https://doi.org/10.5194/egusphere-egu22-2000

Assessment of soil erosion induced by different tillage practices through multi-temporal geomorphometric analyses

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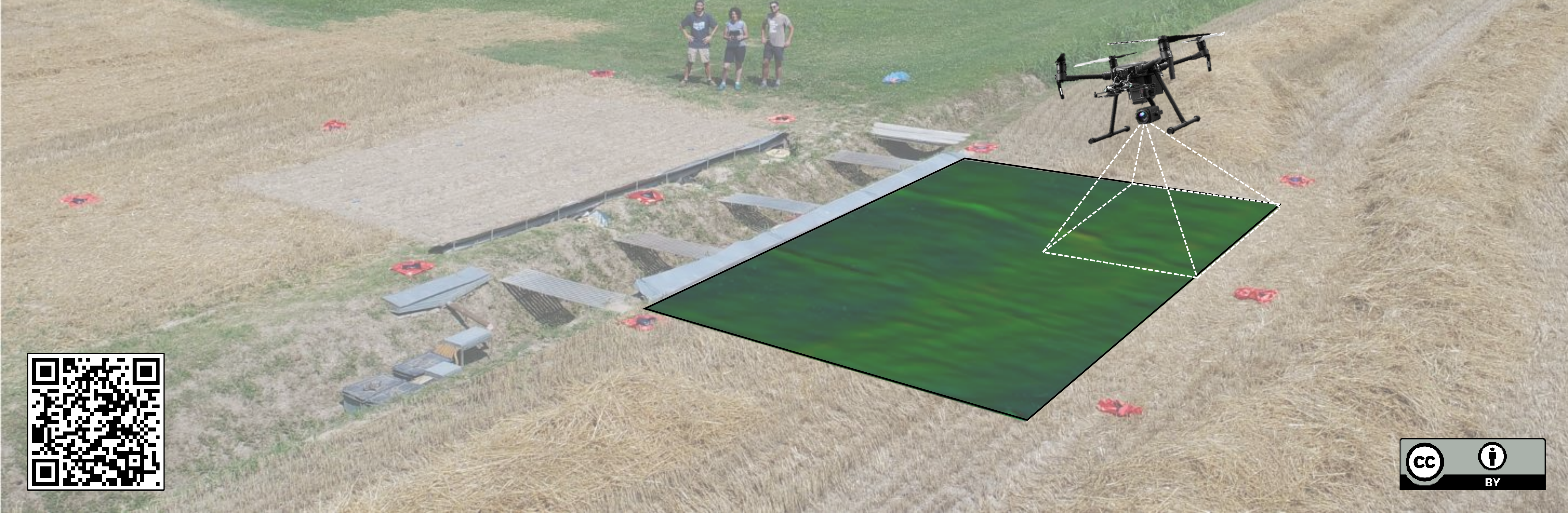


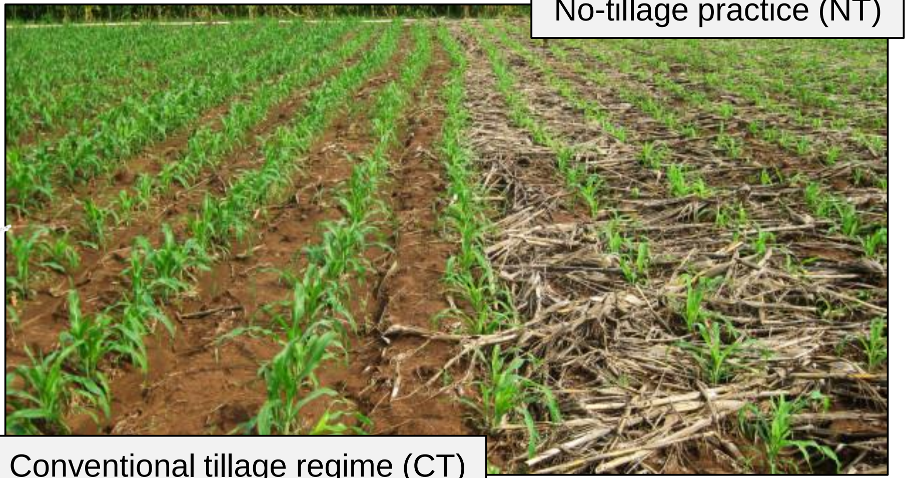
Aim of the research

Cucchiaro et al., 2022 JAE
10.4081/jae.2022.1279

In agricultural fields, **no-till management is considered a key approach** for mitigating soil erosion.

The **measurement of soil erosion** is commonly time-consuming and particularly challenging, especially when surficial morphological changes are relatively small.

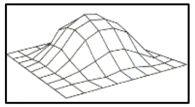
The **Structure From Motion (SfM)** photogrammetry technique has enhanced the experimental activities by enabling the temporal evolution of soil erosion to be assessed through detailed micro-topography.



This work presents a multitemporal **quantification of soil erosion for understanding the evolution of no-till (NT) and conventional tillage (CT)** in experimental plots, using SfM through Uncrewed Aerial Vehicles (UAV) survey.

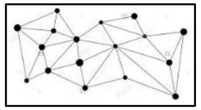
A **methodological workflow** was developed to identify **the effectiveness** of multi-temporal SfM derived products, for soil volume computations:

The conventional difference of digital terrain models **(DoDs)**



VS

The less used differences of meshes **(DoMs)**



Validation of the erosion volumetric changes **with conventional runoff and sediment measurements in the field.**

Study area

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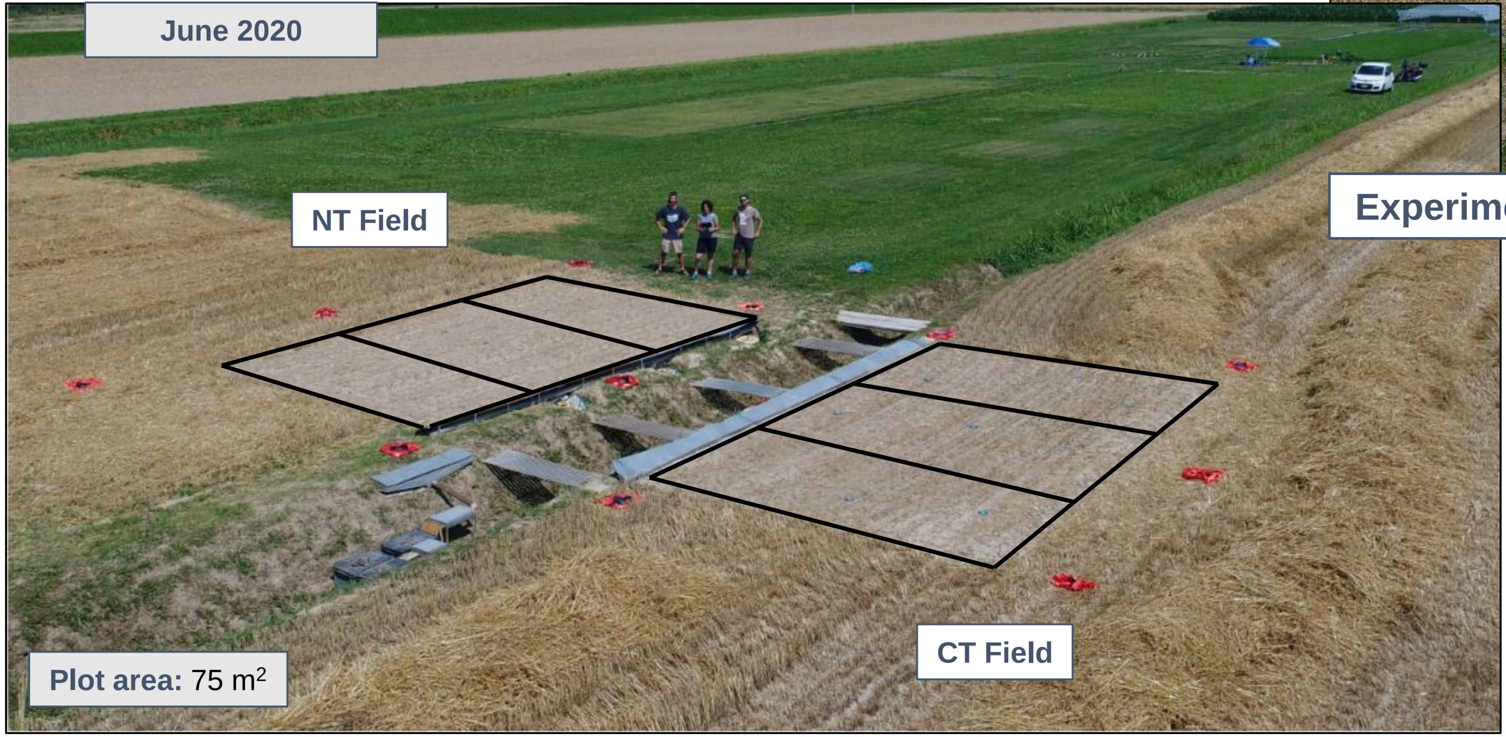
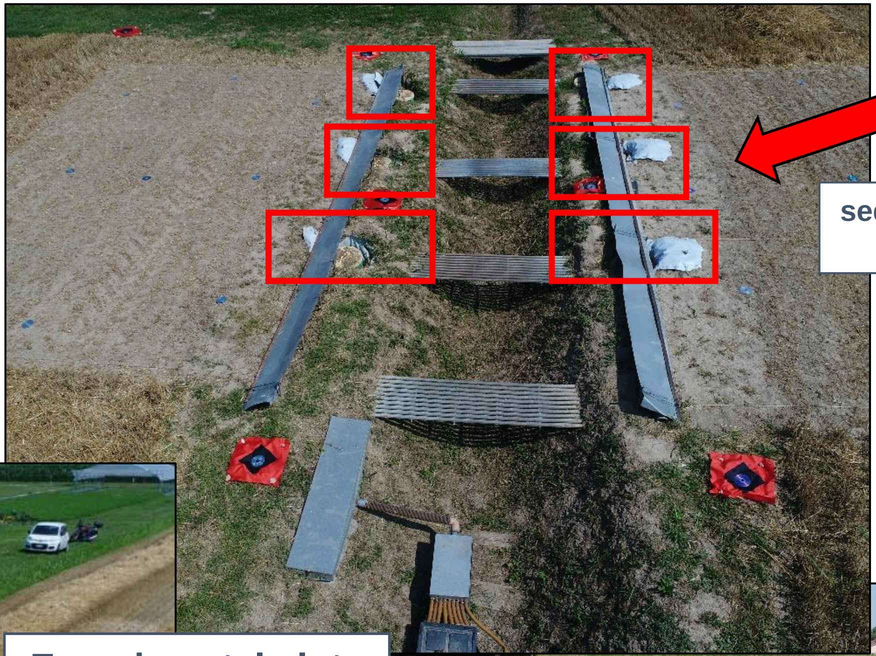
Italy

Experimental Farm of the University of Padova

SfM Multi-temporal surveys

- September 2018
- November 2019
- June 2020





sediment collection tanks

Experimental plots

Data acquisition

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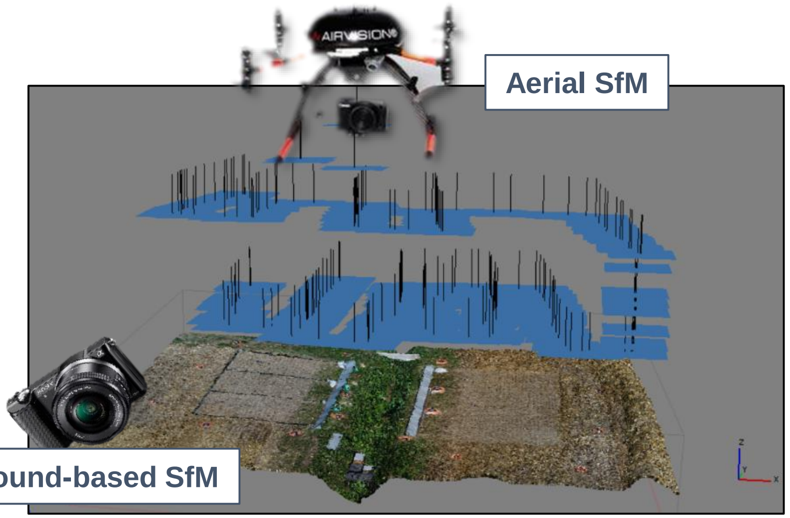
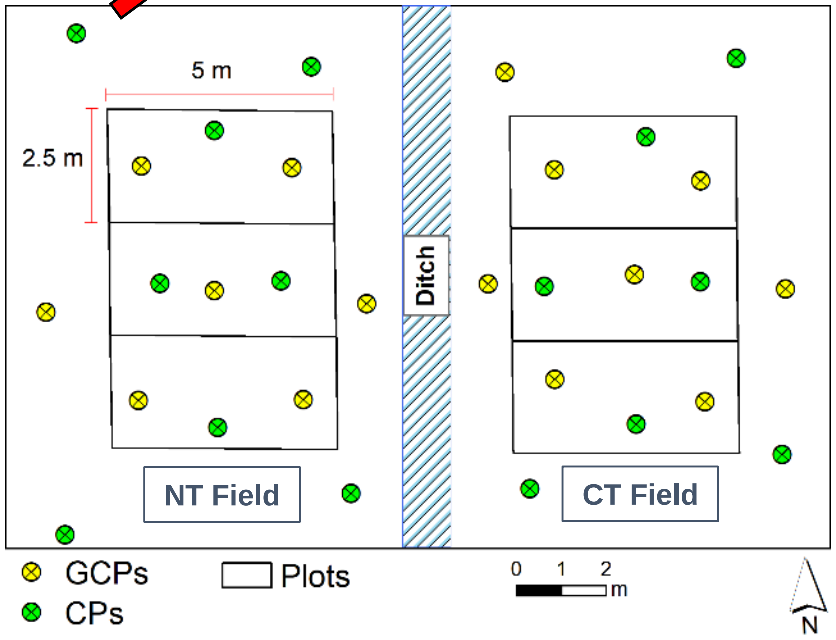
SfM Multi-temporal surveys

- September 2018
- November 2019
- June 2020



Schematic drawing of SfM survey



Date	September 2018	November 2019	June 2020
Field conditions	8 days after maize harvesting	Seven days after wheat sowing	Three days after wheat harvesting
Number of targets (GCP) [CP]	30 [10]	30 [10]	30 [10]
Positional Accuracy (X, Y – Z) (m)	<0.05	0.03-0.04	0.03-0.04
Number of images	308	337	333
Flight Height (m)	8	8	8
Ground Sample Distance (GSD) (m)	0.002	0.002	0.002

Data processing

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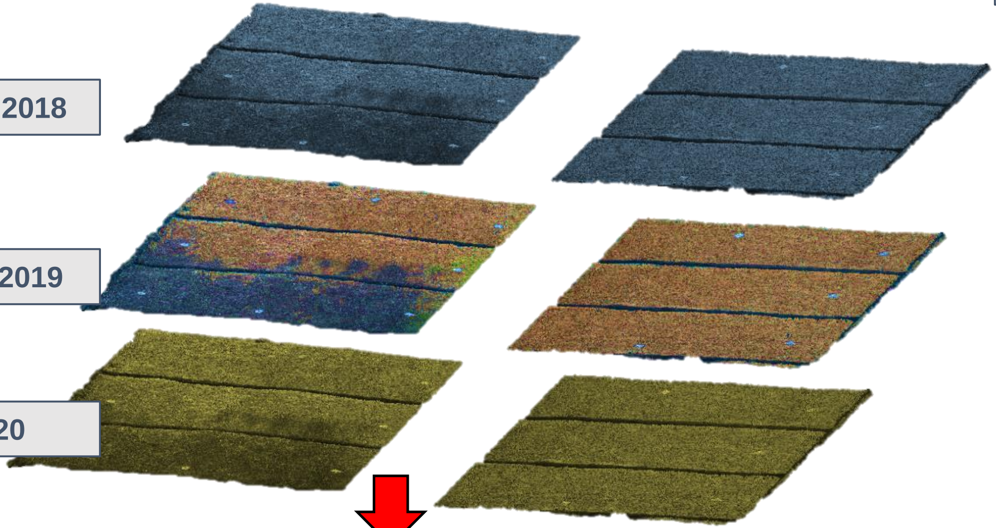
SfM Multi-temporal point clouds

September 2018

November 2019

June 2020



Point cloud filtering

Point cloud co-registration

DTMs | **Mesh**

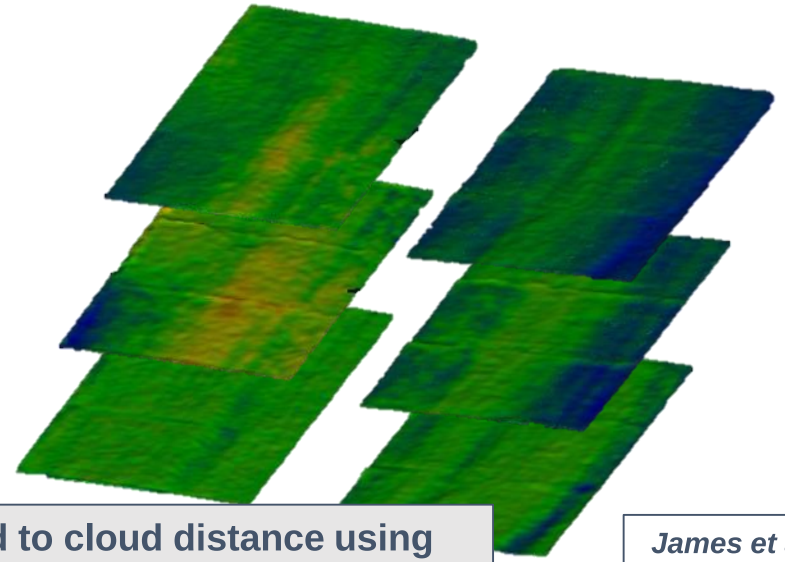
Difference of digital terrain models **(DoDs)**

Differences of meshes **(DoMs)**

The precision maps grids are used as *minLoD*

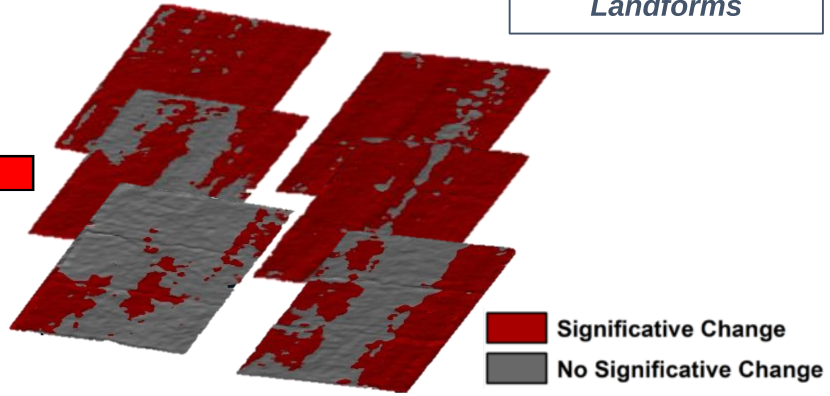
Precision maps of SfM surveys

To evaluate the spatial variability of the whole point cloud precision through the Monte Carlo approach



Cloud to cloud distance using precision maps (M3C2-PM)

James et al. (2017) Earth Surf. Process. Landforms



Significative change masks based on *minLoD*

EGU European Geosciences Union

Approach

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DoDs → Thresholded DoDs

DoMs → Thresholded DoMs

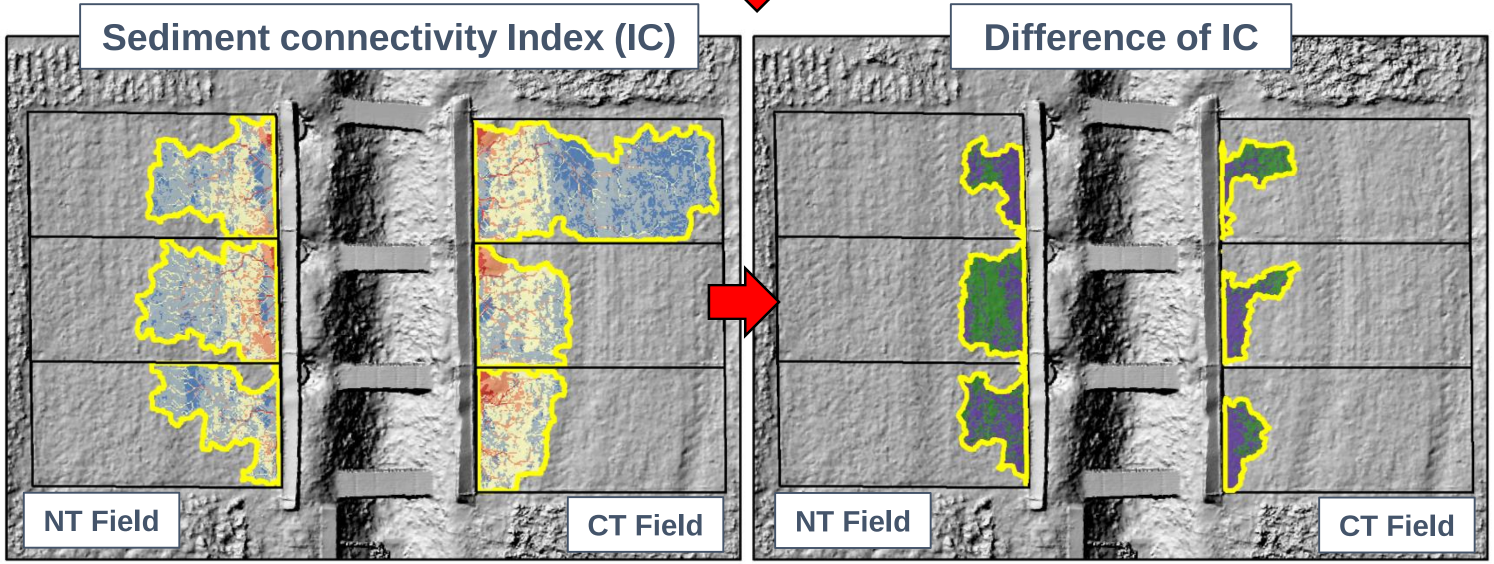
Mask of DoIC increasing values

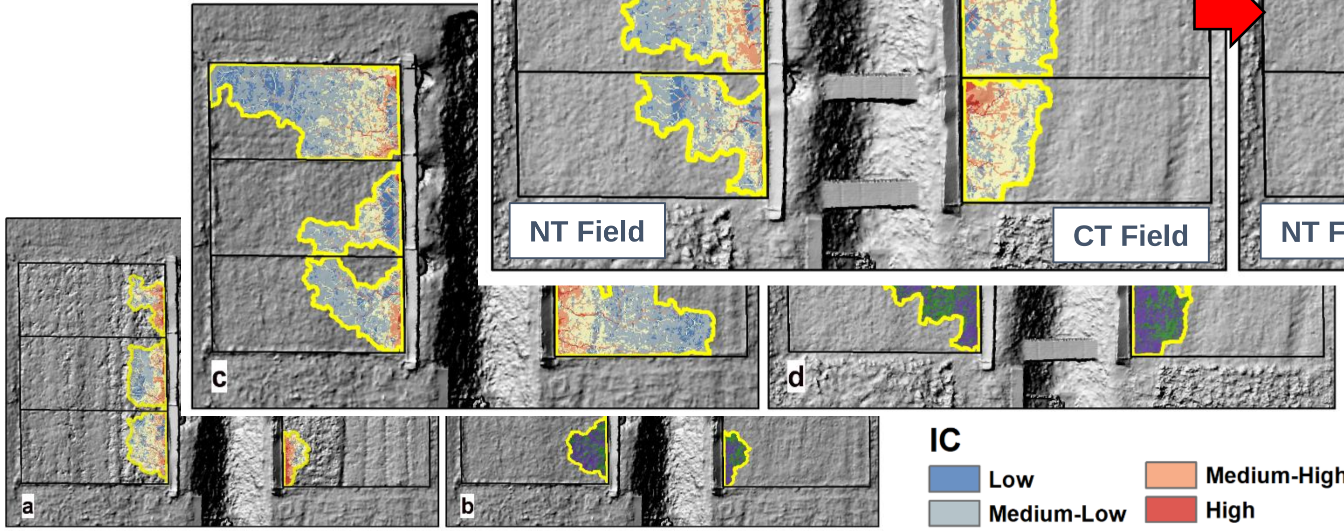
The potential connected areas are only 13%, 54%, and 40% of the whole surface of the experimental plots respectively in September 2018, November 2019, and June 2020.

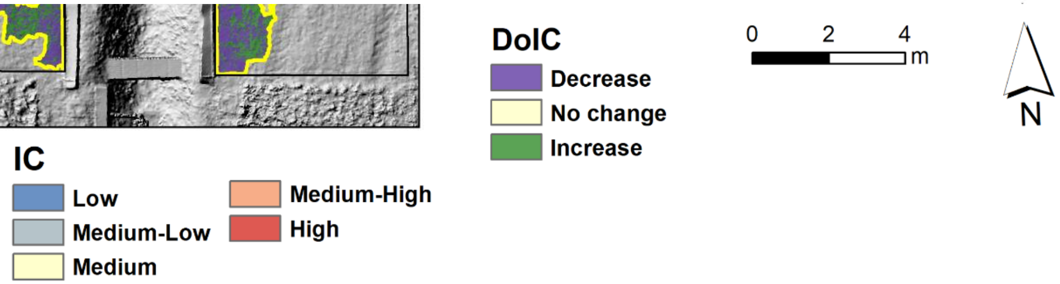
Only areas with IC increments (i.e., positive DoIC values) between two successive surveys were used to identify potentially mobilisable sediment.

Agricultural operations influence the micro-topography that **modifies the soil surface roughness and sediment connectivity.**

Have to be considered in the sediment delivery processes estimations







Results

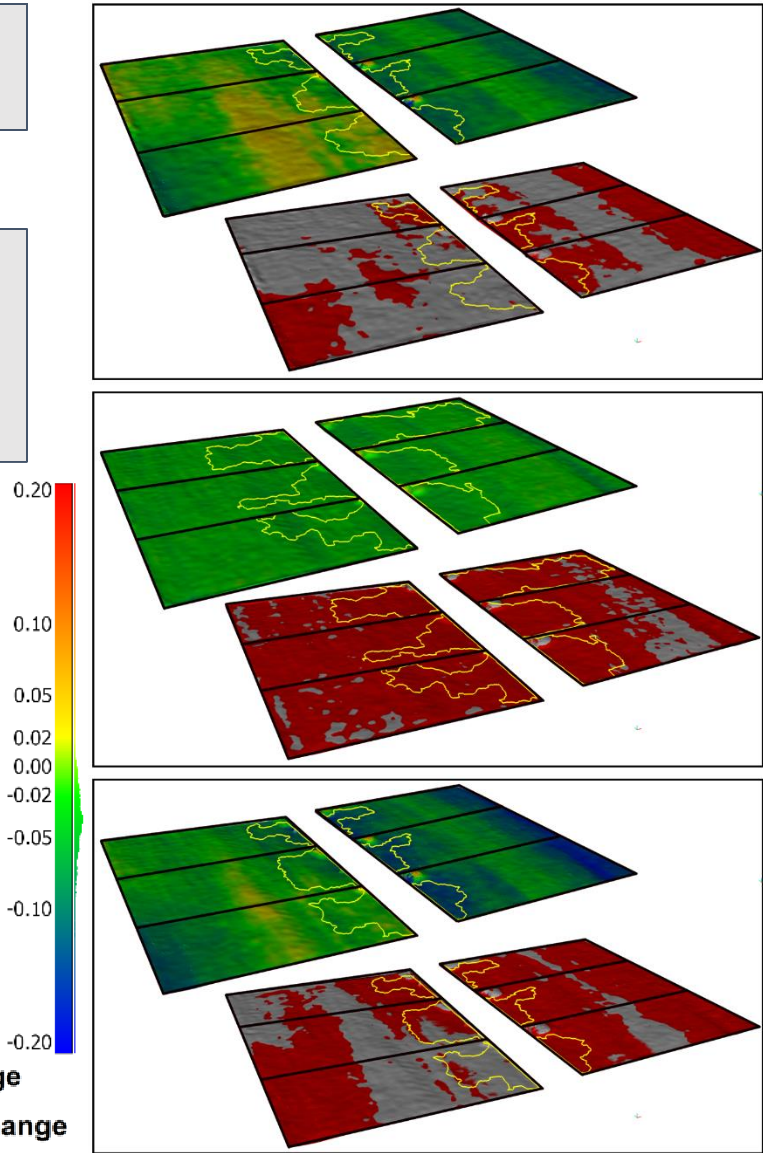
Cloud and Mesh

NT Field CT Field

The JRC 3D Reconstructor Gexcel software

The ‘Cut and fill’ tool is used to calculate erosion and deposition soil volumes

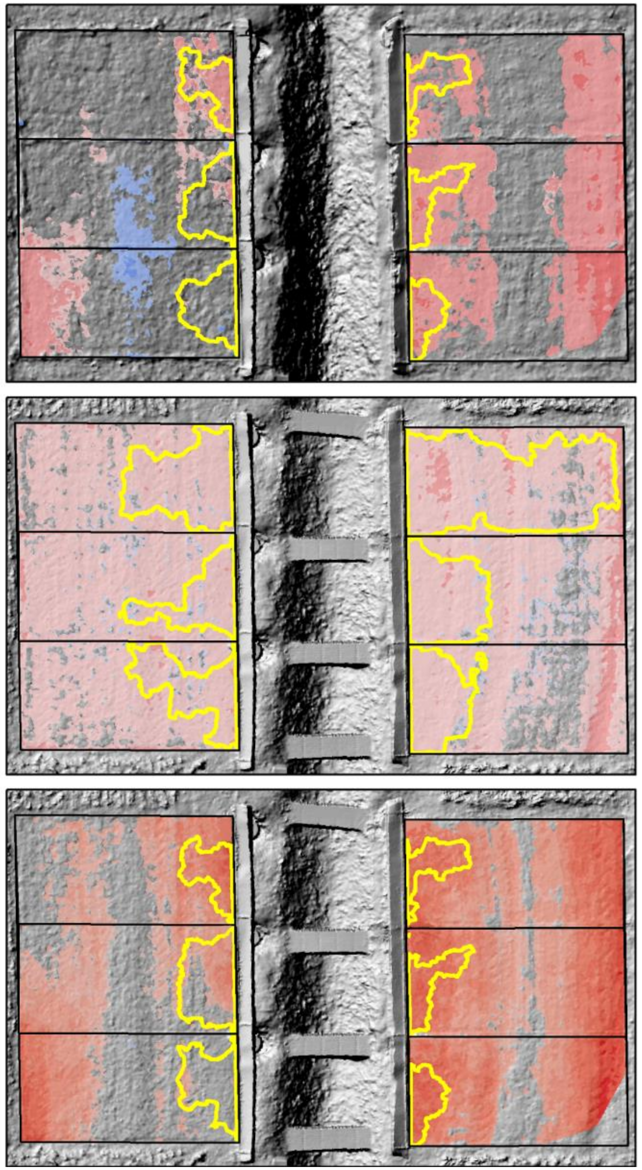
M3C2-PM Distance (m)

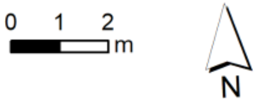


Significative Change
No Significative Change
DoIC area

Grid

NT Field CT Field





the GCD software

to identify soil erosion volumes connected to sediment collection tanks

DoD
Elevation Difference (m)

- < -2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- -0.02 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- Uncertain change
- DoIC area

Field validation

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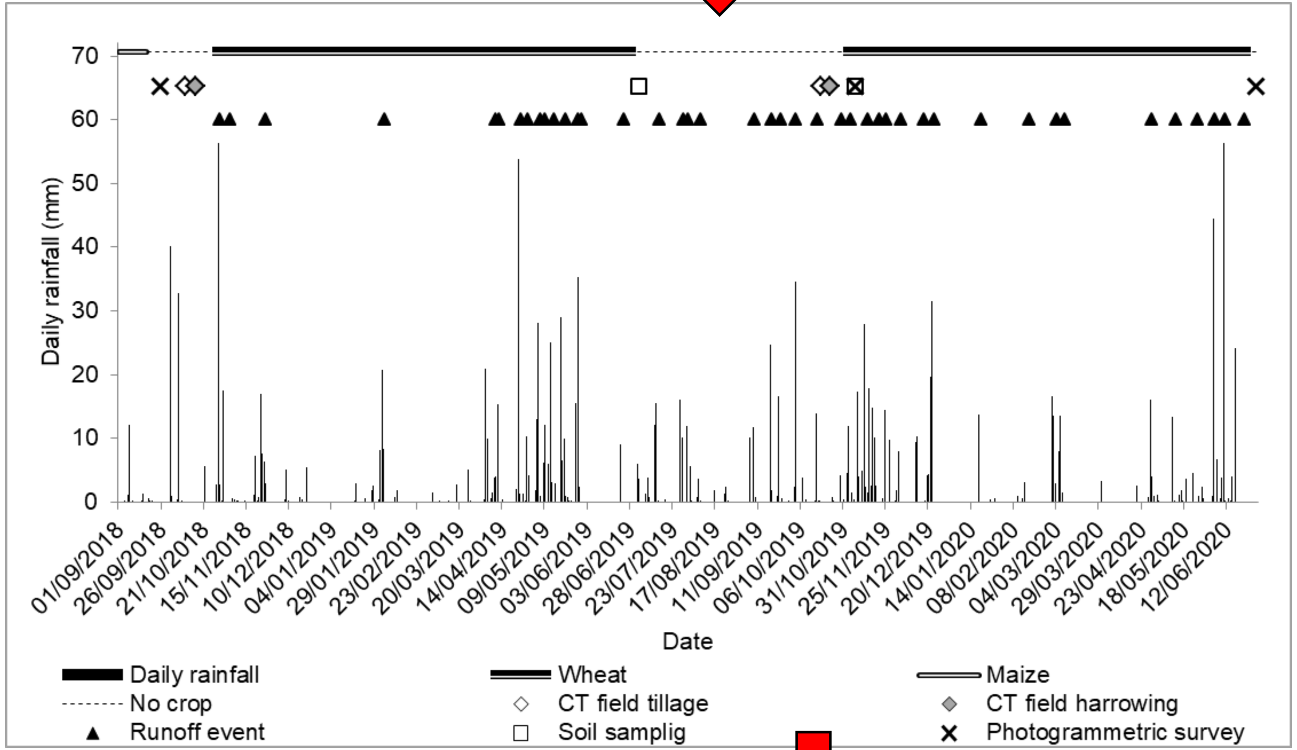
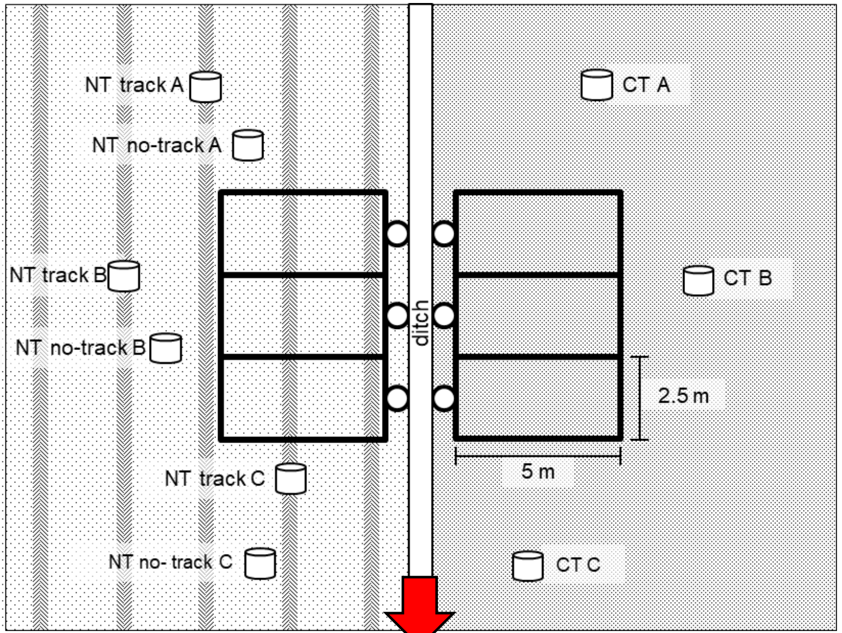
The total runoff water volume collected in the tanks was measured for each **runoff-generating rainfall event**



Sediment concentration was multiplied by the runoff volume to determine **the sediment yield from each sub-plot at each runoff event.**

sediment collection tanks

Caretta et al., 2021 CATENA



To determine the oven-dry **soil bulk density (BD)** undisturbed soil samples were collected from both the NT and CT fields.

November 2017

July 2019

November 2019

Sediment volumes

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	Sediment erosion collection in the field		SfM surveys							
	Soil volumes**		**Raw DoDs**		**Thresholded DoDs**		**Raw DoMs**		**Thresholded DoMs**	
	(cm^3)		Net Volume Difference* (cm^3)		Net Volume Difference* (cm^3)		Net Volume Difference* (cm^3)		Net Volume Difference* (cm^3) - %***	
Survey	NT	CT	NT	CT	NT	CT	NT	CT	NT	CT
September 2018 – November 2019	1225.13	3080.54	1181.69	-39230.91	-2623.80	-33456.63	213.89	-12598.79	-905.27	-9682.21
November 2019 – June 2020	1134.75	1445.15	-29027.24	-51660.25	-28598.72	-48225.51	-24234.13	-40033.81	-23526.96	-35656.99
September 2018 – June 2020	2359.89	4525.69	-11236.50	-79464.74	-9280.06	-79464.74	-2722.15	-38288.13	-2213.76	-38155.13

- **The effectiveness of using an uncertainty threshold** to eliminate some residual phenomena of unrealistic deposition due to possible systematic errors and filtering of crop residues.
- **An overestimation of topographic volumes** was generally found **due to the soil compaction processes in agricultural landscapes.**
- **The thresholded DoMs provided erosion volumes more similar to reference data than DoDs.**
- **The erosive processes in tillage plots were more significant than in those managed with non-tilled.**

Conclusions

- **SfM surveys** help to understand the sediment dynamics → **Workflow** that minimizes errors **to distinguish real erosion processes from noise** due to uncertainties
- The validation of the erosion volumetric changes showed a **slight overestimation of the results** → Other factors (e.g., the **soil compaction processes**) or variables other than photogrammetric or geometric ones
- **The use of DoMs instead of the traditional DoDs** accurately describe the micro-topography and ongoing processes → Especially when **the magnitude of the elevation changes** is low.
- In the monitoring of erosion processes, **the sediment connectivity must be considered** → To obtain an accurate evaluation of the phenomena
- A constant **UAV- SfM monitoring** can provide useful and detailed feedback → Influence decisions concerning the mitigation of erosion processes, (e.g., **the best agricultural management practices to focus on**)

Università degli Studi di Padova

Earth Surface Processes and Society

European Geosciences Union

https://doi.org/10.5194/egusphere-egu22-2000

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Thank you