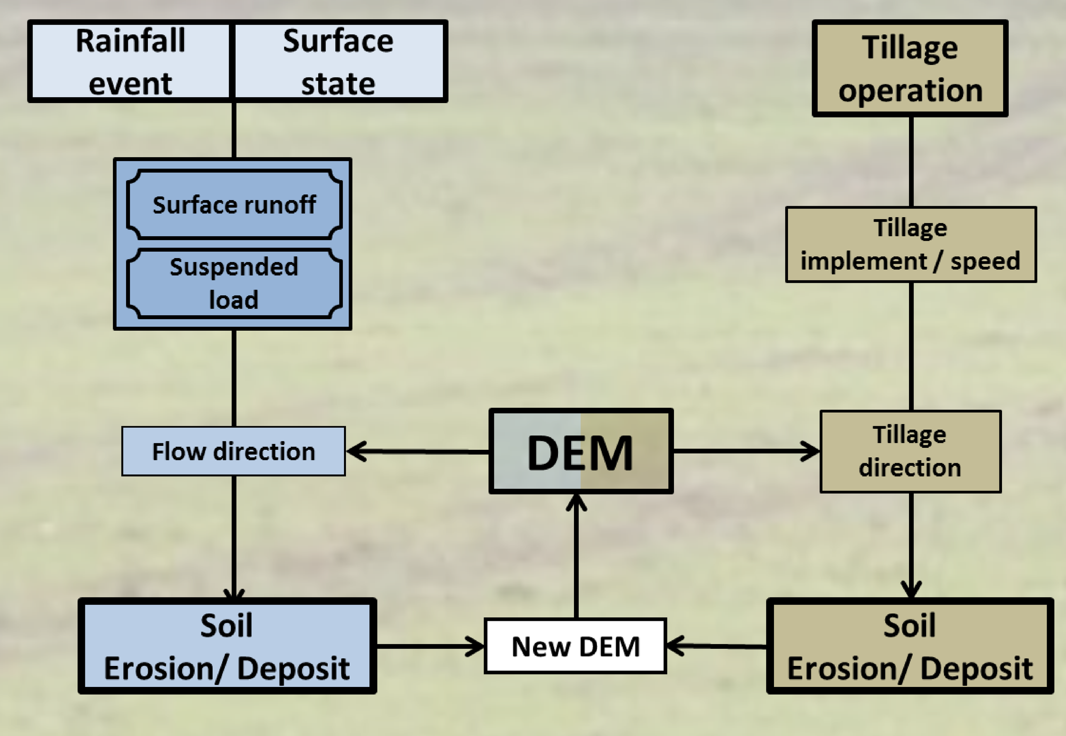


Fig. 2: Model structure

MODEL PARAMETERS

Rainfall events
Simulated till 2100 by using GIEC B1 scenario regionalised data, and implemented as 6 mn data to determine total rainfall, duration, 6mn max. intensity, 48 hrs antecedent rainfall.

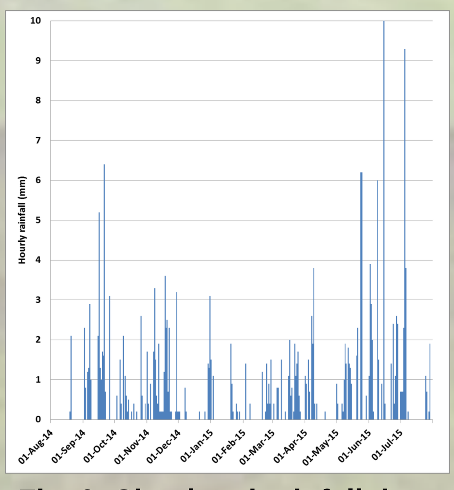


Fig. 3: Simulated rainfall data

Rules for soil susceptibility to erosion (surface runoff, suspended load): adapted to the study site according to literature data.

Flow and tillage direction:
2x2m DEM resulting from the treatment of 2009 LiDAR data (application of filters).

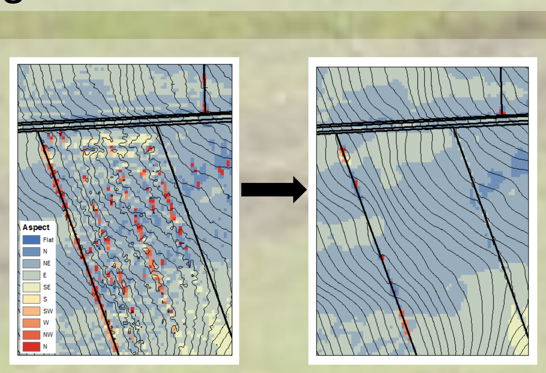


Fig. 4: DEM before/ after filtering

Surface state

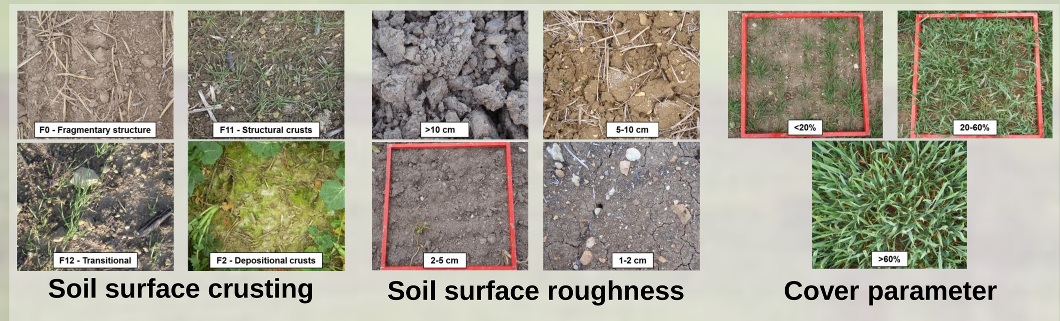


Fig. 5: Surface state classes

6 monthly surface calendars (field observations): 3 main crop types influencing erosion specifically (winter crops (WC), spring crops (SC), oilseed (OS)), 2 soil types.

2 types of crop rotations simulated:
WC-SC-WC-SC and WC-OS-WC-SC

Tillage implement and speed: tillage transport coefficients determined according to litterature (Van Muysen *et al.*, 2000).
1 ploughing/3 yrs + 2 stubble ploughings/yr

APPLICATION OF THE MODEL

Differences in elevation
- 35% > 2 cm
- 13% > 5 cm
- 5% > 10 cm

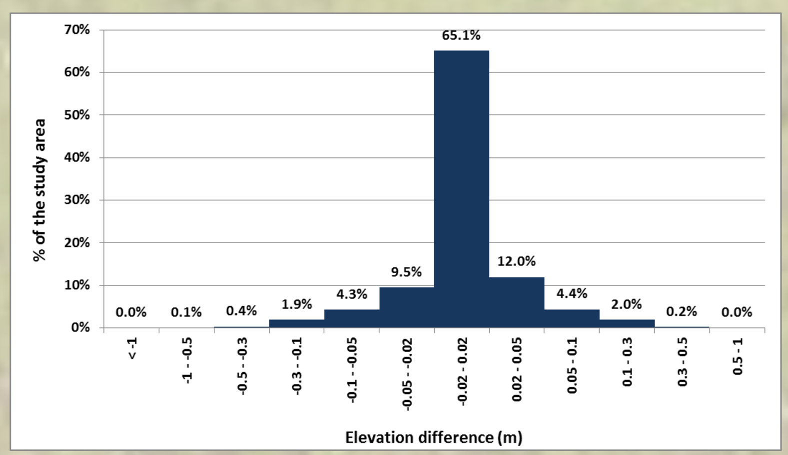


Fig. 6: Histogram of elevation variations

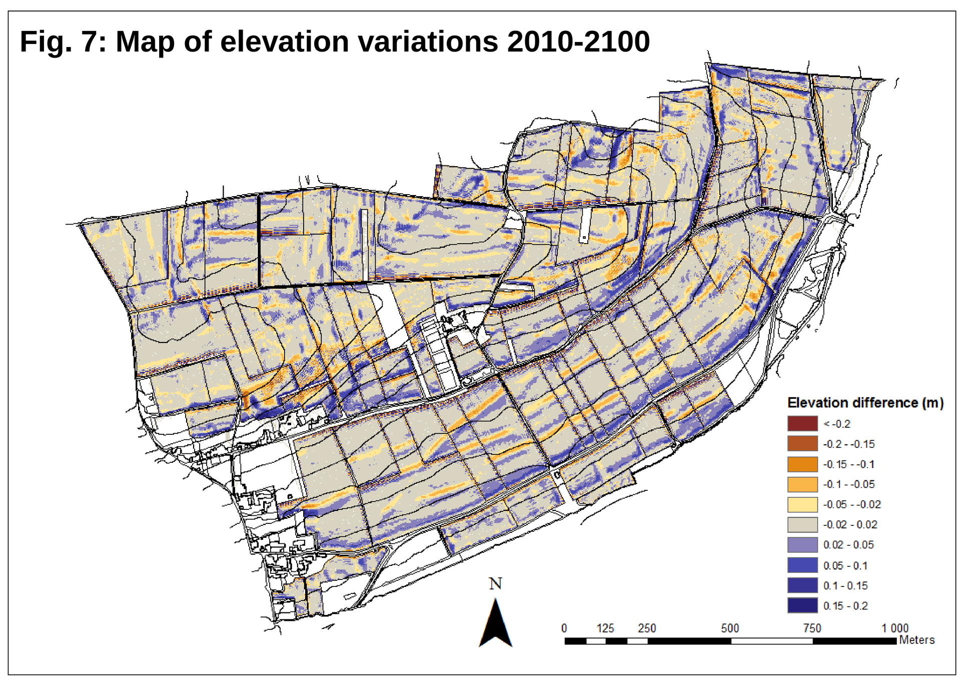
- Erosion area: 33%
- Deposition area: 40%
- Stable area: 27%
- Total sediment export: 212 m³

Spatial structure of variations
Variations spatially structured, showing linear features (Fig. 7), corresponding to current or former field limits that existed before land consolidation.
Current field limits: lynchet accretion, regressive towards upslope (Fig. 8).
Former field limits: erosion of undulations, accumulation observed immediately below (Fig. 9).

⇒ Redistributions mainly due to tillage erosion, comparable to 'sedimentary waves' within fields.

^{137}Cs data comfort this hypothesis (Chartin *et al.*, submitted)

Fig. 7: Map of elevation variations 2010-2100



Few morphological erosion features characteristic of water erosion, except in small valleys of NW part (loamy soils, more susceptible to erosion)

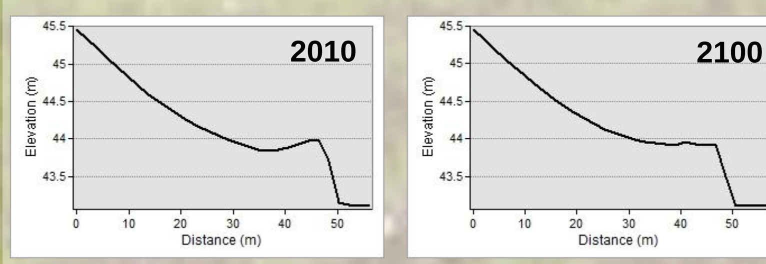


Fig. 8: Lynchet morphological evolution

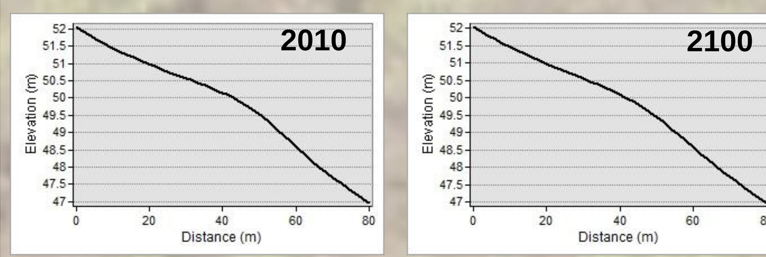


Fig. 9: Undulation morphological evolution

Tillage erosion provokes a progressive smoothing of the topographic discontinuities initially created by human activities.

CONCLUSIONS AND PERSPECTIVES

The application of the Landsoil model over a century in an intensively farmed area mainly occupied by crops shows that the morphological evolution of the landscape is mainly governed by tillage erosion, that results in a progressive smoothing of the landscape features causing sedimentary waves. Areas where water erosion is not the main erosion process and where land consolidation occurred should show a similar evolution.

This should cause a significant modification of soil surface horizons properties. Further analyses are expected to show the evolution of organic carbon in relation to soil redistribution by linking the Landsoil model with a model of organic carbon dynamics (Viaud *et al.*, 2010).

REFERENCES

Cerdan, O., Souchère, V., Lecomte, V., Couturier, A., Le Bissonnais, Y. 2002. Incorporating soil surface crusting processes in an expert-based runoff model: Sealing and Transfer by Runoff and Erosion related to Agricultural Management. Catena, 46: 189-205.

Chartin, C., Evrard, O., Salvador-Blanes, S., Hinschberger, F., Macaire, J.-J., Van Oost, K., Daroussin, J. Quantifying and modelling the impact of land consolidation and field borders on soil redistribution in agricultural landscapes (1954 - 2009). Submitted.

Ciampalini, R., Follain, S., Le Bissonnais, Y, 20##. LandSoil: a model for the analysis of the impact of erosion on agricultural landscape evolution. Geomorphology, in press.

Van Muysen, W., Govers, G., Van Oost, K, Van Rompaey, A. 2000. The effect of tillage depth, tillage speed, and soil condition on chisel tillage erosivity. Journal of Soil and Water Conservation, 55: 355-364.

Viaud, V., Angers, D.A., Walter, C. 2010. Toward Landscape-Scale Modeling of Soil Organic Matter Dynamics in Agroecosystems. Soil Science Society of America Journal, 74: 1847-1860.

This work is part of the ANR 'Landsoil' research project funded by the french Agence Nationale pour la Recherche