SSS2.5 | Soil erosion and driving factors of soil carbon distribution: a worldwide threat

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LATERAL TRANSPORT OF **SOC** INDUCED BY WATER EROSION IN A SPANISH AGROECOSYSTEM

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Research article

Lateral mobilization of soil carbon induced by runoff along karstic slopes

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Background

- Soil erosion induced by runoff is a main hydrological pathway for the lateral transport of carbon in terrestrial landscapes
- There is a need to consider the global significance of soil erosion on carbon cycling schemes

Objective

- Characterize the lateral mobilization of soil organic carbon (SOC)
- Along 5 topographically driven transects over a period of four decades
- In a sub-humid karstic area in northern Spain
- By using information of soil loss or gain based on ¹³⁷Cs inventories
- I) Assess what factors modify the runoff patterns with impact on soil redistribution
- II) Evaluate the mobilization of topsoil organic carbon and the soil carbon balance along the transects
- We obtained information about how water erosion influences the carbon gains and losses at different erosional and depositional landform positions in a fragile agroecosystems with a variety of land uses and ephemeral hydrological and sedimentological pulses, typical of Mediterranean environments.



Location of the study area

- North Spain
- 5 transects T1, T2, T3, T4, T5 | 58 sampling points
- Maps of the drainage network, with the stream order and landscape linear elements





Soil and SOC loss and gain

- Per each soil profiles along the five transects we estimated:
- SOC contents (%) ————
- Rates of soil thickness gained or lost (mm ha⁻¹ yr⁻¹) based on calibration of ¹³⁷Cs inventories
- SOC stocks (Mg ha⁻¹ yr⁻¹) estimated gain and loss of
- + values refer to gain and values refer to loss





Main outputs

- Maximum thickness of soil gained and lost varied from +3.59 to -4.40 mm ha⁻¹ yr⁻¹, respectively, based on ¹³⁷Cs soil redistribution rates for each soil profile.
- SOC contents (%) were converted into contents per surface area (stocks, kg m⁻²) multiplying the content by the mass of the fine fraction and dividing by the surface of the core sampler
- Taking into account the thickness range of soil lost or gained (mm ha⁻¹ yr⁻¹) in each sampling site we derived an average value of SOC loss or gain (Mg ha⁻¹ yr⁻¹) over the 40 years study period based on the percentage of SOC estimated from the topsoil samples
- The water erosion-induced carbon loss and gain was also highly variable ranging between -0.8 and +1.4 Mg ha⁻¹ yr⁻¹ of SOC
- The moderate values of soil loss and gain in uncultivated points confirm the protective effect of the vegetation cover
- The opposite occurs in cultivated steep sites where soil loss doubled the values of uncultivated sites because runoff is not constrained by the vegetation cover.

Vegetation has a significant effect on water erosion processes, intercepts rainfall and protects soil from raindrop impacts by reducing the energy of raindrop through raindrop size fragmentation



Effects of flow accumulation

- From lowest to highest flow accumulation values (axis X) a significant increase in:
 - The loss of soil (axis Y) Brown
 - The loss of SOC (axis Y) Green
- The general trends reflect the runoff effects on soil and carbon mobilization



Blue lines represent the fitted linear models, darker coloured stripes indicate the confidence bands, and the lighter coloured stripes the prediction bands. Dashed lines indicate the limits between values of gain (+) and loss (-) of each variable.



Effects of curvature

• The concave areas and flat cultivated sites at the bottom part of the transects recorded twice of maximum soil gain than in uncultivated sites.

Soil gain/loss (mm ha⁻¹ yr⁻¹) versus SOC gain/loss (Mg ha⁻¹ yr⁻¹)



Scatter plots of gain/loss of soil (mm ha⁻¹ yr⁻¹) versus the gain/loss of SOC (Mg ha⁻¹ yr⁻¹). Lines represent the fitted linear models: I) All samples, II) Cultivated samples at concave sites, III) Cultivated samples at convex sites, IV) Uncultivated samples at convex sites, V) Uncultivated samples at convex sites



Lateral mobilization of soil and SOC

- By using a perceptual model, the thickness loss or gain of soil and the related SOC for each profile was extrapolated along the hillslope, assuming each transect represents a 1 m wide strip
- To obtain sediment budgets for different sections along the transects, the resulting areal estimates provided information on (Similarly for the SOC budgets)
 - Total (gross) soil loss (kg yr⁻¹)
 - Total (gross) soil gain (kg yr⁻¹)
 - Net soil loss (kg yr⁻¹)
 - Sediment delivery ratio (%)





Lateral mobilization of soil and SOC

- The potential highest contribution of sediments and carbon to the lake were identified in T4 and T5
- When considering LLE the sediment budgets showed that the net soil loss was reduced by up to 88% in T4 being also negligible the apportions of the mobilized soil and carbon in T5
- Marked differences between the gain and loss of soil and SOC in concave and convex areas reveal how well-connected concave slopes with predominant interrill erosion deliver rich organic carbon sediment





Sediment and SOC budgets

Schematic sediment budgets obtained for the sections that contribute to the lake for each of the transects





Conclusions

Our results point to the significance of landform position on the erosion-induced terrestrial carbon sink and C sequestration

- The integrated approach employed provides a useful basis for estimating and improving our understanding of mobilization, transport and storage of soil and carbon in the landscape
- The use of ¹³⁷Cs along with the characterization of terrain attributes allowed us to identify whether erosional or depositional processes have been predominant in each study site
- Erosion and depositional processes play an important role in determining landscape scale topsoil SOC distribution, and it also indicates that SOC and sediments follow similar redistribution pathways
- The interactions between topography and land use produce significant effects on SOC
- The presence of LLE creates hydrological disconnection reducing runoff and sediment supply
- The budgets obtained allow us for the first time to have a quantitative estimation of the potential contribution of sediments and SOC to the *Estanque Grande de Abajo* Lake



Thank you for your attention

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Joint FAO/IAEA Division





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Leticia Gaspar^{1*}, Lionel Mabit², Ivan Lizaga¹, Ana Navas¹

Background

Soil erosion induced by runoff is a main hydrological pathway for the lateral transport of carbon in terrestrial landscapes, and there is a need to consider the global significance of soil erosion on carbon cycling schemes.

Objective

Characterize the lateral mobilization of soil organic carbon (SOC) along 5 topographically driven transects over a period of four decades in a sub-humid karstic area in northern Spain: I) Assess what factors modify the runoff patterns with impact on soil redistribution, II) Evaluate the mobilization of topsoil organic carbon and the soil carbon balance along the transects.

We obtained information about how water erosion influences the carbon gains and losses at different erosional and depositional landform positions in a fragile agroecosystems with a variety of land uses and ephemeral hydrological and sedimentological pulses, typical of Mediterranean environments.

Location of the study site 5 Transets 12, 12, 13, 14, 15 58 Sampling sites 0 Study site 10 Concave 0 Concave 0 Concave 10 Concave

Maps of the drainage network, with the stream order and landscape linear elements North Spain | 5 transects | 58 sampling points



each sampling site. Positive values refer to gain and negative values refer to loss.

Soil and Carbon loss and gain | Effects of flow accumulation and curvature

The maximum thickness of soil gained and lost varied from +3.59 to -4.40 mm ha⁻¹ yr⁻¹, respectively, based on 137 Cs soil redistribution rates for each soil profile.

The water erosion-induced carbon loss and gain was also highly variable ranging between -0.8 and +1.4 Mg ha⁻¹ yr⁻¹ of SOC.

The moderate values of soil loss and gain in uncultivated points confirm the protective effect of the vegetation cover. The opposite occurs in cultivated steep sites where soil loss doubled the values of uncultivated sites because runoff is not constrained by the vegetation cover.

Regarding the curvature, we conclude that concave areas and flat cultivated sites at the bottom part of the transects also recorded twice of maximum soil gain than in uncultivated sites.

Vegetation has a significant effect on water erosion processes, intercepts rainfall and protects soil from raindrop impacts by reducing the energy of raindrop through raindrop size fragmentation.



Gain/loss of soil (mm ha⁻¹ yr⁻¹) versus gain/loss SOC (Mg ha⁻¹ yr⁻¹)

Scatter plots of gain and loss of soil (mm ha⁻¹ yr⁻¹) versus the gain and loss of SOC (Mg ha⁻¹ yr⁻¹). Lines represent the fitted linear models: 1) All samples, III (Lutitvated samples at concave sites, III) Cutitvated samples at concave sites, V) Uncutitvated samples at convex sites and the samples at convex sites, V) Uncutitvated samples at convex sites, V) Uncutitvates values at convex sites, V) Uncutitvates values val

The general trends from lowest to highest flow accumulation values, showed a significant increase in the loss of soil and SOC reflecting the runoff effects on soil and carbon mobilization.



Blue lines represent the fitted linear models, darker coloured stripes indicate the confidence bands, and the lighter coloured stripes the prediction bands. Dashed lines indicate the limits between values of gain (+) and loss (-) of each variable.

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Lateral mobilization of soil and SOC | Sediment and carbon budget

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Taking into account the thickness range of soil lost or gained (mm ha⁻¹ yr⁻¹) in each sampling site we derived an average value of SOC loss or gain (Mg ha-1 yr-1) over the 40 years study period based on the percentage of SOC estimated from the topsoil samples.

By using a perceptual model, the thickness loss or gain of soil and the related SOC for each profile was extrapolated along the hillslope, assuming each transect represents a 1 m wide strip. To obtain sediment budgets for different sections along the transects, the resulting areal estimates provided information on total (gross) soil loss (kg yr⁻¹), total (gross) soil gain (kg yr⁻¹), net soil loss (kg yr⁻¹) and the sediment delivery ratio (%). Similarly, SOC budgets.

ΤЗ

The interactions between topography and land use produce significant positive or negative effects on SOC.

The potential highest contribution of sediments and carbon to the lake were identified in T4 and T5. However, when considering LLE the sediment budgets showed that the net soil loss was reduced by up to 88% in T4 being also negligible the apportions of the mobilized soil and carbon in T5.

Marked differences between the gain and loss of soil and SOC in concave and convex areas reveal how well-connected concave slopes with predominant interrill erosion deliver rich organic carbon sediment.

Our results point to the significance of landform position on the

erosion-induced terrestrial carbon sink and C sequestration. Τ5

Transect T5

LLE Landscape Lir Estimates of loss and gain of soil and SOC (kg yr-1) for individual 1-m wide segments along the transects

Т4

Transect T4

Schematic sediment budgets obtained for the potential sections that contribute to the lake for each of the transects

Τ4 Cultivated Uncultivat 00 Concave Convex Topograph Terraces, trails Vegetation strip 2.1 kg yr Total soil loss Total soil gain I NO SDE SOC net loss 2.5 kg yr Τ5 Altitude m Τ1 900 2.6 kg v 550 100 m

Conclusions

The integrated approach employed provides a useful basis for estimating and improving our understanding of mobilization, transport and storage of soil and carbon in the landscape.

The use of $^{\rm 137}\rm{Cs}$ along with the characterization of terrain attributes allowed us to identify whether erosional or depositional processes have been predominant in each study site.

Erosion and depositional processes play an important role in determining landscape scale topsoil SOC distribution, and it also indicates that SOC and sediments follow similar redistribution pathways.

The presence of LLE creates hydrological disconnection reducing runoff and sediment supply.

The budgets obtained allow us for the first time to have a quantitative estimation of the potential contribution of sediments and SOC to the Estanque Grande de Abajo Lake.

REFERENCE

and Agriculture, International Atomic Energy Agency, Vienna, Austria

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Т2

Τ1