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Consiglio Nazionale delle Ricerche STEMS
With collaboration of: Radiometer Physics A Rohde & Schwarz Company; Agrion

The contribution of W-band radar monitoring for understanding of runoff and soil erosion response at field scale

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1. Background

Vegetation cover has a great influence on hydrological response at field scale, and, consequently, on runoff and soil erosion processes. The maintenance of bare soil in vineyard inter-rows with tillage, as well as the tractor traffic, are known to expose the soil to compaction, reduction of soil water holding capacity and increase of runoff and erosion. The use of grass cover is one of the most common and effective practices in order to reduce such threats.

Rain-driven runoff (RO) and soil loss (SL) at sites with different cover have been investigated over last decades. It has been found that RO and SL often correlate with rain properties. This correlation, however, is highly variable among different sites and also for different time periods. In many studies rain is represented only by a few parameters such as e.g. maximum intensity and total precipitation.

Size of rain drops is rarely analyzed, although it is important for an accurate estimation of kinetic energy of rain. Polarimetric millimetre-wavelength radars are one of the instruments capable of drop size measurements. In contrast to in-situ rain sensors, such radars have much larger sampling area and can estimate range profiles of drop size distributions with high spatial and temporal resolution.

Fig. 1. Soil erosion by water in a vineyard in Piemonte, NW Italy

The objective of this work is to relate runoff and soil erosion to rain properties based on traditional monitoring techniques complemented by observations from a radar.

2. Study site

The study is carried out in the Alto Monferrato vine-growing area (Piedmont, NW Italy), considering two vineyard-field-scale plots with inter-rows managed with conventional tillage (CT) and grass cover (GC), respectively, belonging to the Experimental Centre of Agrion Foundation in Carpeneto (AL).

The site was equipped with a 94-GHz radar in June 2023, located about 100 m from the plots. The radar elevation was set to 30° so that the radar samples rain above the plots (Fig.4).

Runoff, soil losses and rainfall characteristics are recorded to determine the hydrological and erosive response of the vineyard plots with different inter-rows soil management.

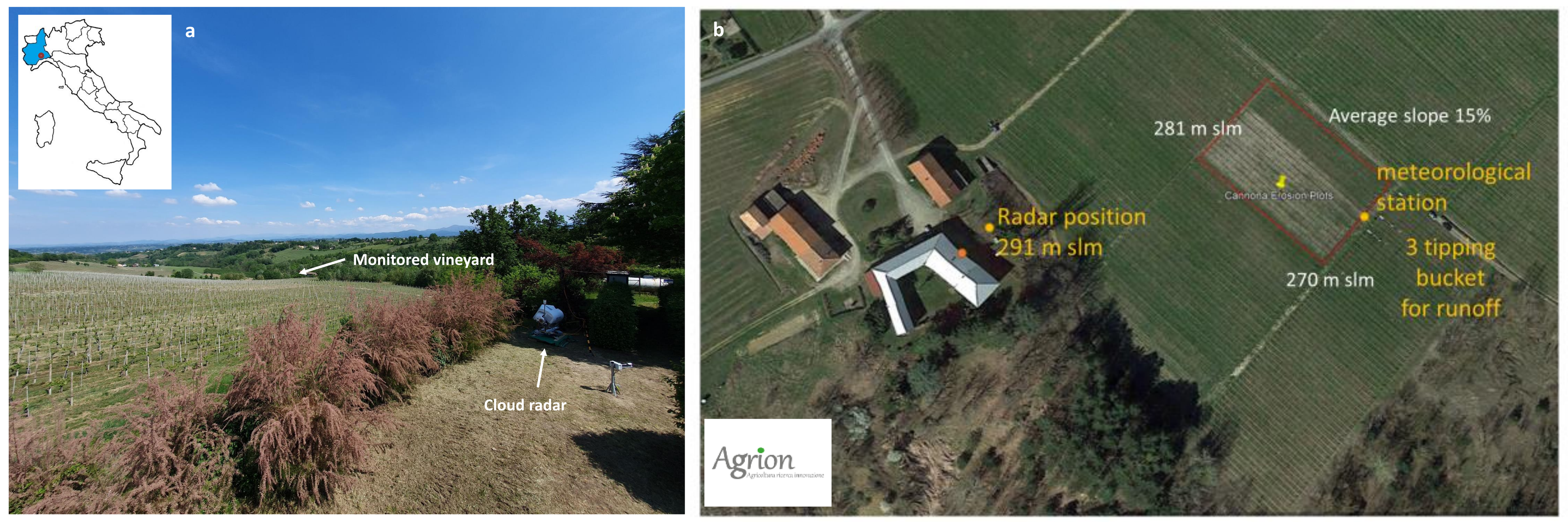

Fig. 2. The study site: a) localization of the study site in Italy; b) view of the monitored vineyard and landscape from the radar side and c) aerial view of the vineyard with localization of the monitored "Cannona Erosion plots", meteorological station and radar.

Link to the abstract

See also the poster at Hall A | A.60

EGU24-12415 | ECS | Posters on site | HS6.8
Applicability of cloud radar observations for an intra-event analysis of runoff on a steep vineyard
Tatiana Nomokonova, Alexander Myagkov, Marcella Biddoccu, Giorgio Capello, Gerrit Maschwitz, Davide Canone, and Stefano Ferraris
Thu, 18 Apr, 16:15–18:00 (CEST) Hall A | A.60

3. Methods

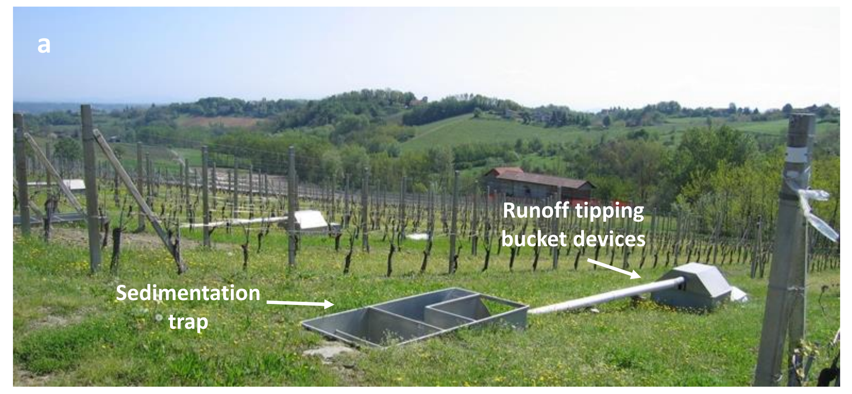

Fig. 3. (a) Runoff and soil erosion system, with measuring system. (b) outlet of the collecting channel with turbidity optical sensors.

Fig.4 The polarimetric cloud radar installed at the monitoring site.

Polarimetric 94-GHz cloud radar

Sampling volume: 150 m^3 (4 ship containers)
Good spatial resolution (3 to 30 m)
Observation area up to few km^2
Doppler and polarimetric capabilities
Accurate calibration
Retrievals based on spectral polarimetry
Estimation of DSD profiles, rain rate, kinetic energy, liquid water content, median diameter

Runoff and soil sediment monitoring system

Each monitored plot was hydraulically bounded. Runoff and transported sediments from each plot were collected by a channel surrounding the plot and connected to a sedimentation trap and, then, to a tipping bucket device to measure the discharge of runoff (Fig.3). After each erosive event, a 1.5 L sample of runoff sediment mixture was collected. Sediments deposited along drains and in the sedimentation traps were also collected and weighed after being dried.

An optical sensor is placed at the outlet of the channel in order to monitor the turbidity of the flow due to the sediment concentration. Rainfall data for the experiment period were obtained from an agro-meteorological station, placed at the border of the plots.

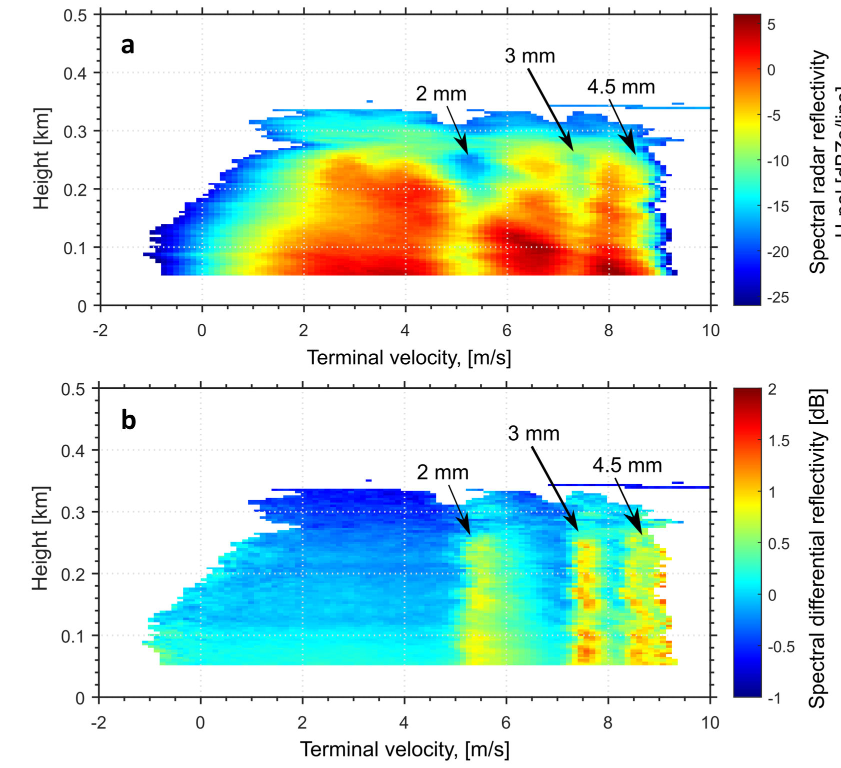

Fig.5 . Spectral reflectivity (a) and spectral differential reflectivity (b) measured by a W-band cloud radar in rain. Measurements were taken at 30° elevation. Distinct polarimetric signatures agree well with the scattering model and allow for assignment of velocity bins to drop sizes even at low elevation angles.

During the summer and autumn seasons of 2023, 26 rain and 13 runoff events were observed. For each runoff event we characterized precipitation in terms of accumulated precipitation, accumulated kinetic energy, and median diameter of raindrops. Stepwise multiple linear regression models for runoff and sediment yield predictions have been obtained considering rainfall variables both traditional and obtained from radar observations. In addition intra-event analysis was performed to investigate relationships between rainfall characteristics retrieved from radar observations and sediment transport by superficial flow.

4. Results

The preliminary results of the conventional analysis show that in this period runoff is directly related to erosivity index (EI30) both in CT and GC plots, and, only in GC treatment to maximum rainfall intensity over 10 minutes and antecedent rainfall in previous 7 days. Maximum rainfall intensity over 30 and 60 minutes, on the contrary, has a negative direct proportion with runoff. Soil erosion for both treatments was also directly related also with maximum rainfall intensity over 10 minutes and antecedent rainfall in previous 7 days and, in addition has a negative proportion with rainfall energy. It should be noted the relevant role played by rainfall intensity over short time interval and the antecedent rainfall, resulting in increased soil moisture. Relationships reflect the peculiarity of summer 2023, characterized by few rainfall events occurred on very dry soil.

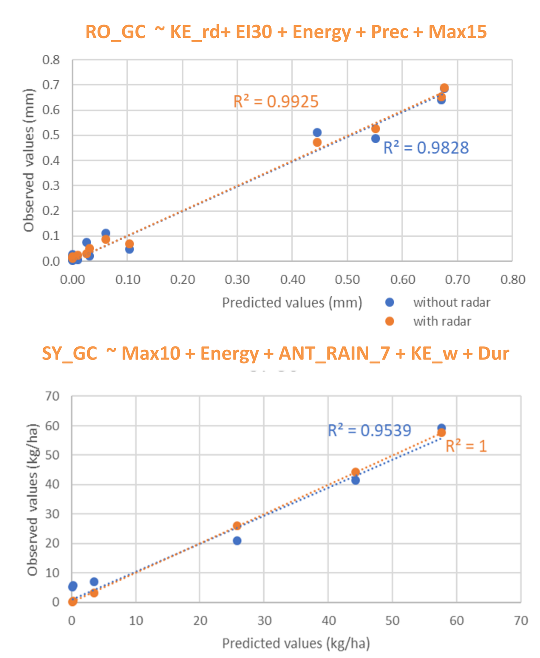

Fig. 6. Prediction of runoff and soil erosion from the GC plots, based on conventional and radar-based variables.

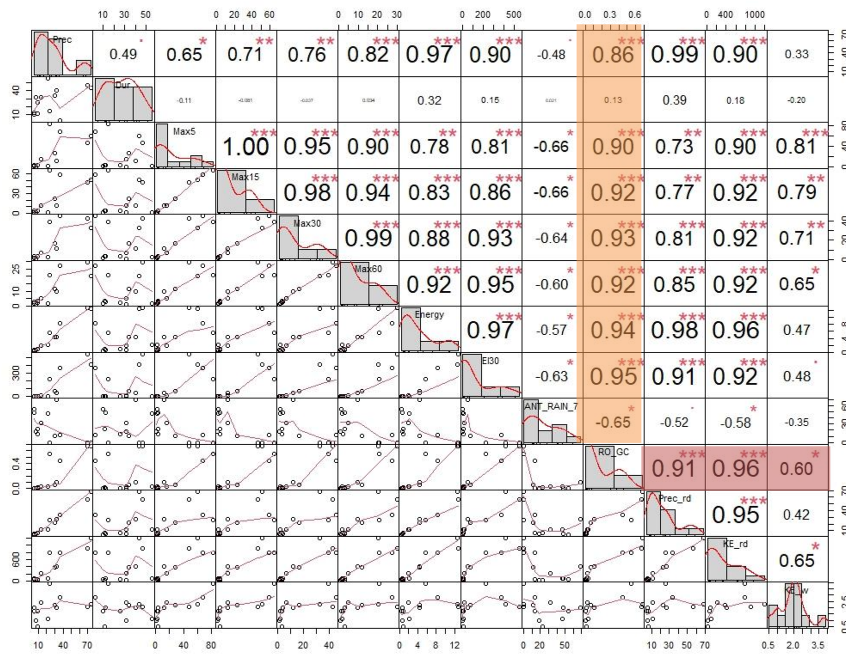

Fig. 7. Pearson correlation among variables obtained from conventional and radar rainfall observations for the GC plot.

Information obtained from W-Band radar monitoring allows to investigate relationships in a deeper way among rainfall characteristics and generation of runoff and soil erosion: kinetic energy and kinetic energy weighted median diameter improve the model for prediction of runoff and soil erosion from the GC plot (Fig.6 and Fig. 7).

Turbidity of the runoff flowed from the CT plot, due to sediment concentration, reflected the trend of rain rate and kinetic energy retrieved from radar observations (Fig. 8, 9 and Fig.10) in a high-erosive summer rainfall event .

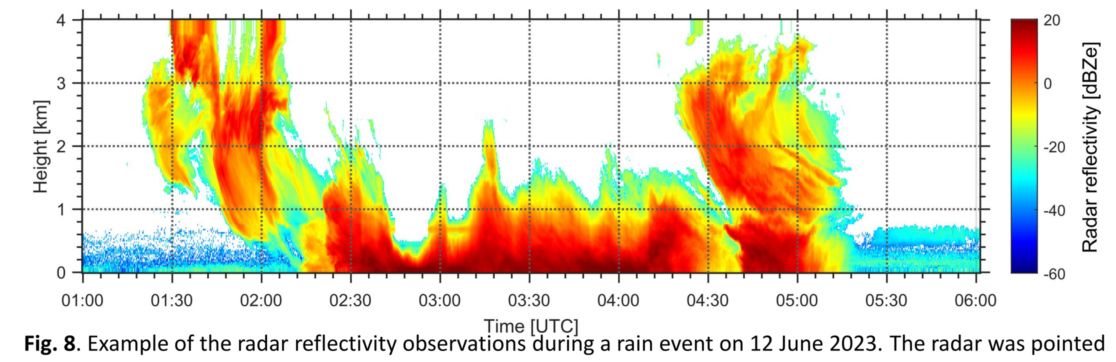

Fig. 8. Example of the radar reflectivity observations during a rain event on 12 June 2023. The radar was pointed at 30° elevation. The reflectivity is proportional to amount of power scattered back by raindroplets. During intence precipitation (e.g. at 2:45 UTC) the radar signal is strongly attenuated, however first few 500 meters could be measured.

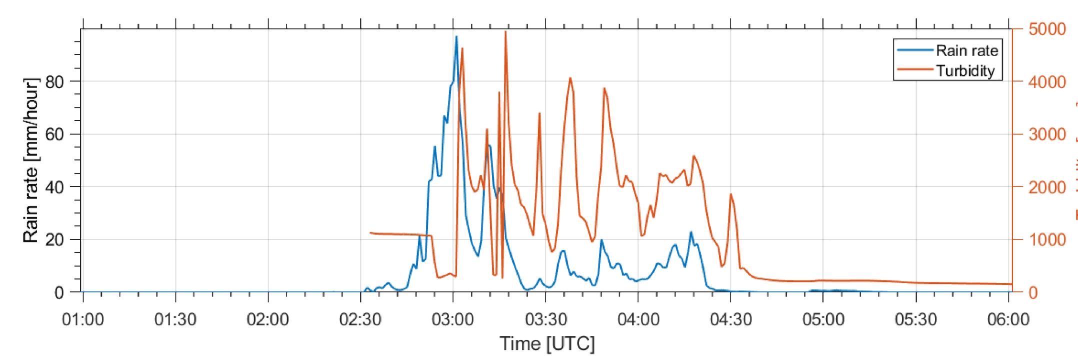

Fig. 9. Rain rate retrieved from radar observations and turbidity measured in situ for the rain event on 12 June 2023.

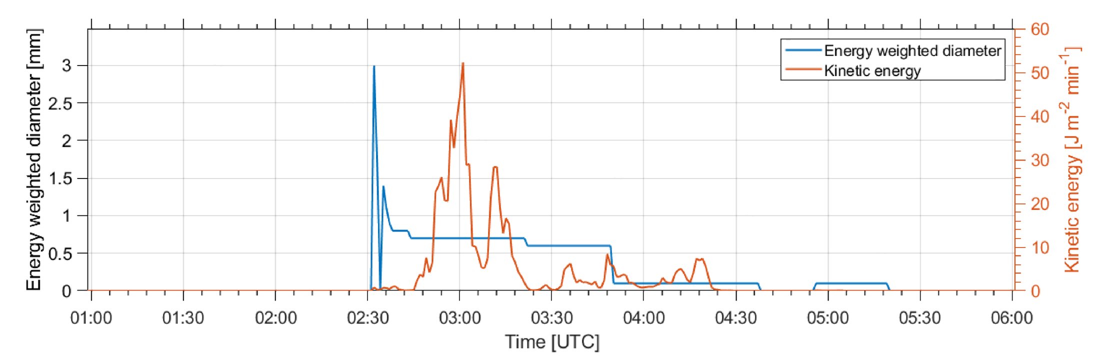

Fig. 10. Energy weighted diameter and kinetic energy retrieved from radar observations for the rain event on 12 June 2023

The preliminary results are encouraging for quantifying the runoff and soil erosion response at field/slope scale using information about rainfall energy and drop sizes retrieved from cloud radar

5. Aknowledgments

We would like to acknowledge the Research, Innovation and Technological Development in Piedmontese Agriculture (Agrion) for the help with the installation of the W-band radar, runoff sampling and for providing infrastructure.

The in-field monitoring system for soil water content and runoff collection was improved thanks to the IN-GEST SOIL Project, receiving funding by the Rural Development 2014–2020 for Operational Groups (in the sense of Art 56 of Reg.1305/2013).

6. References

1. Myagkov, A., et al., 2020. Evaluation of the reflectivity calibration of W-band radars based on observations in rain, AMT.

2. Biddoccu M. et al. 2017. Temporal variability of soil management effects on soil hydrological properties, runoff and erosion at the field scale in a hillslope vineyard, North-West Italy. Soil and Tillage Research 165, 46-58, http://dx.doi.org/10.1016/j.still.2016.07.017