UNIVERSITÀ DEGLI STUDI DI MILANO

SCUOLA DI DOTTORATO TERRA AMBIENTE E BIODIVERSITÀ

Dipartimento di Scienze Agrarie e Ambientali Produzione Territorio
Agroenergia

Ph.D. in Agricultural Ecology
XXV Cycle

Field-scale assessment of nutrient and soil losses during surface runoff events, in an Oltrepò Pavese (southern Lombardy – Italian region) vineyard hill

Ettore Bernardoni
N° R08075

Supervisor	Academic Year	Coordinator
Prof. Marco Acutis	2011-2012	Prof. Graziano Zocchi

UNIVERSITÀ DEGLI STUDI DI MILANO

Università degli Studi di Milano
Dipartimento di Scienze Agrarie e Ambientali Produzione Territorio Agroenergia
Via Celoria 2, 20133 Milan – Italy
ettore.bernardoni@unimi.it

Titolo in Italiano: “Valutazioni a scala di campo della perdita di nutrienti e di suolo in occasione di eventi deflusso superficiale, in un vigneto dell’ Oltrepò Pavese

Tesi di Dottorato in Ecologia Agraria

XXV Ciclo, Anno Accademico 2011-2012

UNIVERSITÀ DEGLI STUDI DI MILANO

Ph.D. in Agricultural Ecology - XXV Cycle

Ettore Bernardoni

Bernardoni, E., 2012. **Field-scale assessment of nutrient and soil losses during surface runoff events, in an Oltrepò Pavese (southern Lombardy – Italian region) vineyard hill**. Ph.D. Thesis, University of Milan, pp. 112.

The aim of my Ph.D. work was to investigate sediment transport and nutrient content in runoff water from an agricultural system.

The study was carried out in a representative sites of the Oltrepò Pavese, in Lombardy region (northern Italy) in a vineyard equipped with instruments for measuring volume and rate of runoff and collecting samples to determine the amount of soil loss related to each rainfall event. The site was equipped with a weather station, which included a recording rain gauge.

The analysis was done under natural rainfall condition during the period December 2008 - December 2012, in which 15 rainfall events were recorded.

The first step of the research was to equip the field plot with a collection system. An in-field runoff multislot collector, exploitable for monitoring

nutrients, pesticides and sediments loadings in runoff, was installed in the field and was improved with a home made level reading system able to measure with high temporal resolution, the runoff rate variation. Subsequently every runoff event was investigated. Samples were taken and analysed for quantifying the sediments loaded from runoff event and the nutrient losses from the system. Samples were also analysed with a laser diffraction technique in order to characterize, in natural conditions, the distribution of sediment grain-size transported by rainfall runoff.

Credits evaluation

- Courses:

Elements of statistics.
Instrumental analysis.
Image analysis

- Attendance at international/national congress:

XI Convegno Nazionale di Agrometeorologia, (Italy)
XVI Nitrogen Workshop: Connecting different scales of nitrogen use in agriculture. June 28th – July 1st 2009, Turin, Italy.
17th Nitrogen Workshop, Wexford (Ireland), June 26th – 29th

- Poster presentation at international/national congress:

Perego A., Brenna S., Carozzi M., **Bernardoni E.**, Giussani A., Acutis M. Model estimation of nitrogen leaching under derogation measures on organic nitrogen fertilization of intensive cropping system in Lombardy (northern Italy). Proceedings of the 17th

Nitrogen Workshop, Wexford (Ireland), June 26th – 29th,1 2012: 150-151.

Carozzi M., **Bernardoni, E.**, Fumagalli M., Acutis, 2011. “Analisi del contenuto idrico del suolo per due differenti sistemi di irrigazione”. Atti del XIV Convegno Nazionale di Agrometeorologia, Bologna, 7-8-9 Giugno 2011: 41-42.

Bernardoni, E., Carozzi M., Fumagalli M., Acutis M., 2011. “Tecnica di misura dei fenomeni di ruscellamento superficiale”. Atti del XIV Convegno Nazionale di Agrometeorologia, Bologna, 7-8-9 Giugno 2011: 99-100.

Perego, A., Acutis, M., Carozzi, M., **Bernardoni, E.**, Brenna, S., 2010. Model forecast of N dynamics in Po Plain under different cropping systems provided for EU Nitrates Directive derogation. Proceedings of the 12th Congress of the European Society for Agronomy, Montpellier (Italy), August 29th-September 3rd: 379-380.

Perego, A., Fumagalli, M., Carozzi, M., **Bernardoni, E.**, Brenna, S., Pastori, M., Acutis, M., 2009. Regional application of ARMOSA model to estimate nitrate leaching. Proceedings of the 16th Nitrogen Workshop, Turin (Italy), June 28th – July,1st 2009: 553-554.

- Publication:

Bernardoni E., Acutis M., Ventrella D., 2012. Long-term durum wheat monoculture: modeling and future projection. Italian Journal of Agronomy, 7, 86-92.

Bernardoni E., Carozzi M., Acutis M., 2012. Technical approach for the measurement of surface runoff. Italian Journal of Agrometeorology, 1, 29-34.

Perego A., Brenna S., Carozzi M., **Bernardoni, E.**, Giussani A., Acutis M. Model estimation of nitrogen leaching under derogation measures on organic nitrogen fertilization of intensive cropping system in Lombardy (northern Italy). Proceedings of the 17th Nitrogen Workshop, Wexford (Ireland), June 26th – 29th,1 2012: 150-151.

Ruggieri S., Acutis, M., **Bernardoni, E.**, Rinaldi M., 2011. “Un sistema di supporto alle decisioni per la gestione delle risorse idriche a scala comprensoriale”. Atti del XIV Convegno Nazionale di Agrometeorologia, Bologna, 7-8-9 Giugno 2011: 25-26.

Carozzi M., **Bernardoni, E.**, Fumagalli M., Acutis, 2011. “Analisi del contenuto idrico del suolo per due differenti sistemi di irrigazione”. Atti del XIV Convegno Nazionale di Agrometeorologia, Bologna, 7-8-9 Giugno 2011: 41-42.

Bernardoni, E., Carozzi M., Fumagalli M., Acutis M., 2011. “Tecnica di misura dei fenomeni di ruscellamento superficiale”. Atti del XIV Convegno Nazionale di Agrometeorologia, Bologna, 7-8-9 Giugno 2011: 99-100.

Acutis, M., Perego, A., **Bernardoni, E.**, Rinaldi, M., 2010. AQUATER software as a DSS for irrigation management in semi-arid Mediterranean areas. Italian Journal of Agronomy 5, 205-215.

Perego, A., Acutis, M., Carozzi, M., **Bernardoni, E.**, Brenna, S., 2010. Model forecast of N dynamics in Po Plain under different cropping systems provided for EU Nitrates Directive derogation. Proceedings of the 12th Congress of the European Society for Agronomy, Montpellier (Italy), August 29th-September 3rd: 379-380.

Carozzi, M., Ferrara, R. M., **Bernardoni, E.**, Bassi, L., Brenna, S., Acutis, M., 2010. Emissione di ammoniaca da suoli agricoli: approccio a diffusione passiva. Atti del XIII Convegno Nazionale di Agrometeorologia, Bari, 8-10 giugno 2010. Italian Journal of Agrometeorology: pp. 93-94.

Carozzi, M., Ferrara R.M., Martinelli, N., Di Tommasi, P., Bertolini, T., **Bernardoni, E.**, Brenna, S., Acutis, M., 2009. Valutazione delle emissioni di ammoniaca da suoli agricoli in Lombardia: possibili approcci. Atti XXXVIII Convegno della Società Italiana di Agronomia, 21-23 settembre 2009, Firenze, pp. 301-302.

Perego, A., Fumagalli, M., Carozzi, M., **Bernardoni, E.**, Brenna, S., Pastori, M., Acutis, M., 2009. Regional application of ARMOSA model to estimate nitrate leaching. Proceedings of the 16th Nitrogen Workshop, Turin (Italy), June 28th – July,1st 2009: pp. 553-554.

- Publication in regional research notebook:

Acutis, M., Bechini, L., Fumagalli, M., Perego, A., Carozzi, M., **Bernardoni, E.**, Brenna, S., Pastori, M., Mazzetto, F., Sali, G., Vidotto, F., 2008. "Gestione dell'azoto sostenibile a scala aziendale, Itinerari tecnici – Progetto GAZOSA". Regione Lombardia quaderno della ricerca n. 94.

Nitrati: come gestirli. Schede informative sulla gestione dei nitrati a scala aziendale.

http://www.ersaf.lombardia.it/upload/ersaf/NITRATI/03_00_presentazione.html

Gestione dell'azoto sostenibile a scala aziendale. Itinerari tecnici - Progetto GAZOSA. Quaderni della ricerca n. 94 - ottobre 2008

UNIVERSITÀ DEGLI STUDI DI MILANO

Supervisor:

Prof. Marco ACUTIS

Coordinator:

Prof. Graziano ZOCCHI

“The nation that destroys its soil destroys itself”
Franklin D. Roosevelt

"The threat of nuclear weapons and man's ability to destroy the environment are really alarming. And yet there are other almost imperceptible changes - I am thinking of the exhaustion of our natural resources, and especially of soil erosion - and these are perhaps more dangerous still, because once we begin to feel their repercussions it will be too late."
The Dalai Lama

CONTENTS:

Introduction

Erosion is a physical process responsible for the continuous remodelling of the earth's surface, which determines the removal of solid material from the surface of the soil and its deposition elsewhere.

The erosion is a natural phenomenon that human activity is accelerating, causing a gradual degradation of fertility and then the potential productivity of the soils. It is defined as a process of detachment and transport of soil particles operated by erosive agents (Ellison, 1944).

Soil may be detached and removed by water, wind or tillage. These three erosive agents however differ greatly in terms of where and when they occur; what happens to the area that is being eroded (on-site impacts) how far the eroded soil is moved and, if the soil is moved away from the place where it was eroded, what happens to the result (off-site impacts).

Speth (1994) suggest that about 80% of the world's agricultural land suffer moderate to severe erosion and 10% suffers slight to moderate erosion.

Pimentel et al. (1995) calculates that during the last 40 years, approximately 30% of the world's arable land has been lost by erosion and the process continues at a rate of more than 10 million hectares per year. They calculate that in the United States, an estimation of 4×10^9 Mg of soil and 130×10^9 Mg of water are lost from the 160×10^6 ha of cropland each year. They report an economic loss of more than 27 billion dollars each year, of which 20 billion is for replacement of nutrients and 7 billion for lost water and soil depth.

1.1. Soil erosion by water

Soil erosion by water on cultivated land is a worldwide problem. It causes loss of a non renewable resources (Warrington et al., 2009) and a series of damages on-site and off-site, including soil and nutrient losses (Poesen and Hooke, 1997; Douglas et al., 1998; Corell et al., 1999; Woodward, 1999; Gunatilake and Vieth, 2000; Steegen et al., 2001; Verstraten and Poesen, 2002; Ng Kee Kwong et al., 2002; Ramos and Martinez-Casasnovas, 2004), loss of productivity by soil degradation (Lal, 1995; Roose, 1996; Alfsen et al., 1996; Gunatilake and Vieth, 2000) reduction of fertility (Pimentel et al., 1995) and countless environmental problems due to sediment shift from soils to the drainage network, river systems and sea (Young and Onstad, 1978;Ongley et al., 1992; Ghadiri and Rose, 1993; Hansen et al., 2002; Verstraeten et al., 2003). Soil erosion is identified as the major cause of diffuse pollution and specifically one of the major factors liable of water quality degradation in lakes and reservoir over the world (Water National Quality Inventory, 1994). Suspended sediment is also considered the most visible pollutant (Clark et al., 1985) and the physical pollutant in the surface water environment (Guy and Ferguson, 1970). It has been recognized as an important control factor related to geomorphological and biological processes. Ongley (1996) highlights the impact of sediments on turbidity that affects the penetration of sunlight into the water reducing food chain production and limiting or prohibit the growth of algae and aquatic plants. In addition to its physical role, suspended sediment plays an important role in the transport and in biogeochemical cycling of nutrients and other contaminants in the aquatic system (Ongley et al., 1981; Gao et al., 2003).

Soil erosion by water involves two main processes, the detachment of soil material from parental soil by the effect of raindrop or runoff shear; and the transport of the sediment by raindrop splash effect and flowing runoff.

The detachment of soil material is mainly influenced from the coverage because the kinetic energy of raindrops is much larger than that of surface flow. Than in bare soil the most important component of detachment is due to the raindrop effect (Hudson 1971). Erosion process is also intensified on sloping land, where more than 50% of the soil contained in the splashes is transported downhill (Pimentel, 1995).

The transport of the detached soil is mainly due by surface overflow (Young and Wiersma, 1973) witch increase sharply with slope and when rilling is initiated (Warrington et al., 1989; Shainberg et al., 1992).

When precipitation exceeds the infiltration rate of the soil, or when the soil is saturated, soil erosion by runoff occurs.

The infiltration capacity of the soil is a measure of the capability of the soil to absorb and convey water. Runoff is limited on soils with high infiltration capacity. This fact depends on the water transmission characteristics and structural stability of the soil and its ability to maintain continuous pores. The rate and amount of runoff are also influenced by the intensity and the amount of rainfall, the soil moisture content, the degree of relief, slope steepness and aspect. These factors manifest themselves in a wide range of runoff management problems and conservation requirements.

1.2. Runoff and nutrients

Soil transported with water erosion can reach receiving waters as streams, rivers and lakes, causing sedimentation problems and are often associated to a nutrient load.

The presence of nitrogen (N) and phosphorus (P) in surface water is a major environmental problem because of the risk of eutrophication (excessive growth of photosynthetic plants) caused by these elements, with severe water quality deterioration. Several studies about erosion processes take into account also the quantification of nutrient loss (Reposa et al., 1994, Papini et al., 1997, Hussein et al., 1999, Ramos and Martinez-Casasnovas, 2004, Pansak et al., 2005, Ramos and Martinez-Casasnovas 2006, Lopez et al., 2007, Lu et al., 2007, Casali et al., 2008, Xue et al., 2008) as an important aspect in these studies.

In particular, phosphorus is the limiting nutrient for the growth of aquatic plants such as algae and water weeds .When it’s in excess, it causes eutrophication, with abundant algal blooms, reduction of oxygen during their decomposition, loss of aesthetic and ecological value of water bodies, increased of cost for drinking water production.

The presence of N and P compounds are relevant parameter for water protection plans at national scale, and are inserted in the macro descriptors that define water quality standards (Legislative Decree 152/2006), which must reach the "good "category for all fresh water bodies within 2016.

According to this law the following values (expressed in mg l^{-1}) are considered optimal: $N0_3\_N < 0.3$, $NH_4\_N < 0.3$ and total $P < 0.07$ and low-quality values are considered if values are major of 1.5, 10 and 6 respectively for $N0_3\_N$, NH_4_N and P total.

The danger of eutrophication of waters is also perceived at international level, and various environmental agencies indicate that runoff waters from agricultural river basins often largely exceeded by the threshold values.

Sharpley and Smith (1992) indicate in their study, for soluble phosphorus a value of 0.01 mg l^{-1} like the threshold beyond which there's eutrophication water risk. The American Environmental Protection Agency indicates in 0.1 mg l^{-1} the threshold beyond which there's accelerated eutrophication, while for nitrate they indicate a thresholds ranging between 0.3 e 1 mg l^{-1}.

Various studies in Italy (Acutis et al., 1996, Papini et al., 1997, Balestra et al., 2001) and abroad (Sharpley and Smith, 1995, Heathwaite and Johnes, 1996, Sharpley, 1997, Udawatta et al., 2004, 2006) refer highly variable concentrations of nitrogen and phosphorus depending on the type of the soil, the use of fertilizers and their doses and, more generically, depending on the management.

1.3. Research framework

Nutrient losses from agricultural systems is a crucial concern in the intensive agriculture of Lombardy region. Surface runoff from hill slope area could represent a nonpoint source of pollution that we have to take into account. No research has ever been carried out previously in these areas.

The research consisted in:

- monitoring in natural condition the tendency of the selected system to generate runoff;
- equip the vineyard plot with instruments able to collect and sampling the runoff, measuring volume and rate of runoff;
- investigate about the sediment transported and the nutrient losses during runoff event from an agricultural vineyard system under natural condition;
- analyse the sampler in order to characterize, the distribution of sediment's grain-size transported by rainfall runoff.

1.4. Synopsis

In Chapter 2 (Technical approach for measurement of the surface runoff) was presented the practical application, design and installation of an in-field runoff collector, improved with a home made level reading system able to measure the runoff rate variation.

Chapter 3 (Nutrient losses by runoff in a vineyard of the Oltrepò Pavese (southern Lombardy – Italian region)) discuss about nutrient and sediments losses by runoff events. The monitoring results are presented in terms of registered runoff ratio, sediment concentration and nutrient losses.

Chapter 4 (Particle size distribution of eroded material during runoff events) eroded material was investigated for different runoff erosion event on a field plot, to assess the soil size fraction involved in transport.

Chapter 5 (Appendix) reports some common practices for reducing the runoff and his environment negative effects.

1.5. Notes

Chapter 2 has been published by Italian Journal of Agrometeorology.

Chapter 3 has been submitted for publication to Catena.

Chapter 4 has been submitted for publication to SSSAJ

The reference lists from individual chapters have been combined into one list at the end of the thesis.

Chapter 2

Technical Approach For The Measurement Of Surface Runoff

Bernardoni Ettore, Carozzi Marco, Acutis Marco.

Italian Journal of Agrometeorology (2012), 1, 29-34.

Keywords

Runoff, multislot, floating level system.

2.1. Abstract

In this paper we describe practical application, design and installation of an in-field runoff collector exploitable for monitoring nutrients, pesticides and sediments loadings in runoff, improved with a home made level reading system able to measure with high temporal resolution, the runoff rate variation.

This configuration simplifies and lower the cost of conventional instruments used for measuring runoff. A multislot divisor was used to reduce the volume of runoff and plastic tank were use to collect it. An electro-mechanic type, floating level transducer was proposed. The homemade level reading system is composed of three parts: floating level transducer, signal conditioning system and data storage. The total cost for entire system is approximately € 642.

2.2. Introduction

A better understanding about nutrients, pesticides and sediments loadings in runoff and in surface water, at field scale, is of fundamental importance in many environmental studies, especially to evaluate different management practices and its role in soil and water degradation. Many instruments have been developed to measure runoff and sediment transport (PAP/RAC, 1997), using different approaches (Hudson, 1993). Direct measurements are normally carried out in medium size plots (Hudson, 1993) (<100m^2) where runoff is collected using tanks (Hudson, 1993; Bonilla et al., 2006). To avoid big tank, necessary to collect all the runoff derived from the plots, and reduce costs, the plots are frequently characterized by small size (2-5m^2) and therefore can become not much representative of the field condition (Toy et al., 2002). Moreover total collection tanks are often unsuitable also for medium plots because the runoff can be excessive (Brakensiek et al., 1979). Other commons instruments used in several runoff studies consists in sophisticated instrumentation able to measure and sample runoff at field scale (Bonilla et al., 2006). These instruments continuously measure and record the runoff rate in a control section, and an automatic pumping sampler is used to draw samples. These instruments returned more detailed information about runoff and its rate evolution, through a mechanism to measure the depth of water and the velocity or the flow rates in a known section; but they are often too expensive and such system assume that samples extracted non-continuously could be representative of the entire phenomenon (Pinson et al., 2004; Bonilla et al., 2006).

To avoid problems in measuring, tools were introduced to collect runoff water. Slot-type sampler, using multislot divisors, collect a representative portion of runoff allowing to increase the plot size to better represent the field condition (Sombatpanit et al., 1990; Reyes et al., 1999; Franklin et al., 2001; Pinson et al., 2004; Bonilla et al., 2006), reducing the amount of runoff that must be stored. Multislot dividers also know as slot dividers, slot samplers or multislot samplers; were firstly introduced by Geib (1933). In general a slot divisor consists in a box were the entire flow pass throughout a multiple outlet slot. The output of one of these slot was collected, between collection port or channel, to a tank and this single sample represent a known portion of the entire runoff volume (Pinson et al., 2004).

For studies that do not required a time variation data of the runoff but only total event information, the slot dividers represent a low cost method. To be representative, not only for the volume but also for the sediment and contaminant concentration, the divisor should not permit the deposition of the solid part of the runoff during the splitting.

The goal of this paper is to describe practical application, design and installation of an infield runoff collector for measuring runoff, sediment and chemical losses, enhanced with a level reading system able to measure the runoff rate.

2.3. Materials and Methods

2.3.1. Study area and site

The study area is located in the *Oltrepò Pavese*, part of the Province of Pavia, in the southwest Italian region of Lombardy. The area has an Apennine mesoclimate (Mariani L., 2008) with an annual average temperature of about 12°C and an annual rainfall of about 680 mm, mainly concentrated in spring (May) and autumn (November) (Ottone and Rossetti, 1980; Mariani L., 2008).

The study was carried out in a 9-year-old vineyard at the “Centro Vitivinicolo Riccagioia” located in Torrazza Coste (latitude 44°58'40"44 N, longitude 09°5'4"56 E, 159 m a.s.l.). The plantation consists of single

Guyot trained vines, at 2.5 m × 1.0 m pattern, which run along the maximum slope degree direction.

The plot of about 686 m^2 includes four rows (three in-row), 88 meters long. The slope of the plot is about 17%. Each plot is delimited by a longitudinal, approximately 15 cm high earth embankment.

The grass cover in the inter-row is cut four or five times from April to August, chemical weeding in row is renewed in March and July.

2.3.2. Multislot divisor

The multislot divisor used in this work (Fig. 1) is the same proposed in Franklin et al. (2001).The only difference was in the use of a more thick stainless steel sheet for the collector floor, to avoid the risk of warping, indicated as a possible cause of the percent capture of runoff double than expected recorded by Franklin et al. (2001). We used a 2 mm thickness stainless sheet respect to the original 16 gauge (approx. 1.59 mm) sheet. The height of the side wall and of the dividers, that it was not specified in the original paper, was set to 15 cm.

2.3.3. Collection tanks

The two collection tanks (Fig.1) have been sized on the base of the maximum volume of water potentially collectible by the multislot on 1/100 partition. In this way the 1/10 partition tank is useful to measure runoff in small events and for the initial part of bigger events.

Fig. 1: Multislot divisor with tanks.

To calculate the size of the tank were necessary to estimate the probability distribution of extreme runoff events and the corresponding peak runoff rates, applying the Curve Number method (United States Department of Agriculture, 1986). The volume was calculated on the base of the years when the weather data were available, period 1992-1996. A 125 dm^3 (516 mm Ø × 568 mm height) PPE tank, with vertical walls, was used for the application in reason of the entrance of the 25 cm high collector from the multislot. At the bottom side of both tanks a water taps were installed to evacuate the liquid after the sampling. Each

125 dm^3 tank was allocated on a supplementary buried 380 dm^3 PPE tank (638 mm Ø × 1200 mm height) to simplify the operation of cleaning and to place the level measuring device. The external tanks were equipped with drainpipes, to permit the evacuation of the liquid, and with caps.

2.3.4. Level reading system

Three parts compose level reading system proposed: i) a transducer, ii) a signal conditioning system, iii) and a data storage.

The chosen of the transducer was done considering the power consumption, the accuracy, the spatial encumbrance and the minimum of liquid height requested by some sensors to make a significant measure.

An electro-mechanic type, floating level transducer was selected for both tanks as best meets the requirements described above. This device (Fig. 2) is composed by a floating part, a 250 mm diameter circle of 20 mm high made by polystyrene in adherence with the liquid, linked to the transducer organ through a timing belt (T5 type) connected in the centre of the floating with a screw. The transducer is a 10 turn, metric, 10 kΩ precision wire wound potentiometer 5% accuracy (Vishay Intertecnology Inc. mod. (http://www.vishay.com/docs/57065/533534.pdf) and was chosen for the reliability and the low friction on the starting movement. This device is able to convert the rotary movement of the knob in a variation of resistance and a consequent voltage change when powered. The movement of the knob is allowed by a 18.25 mm Ø pulley (type 21 T5 12) mounted directly above the knob, that allows a measure of 573 mm in 10 turns of potentiometer. Major diameters allow covering more length but in the same time decrease the measurement sensibility. A timing belt runs up two pulleys, one connected to the potentiometer and one idle. The timing belt is connected with polystyrene floating in one side, and to a 150 g counterbalance in the other side.

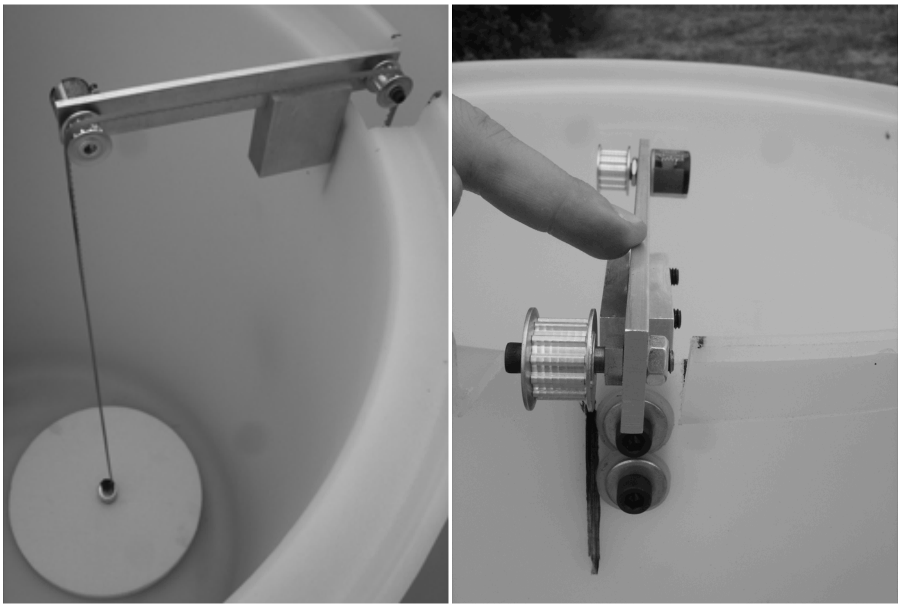
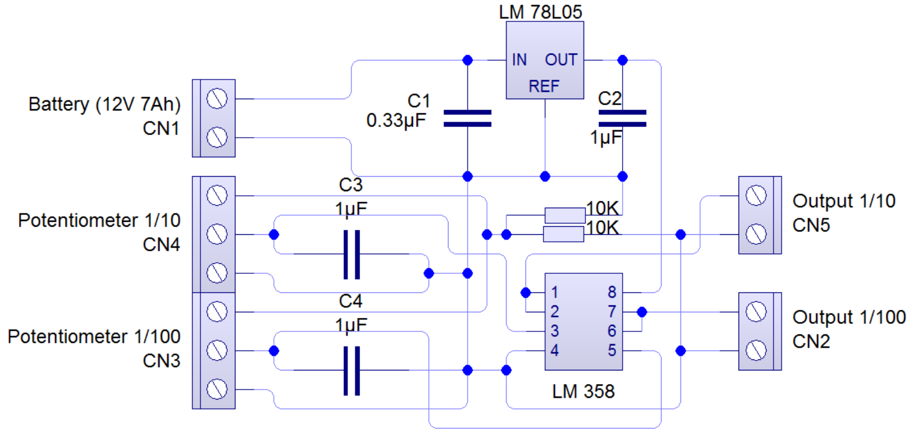


Fig. 2: Floating level system.

The potentiometer is powered by the signal conditioning system. This system is a simple board (Fig. 3) which permit the power alimentation of the transducer and it receive back the voltage signal to sends to the data storage. Specifically the board contains a 12 V to 2.5 V DC voltage regulators (model LM 78L05) to supply the transducer, a unity gain buffer amplifier (model LM 358) to improve the impedance of the entrance signal and the basic electronics to operate these components.

The transducer receives tension from the regulator and provides a signal from 0 to 2.5 V DC in function of the rotary movement of the pulley linked to the floating. The power supply board is conducted by a12 V, 7 Ah battery connected to a solar panel of about 1W(12 V and 75mA).



Component	Quantity
0.33µF Capacitor	1
1µF Capacitor	3
10K Resistor (1% 1/4W)	2
2 pin Terminal Block	3
3 pin Terminal Block	2
7805 (5V, 1A) Voltage Regulator	1
LM 358 Low Power Dual Operational Amplifier	1

Fig.3: Scheme of the signal condition system and component list.

The signal overcoming to the board goes directly to the data storage, a 12-bit HOBO U12-006 data logger (http://www.onsetcomp.com/products/data-loggers/u12-006). This device is battery powered, with four input channels and permits the storage of 0 to 2500 mV voltage signals at a frequency from 1 second to 18 hours, with a resolution of 0.6 mV. For our purpose we use a 1 minute time step acquisition with permit a 15 days data storage.

2.3.5. Field arrangement

Divider system and tanks are located over the field headland and the water is conveyed to the multislot through earth embankment (Fig. 4).It is planned to protect the embankments with plastic sheets. The field headland is considered part of the experimental field and its contribute in generate runoff is taken into account. The divider is placed at the end of the headland, where the slope is about 2%.

2.3.6. Field installation

Field installation was initiated using a multislot divisor template to identify holding tanks and divisor position. After the excavation, levelling was done for the bottom of the holes and a 10 cm of sand bed was created to ensure the stability of the tanks. The external tanks were embedded until the collection port enters in a tank as high as possible.

Threaded rods were cemented into earth for levelling and fixing the multislot. Nuts are places above and below the eyelet to level the multislot.

Fig. 4: Field arrangement.

2.3.7. Operation

After every runoff event, the data logger is downloaded, water sample are taken for analysis making sure to mix very well, tanks are emptied opening the tap, and cleaned. Also the floating systems are rearranged to the bottom of the tanks.

2.3.8. Calibration

Calibration of every tank is necessary to convert, in post processing, the volts value in litres of runoff. For every 125 dm^3 tank a known increment in litres were applied. First we put in the tanks 5 litres of water in 10 steps of 0.5 litres, then we put, in steps of 5 litres, the volume of water necessary to fill the tanks. Moreover, the percentage water of recovery was assessed with the instrument installed in the field, using a tank of 0.5 m^3 of water. 2 flow rates of 0.11 and 0.65 $l\ s^{-1}$ with 2 replication was used. The flow rate was obtained discharging 400 l of water in 10 and 60 minutes, respectively. Due to the long distance between the source of water and the field equipped with the sampler, was not possible to perform more replication and to test the device for other flow rates.

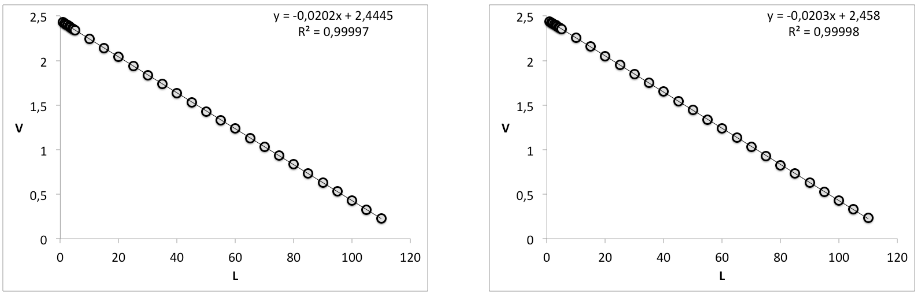
Franklin (2001) did not test the accuracy of division for transported sediment, however precedent studies using very similar designs (Sheridan et al., 1996) used also in Sheridan et al., 1999 and modified by Franklin (2001) for use in water quality studies, indicated good sediment division. Also recent studies (Butler et al., 2010; Matos et al., 2008; Ortega et al., 2007; Sistani et al., 2008; Sotomayor-Ramírez et al., 2008; White et al., 2003) use the Franklin splitter with good results.

Rayan (1981) attributes the accuracy of systems similar to that discussed in this paper, in the use of a sludge tank so that the divisor only handles water and suspended sediment in a smooth flow and the reliability of the divisor system because there are no moving parts (Rayan, 1981).

2.4. Results

2.4.1. Calibration

Calibration lines for both tanks are shown in Figure 5. The determination coefficients are close to 1 and linearity is excellent. Moreover, the slope and the intercept of the linear regression are very similar for the two tanks.



Tank of the 1/10 splitter

Tank of the 1/100 splitter

Fig. 5: Calibration curves of the two tanks.5 litres of water was added in 10 steps of 0.5 litres than the volume of water necessary to fill the tanks was added in steps of 5 litres.

Calibration of the tanks and of the automatic level meter also shows that the material used is not subject to deformation due to the weight of the water.

Tab. 1: Field calibration results. Mean recovery rate (%)

	10x Divider		100x Divider	
Flow rate	0.11 l s^{-1}	0.65 l s^{-1}	0.11 l s^{-1}	0.65 l s^{-1}
Mean	9.88	10.50	0.98	1.01
CV %	3.58	3.37	7.25	8.73

Table 1 showed the percentage of water recovery with its coefficient of variation for the trials carried out. All the values are close to the expected ones, for both flow rates, with little variations between the two replications. The issue of a relevant overestimate of runoff from the 100x divider highlighted by Franklin et al (2001) was not present in our prototype. Moreover, the divider was tested for flow rates up to 5 times greater of which was used by Franklin et al. (2001), demonstrating the ability of the instrument to be used also for the evaluation of the discharge of a whole plot, and not only for the width of the instrument as in the Gerlach type sampler.

2.4.2. Cost

The total cost for the instrument is about 642 € per installation. Detailed coasts are resumed in Table 2. A considerable amount of labour is required for installation, but no additional cost for mechanical means are necessary and low maintenance is required.

The cost is comparable to the system proposed by Pinson (Pinson et al., 2004) but in addition, our system is able to register the runoff rate during an event. Other systems able to register runoff data variation are often more expensive (up to 5000 $) (Bonilla et al., 2006).

Tab. 2: Detailed cost for components.

Quantity	Component	Unit price	Amount
2	Tank dm^3 125	€ 39,00	€ 78,00
2	Tank dm^3 380	€ 89,00	€ 178,00
1	Multislot	€ 150,00	€ 150,00
4	Pulley	€ 5,50	€ 22,00
2	Aluminium parts	€ 5,00	€ 10,00
2	Potentiometer	€ 11,50	€ 23,00
1	Solar panel	€ 32,00	€ 32,00
1	Battery	€ 12,00	€ 12,00
1	Regulator board	€ 5,00	€ 5,00
2	Cables 5m	€ 5,00	€ 10,00
1	HOBO 12-bit	€ 72,00	€ 72,00
2	HOBO stereo cable	€ 8,00	€ 16,00
2	Float	€ 10,00	€ 20,00
2	Timing belt	€ 7,00	€ 14,00
Total			€ 642,00

2.5. Conclusions

The main object of this work was to present a practical application for the study of runoff. The configuration proposed in this article is an efficient and inexpensive method for measuring and study sediment and chemical losses under rainfall event. Measurement can be made at field scale, for different size plot and also where external power sources are not available. This instrument has been successfully used for over two years in farm field providing several data about runoff process in vineyard. Instrument’s low price permits the use of this equipment in several replicates reducing the potential errors of singles observations.

Chapter 3

Nutrient losses by runoff in a vineyard of the Oltrepò Pavese (southern Lombardy – Italian region)

Bernardoni Ettore, Acutis Marco.

Keywords: Runoff; Nitrogen; Phosphorus; Soil Losses; Vineyards.

3.1. Abstract

In this paper we discuss about nutrient and sediments losses by runoff events in a vineyard of the Oltrepò Pavese.

The study was carried out in a commercial vineyard fitted with an in-field runoff collector. The monitoring was carried out under natural rainfall condition from December 2008 to December 2012, in which 15 runoff events was registered. Runoff ratio varied from 0.12% to 31.32%. Sediment concentration was very variable ranging between 0.26 to 2.20 g l^{-1}, which also affected nutrient losses. Only few samples have total nitrogen (TN) greater than 10 mg l^{-1}. N loss does not pose an immediate threat to the aquatic system, while the amount of total phosphorus (TP) losses could have effects on eutrophication. The results show that the soil losses are acceptable and are under the tolerable soil erosion values.

3.2. Introduction

Agriculture is a major cause of degradation of surface and groundwater resources through erosion and chemical runoff (Ongley, 1994).

Soil erosion by water on cultivated land is a worldwide problem. It causes loss of a non-renewable resources (Warrington et al., 2009) and a series of damages on-site and off-site, including soil and nutrient losses (Poesen and Hooke, 1997; Douglas et al., 1998; Corell et al., 1999; Woodward, 1999; Gunatilake and Vieth, 2000; Steegen et al., 2001; Verstraten and Poesen, 2002; Ng Kee Kwong et al., 2002; Ramos and Martinez-Casasnovas, 2004), loss of productivity by soil degradation

(Lal, 1995; Roose, 1996; Alfsen et al., 1996; Gunatilake and Vieth, 2000) reduction of fertility (Pimentel et al. 1995) and countless environmental problems due to sediment shift from soils to the drainage network, river systems and sea (Young and Onstad, 1978; Ongley et al., 1992; Ghadiri and Rose, 1993; Hansen et al., 2002; Verstraeten et al., 2003). Soil erosion is identified as the major cause of diffuse pollution and specifically one of the major factors liable of water quality degradation in lakes and reservoir over the world (Water National Quality Inventory, 1994). Suspended sediment is also considered the most visible pollutant (Clark et al., 1985) and the physical pollutant in the surface water environment (Guy and Ferguson, 1970).

Non-point source pollution (NPSP) of water bodies has become a growing concern among scientists, policy makers, and the public at large, particularly where point sources of pollution have been identified and resolved. The fact that non-point source pollution accounts for most of the total pollution contribution was reported in several studies (Isermann, 1990; Heckrath et al., 1995; Chiaudani and Premazzi, 1998; Stutter et al., 2008). Agricultural sources of nitrogen (N) and phosphorus (P) often contribute in the largest part in generating NPSP. N and P losses from arable lands, both in dissolved and particle forms, not only tend to deplete the stock of soil nutrient, lowering the soil productivity (Pimentel et al., 1995), but may also cause eutrophication in water bodies (Foy et al., 1995). Even if N and P transported by surface runoff are agronomically not relevant, they may increase the concentration of N and P in runoff waters to levels higher than the values generally proposed as guidelines for degraded waters (Ng Kee Kwong et al., 2002). Study conducted by Zhang et al., (2003) recognized that a large portion of P enters water in particulate-aggregate form. Where dissolved phosphorus (DP) represents a readily available source of P for the algae, the P linked to suspended soil particles represents a long-term reserve of available P (Sharpley et al., 1992, Ekholm, 1994).

The contributing factors of agricultural NPSP nutrient loss by runoff from arable land, have been widely studied (Zeng et al., 2008) and rainfall intensity is considered the most important factor leads soil erosion (Laly, 1988).

Runoff occurs when rainfall intensity exceeds the infiltration capacity of the soil which is a measure of the ability of the soil to absorb and transmit rain water. Therefore runoff is limited on soils with high infiltration capacity. The rate and amount of runoff are besides influenced by the intensity and amount of rainfall, the soil moisture content and the slope.

These factors manifest themselves in a wide range of runoff management problems and conservation needs.

Vineyards are one of the lands where the highest soil losses occur (Tropeano, 1983, Wicherek, 1991, Wainwright, 1996), which increase after the introduction of mechanisation due to trampling that reduced the water infiltration capacity of the soil (Ramos and Martinez-Casasnovas, 2006). Because its diffusion and the different methods of cultivation adopted around the world, more knowledge are needed. In hilly areas of Italy, suitable to viticulture, the agricultural practices may results in high loss of soil with high consequent degradation of the soil resource, both in terms of reduction in thickness and soil quality. In addition to it, off-site effects of soil erosion in vineyards are very important, due to sediment transfer to the channel network and human infrastructures, especially during extreme rainfall events (Bazzoffi and Chisci 1999).

The Oltrepò Pavese is located in the south-west of the Italian region of Lombardy, where the vineyards account for 40% of the cultivated area, mainly located in hilly terrains (ISTAT 2010). Nothing is known about runoff erosion and nutrient losses in the Oltrepò Pavese area. In order to contribute to the knowledge, the study presented in this paper attempts to fill this gap of information. In this research we: i) measured runoff events, ii) quantified the sediments loaded from runoff event, iii) quantified the nutrient losses from the system.

3.3. Materials and methods

3.3.1. Site description

The study area is located in the south-west of the Italian region of Lombardy where vineyards represent the largest use in hilly terrain. The area has an Apennine mesoclimate (Mariani, 2008) with an annual average temperature of about 12°C and an annual rainfall of about 680 mm, mainly concentrated in spring (May) and autumn (November) (Ottone and Rossetti, 1980; Mariani, 2008).

3.3.2.Plot characteristics

The study was carried out in a 9-year-old vineyard at the “Centro Vitivinicolo Riccagioia” located in Torrazza Coste (latitude 44°58'40"44 N, longitude 09°5'4"56 E, 159 m a.s.l.). The plantation consists of single Guyot trained vines, at 2.5 m × 1.0 m pattern, which run along the maximum slope degree direction. The plot is about 686 m^2 includes four rows (three in-row), 88 meters long. The slope of the plot is about 17%.

The grass permanent cover in the inter-row is cut four or five times a year, from April to August. Chemical weeding in row is renewed yearly in March and July.

To assess the soil characteristics a soil profile was performed near the plot and a series of soil samples for each horizon identified, were collected

3.3.3. Rainfall and runoff data

Rainfall data was recorded, since December 2008, with a meteorological station at the same field, having a tipping bucket system linked to a data storage system. Total rainfall, duration of the events and rain intensity were derived from the data registered.

Runoff data was collected using a system composed from a multislot divisor with collection tanks, engaged with a level reading systems. The entire scheme is described in Bernardoni et al., 2012.

After every runoff event, a representative quote of runoff samples were collected in plastic bottle and transported to the laboratory.

The analysis of runoff water has been done separately on the samples as it for total nitrogen (TN), total phosphorus (TP), and total sediments. On the clear water, after filtration with 0.45 µm PTFE filters, we performed the analysis for NO_3_N, NH_4_N and orthophosphates (thereafter indicated as PO_4^{3-}). TN and TP were determined, in runoff water samples unfiltered, previously digestion using Valderrama (1981) procedure. With a continuous flow analyser, FIAstar 5000 Flow Injection Analyzer spectrometric detector, the TN content has been determinate on samples digested; with the same instrument have been measured also mineral nitrogen contents on the filtered water. Analysis of NH_4_N was performed by the gas semi-permeable membrane method according to the ISO 11732 procedure (1997), nitrate (N_NO_3) analysis instead, was quantified after reduction to nitrite in copper–cadmium columns by the spectrophotometric determination of the azo dye formed from the reaction of the nitrite with sulphanilamide and N-(1-Napthyl) ethylenediamine dihydrochloride (Rayment and Higginson, 1992). TP of the runoff has been determinate from the digested sample, while mineral phosphorous determination in the filtered sample was performed, using the green malachite spectrophotometric method, following Ohno e Zibilske (1991).

Total suspended solids will be determined by drying (105 °C) a specific volume of runoff sample.

Runoff nutrient concentrations were used in conjunction with runoff water volumes to calculate the total nutrient losses.

3.4. Results

3.4.1 Soil characteristics

The soil of the study field is classified as a fine silty Typic Calciusteps mixed superactive mesic for the USDA (2010) classification or an Hapli-Hypocalcic Calcisol (Siltic) for the WRB (2006) classification. Characteristic of the soil profile and analysis are show in Table 3.1.

Soils samples have relatively high silt and sand content, and moderate organic matter content.

Table:3.1 Soil profile characteristic of the study area.

Horizon	Depth	Texture (%)			pH		O.M.
		Clay	Silt	Sand	(H_2O)	(KCl)	%
Ap1	30	13.5	47.4	39.1	8.1	7.0	1.9
Ap2	60	14.0	57.0	29.0	8.2	6.9	1.0
Bw	80	13.5	63.5	23.0	8.2	6.9	0.8
Bk	120	15.6	70.5	13.9	8.3	6.8	0.2
BC		12.3	59.8	27.9	8.3	6.8	0.3

3.4.2. Rainfall and runoff data

Total monthly precipitation recorded from December 2008 to December 2012 is resumed in Table 3.2.

209 rainfall days from December 2008 to December 2012 was registered, the most relevant was of 64 mm in one day (08/11/2009), while the

maximum rain rate was 430 mm h^{-1} (registered at 1 minute interval), recorded during the event of the 05/02/2011.

Fifteen runoff events were recorded during the four years.

Table 3.2 Amount of monthly precipitation recorded during the monitoring period (* indicates the month with runoff events)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2008	-	-	-	-	-	-	-	-	-	-	-	72
2009	57	91*	102*	155*	8	40	13	29	76	56	194*	57
2010	67	113	65	57	116*	54	3	71	47	188*	175*	97
2011	30	64	85	4	46	127*	15	0	61	30	107*	6
2012	27	15	40	84	63*	25	43	7	90	117	100	38

Table 3.3 shows total rainfall, event duration, rainfall duration, runoff duration, maximum rainfall intensity, total runoff and runoff ratio (runoff/rainfall) for each rainfall event that generate runoff.

Six events were recorded in both 2009 and 2010. Years 2011 and 2012 were drier than the two previous years, in consequence only two events were recorded in 2011 and one in 2012.

Runoff ratio varied from 0.12% to 31.32%. The maximum runoff ratio was registered during the 05/05/2010 second event (II). This is due to the succession of two distinct events. In fact a 29.80 mm of precipitation was registered from 03/05/2010 to 05/05/2010. This rainfall event ends in the morning of the 05/05/2010, and after another event was registered (05/05/2010 (II)) of about 32 mm. The soil already wetted from the previous precipitation resulted in a reduced water intake capacity of the soil and generated large runoff.

Table 3.3 Total rainfall, event duration, rainfall duration, runoff duration, maximum rainfall intensity, total runoff and runoff ratio (runoff/rainfall) for each rainfall event that generate runoff.

Event	Data or period	Total Rainfall (mm)	Event Duration (h)	Rainfall Duration (h)	Runoff Duration (h)	Max rainfall Intensity (mm h^{-1})	Total Runoff (mm)	Runoff ratio (%)
07/02/2009	07/02/2009	7.70	19.50	4.60	18.70	14.00	0.14	1.77
05/03/2009	05/03/2009	25.80	11.50	11.50	1.00	10.90	0.14	0.53
29/03/2009	29/03/2009	47.80	21.10	21.10	0.60	8.40	0.06	0.12
21/04/2009	19-21/04/2009	44.40	35.00	17.60	20.20	22.10	0.64	1.43
28/04/2009	26-28/04/2009	68.40	30.40	23.50	32.00	25.70	4.56	6.66
08/11/2009	05-08/11/2009	97.40	66.50	32.60	56.50	20.30	7.49	7.69
05/05/2010	03-05/05/2010	29.80	36.80	12.30	6.30	28.20	0.26	0.89
05/05/2010 (II)	05/05/2010	32.20	7.30	5.30	5.10	86.10	10.08	31.32
13/05/2010	13/05/2010	13.00	3.30	2.00	3.30	42.40	1.81	13.95
04/10/2010	04/10/2010	47.80	13.50	8.60	13.00	44.50	4.66	9.74
25/10/2010	25/10/2010	48.40	21.80	14.50	10.10	16.80	6.65	13.74
02/11/2010	30/10-2/11/2010	144.60	69.20	39.30	62.50	25.10	7.70	5.32
05/06/2011	05/06/2011	20.00	4.00	3.30	3.70	101.00	2.38	11.90
05/11/2011	04-05/11/2011	85.80	39.00	27.30	22.60	23.20	1.63	1.90
01/05/2012	01/05/2012	21.80	6.00	1.00	1.50	53.60	0.74	3.39

3.4.3. Nutrient and sediment concentration in surface water runoff

Runoff was collected for nutrient and soil losses analysis after the fifteen runoff events registered. Sediment concentration in runoff ranged from 0.26 to 2.20 g l^{-1}.

The observed sediment concentrations in runoff represent soil losses by up to 101 kg ha^{-1} in one single event. In the analysed years the value of total annual losses is never higher than the upper value of 11 Mg ha^{-1} $year^{-1}$ (McCormack et al., 1982, Hall et al., 1985), which is considered the maximum annual amount of soil, which can be removed before the long term natural soil productivity is compromised.

In this study we found that soil loss depend on total runoff more than on rainfall intensity and follow a linear function (Figure 3.1).

Table 3.4 Sediment concentration in runoff, soil losses, total nitrogen (TN) and total phosphorus (TP) in runoff and nutrient losses by runoff for every runoff event.

		Nutrient concentration			Nutrient losses by runoff	
Event	Sediment ($g\ l^{-1}$)	TN ($mg\ l^{-1}$)	TP ($mg\ l^{-1}$)	Soil loss ($kg\ ha^{-1}$)	N ($kg\ ha^{-1}$)	P ($kg\ ha^{-1}$)
07/02/2009	0.520	10.711	0.032	0.708	0.015	< 0.001
05/03/2009	0.511	2.494	0.367	0.700	0.003	0.001
29/03/2009	2.207	4.748	0.990	1.223	0.003	0.001
21/04/2009	0.464	3.363	0.393	2.946	0.021	0.003
28/04/2009	0.767	2.933	0.457	34.928	0.134	0.021
08/11/2009	1.357	2.234	0.849	101.696	0.167	0.064
05/05/2010	0.408	6.375	2.066	1.077	0.017	0.005
05/05/2010 (II)	0.423	3.460	2.025	42.658	0.349	0.204
13/05/2010	0.845	10.925	1.988	15.314	0.198	0.036
04/10/2010	0.882	4.904	2.153	41.102	0.228	0.100
25/10/2010	0.433	2.624	1.481	28.822	0.174	0.098
02/11/2010	0.398	1.617	0.885	30.645	0.125	0.068
05/06/2011	0.544	4.220	2.119	12.942	0.100	0.050
05/11/2011	0.811	1.761	0.343	13.209	0.029	0.006
01/05/2012	0.266	2.381	0.304	1.962	0.018	0.002

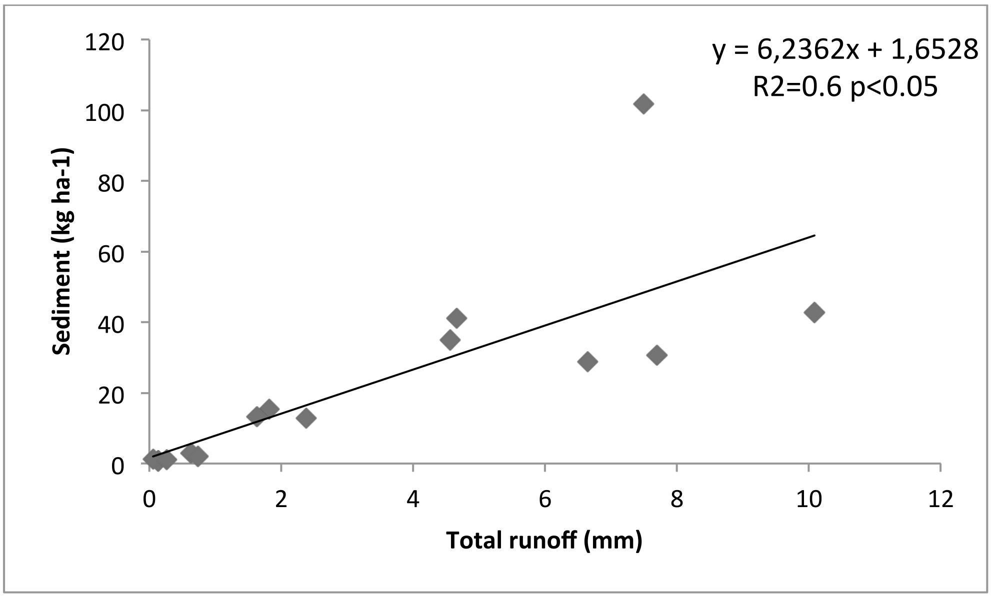


Figure 3.1: Sediments on runoff samples as a function of total runoff.

Sediment concentration was not significantly correlated with mean and maximum rainfall intensity.

Some studies carried out in the Mediterranean European region, representing different landscapes and different land uses, point out that vineyards are one of the lands that incur the highest runoff and soil losses, ranging between 0.67 and 4.6 Mg ha^{-1} year^{-1}, (Kosmas et al., 1997). Other authors give much higher values for other specific sites. For example Tropeano (1983) found values between 47 to 70 Mg ha^{-1} year^{-1} in northwest Italy, Wicherek (1991) register soil loss value of 35 Mg ha^{-1} year^{-1} in the Mid Aisne region (France), and 22 Mg ha^{-1} year^{-1} in the Penedés–Anoia region (NE Spain) was registered by Usón (1998). Even higher soil losses have been associated with extreme rainfall events as demonstrated in Wainwright, (1996), that register a value of soil loss of

34 Mg ha^{-1} in an extreme rainfall event in the SE France, 18–22 Mg ha^{-1} was measured at plot scale from Ramos and Porta (1994) in NE Spain, 11.51 Mg ha^{-1} in an extreme event in the Alt Penedès region (NE Spain) (Ramos and Martínez-Casasnovas, 2006).

The difficulties in establishing a clear relationship between rainfall characteristics and soil detachment and transport have been pointed out by many authors. Reichert et al. (1994) said that sediment transport is dependent on rainfall intensity, Spann et al. (2005), studying the relationship between soil losses and rainfall characteristics under different conditions, found that the maximum 10-min intensity and the runoff percentage did not result in good correlations, however he found good correlations with kinetic energy, total rainfall and an index of erosivity (total rainfall x maximum intensity). Ramos and Martínez-Casasnovas (2006) found that soil losses depend on rainfall intensity more than on total rainfall, and the sediment concentration in runoff is more correlated with rainfall erosivity, but not with kinetic energy and maximum intensity. Pieri et al., (2009) found contrasting results for bare and covered soils. In particular rain kinetic energy resulted not correlated with sediment yield in covered soil; however the same Author found that sediment yield is a function of total runoff water in both covered and bare soil.

NH_4_N in our study range between 0.05 and 2.36 mg l^{-1} and NO_3_N values range between 0.03 and 9.84 mg l^{-1}. Average TN concentrations in runoff ranged from 1.61 to 10.92 mg l^{-1} and mineral N ranged between

5% and 92% of the TN. Nitrogen concentration resulted not related to sediments or runoff volume.

It is to be noted that N losses through surface runoff are generally small, unless high rates of N fertilizer are not applied at the surface just before heavy rains (Legg and Meisinger, 1982). Also Daniels et al., (1998) reviewed that the amount, intensity and timing of the first rainfall event after the application of the fertilizer are among the most important factor affecting the concentration found in runoff.

Immediately algal available P values (dissolved orthophosphates – DP; Pierzynsky, 2000), ranged between 0.01 to 0.84 mg l^{-1}. DP is on average 35% of the TP. TP concentrations ranged from 0.03 to 2.15 mg l^{-1}. In general the TP concentration in runoff water is higher than DP, this leads us to the P is mainly contained in the sediments. For example Gilliam et al. (1999) reports that around 75 – 90% of P transported in runoff in conventionally tilled land is associated with sediments and organic matter and also Johnson et al. (1979) reports that 80-99% of the TP losses are associated with the sediment.

There is a lack of consensus concerning the concentration at which P in agricultural runoff leads to eutrophication, but it is generally accepted that the critical level of TP in runoff is 0.1 mg l^{-1} (US EPA, 1986). In this study, DP, exceeded the guideline value of 0.1 mg l^{-1} in 94% of the case.

Portielje and Van der Molen (1999) pointed out that TP concentrations in water of 0.03-0.1 mg l^{-1} are associated with eutrophication. In Smith et al. (1995), the authors state that a phosphorus soluble concentration above 0.01 mg l^{-1} and a total concentration above 0.02 mg l^{-1} may accelerate eutrophication.

In our study N and P concentrations in runoff implied nutrient losses ranging between 0.01 and 0.34 kg ha^{-1} of N and between a value minus of 0.001 and 0.20 kg ha^{-1} of P in single events.

As shown in Figure 3.1 NO_3_N was often the dominant form of mineral N moved from surface runoff, and seems to be the dominant form loaded between mineral and undissolved nitrogen, during runoff events. (Figure 3.2). Selectivity in transport forms of nitrogen are not clearly linked with the sediments or the rainfall amount or intensity.

N and P in runoff are also not clearly related with sediments concentration. Furthermore TP results in a significant correlation with the maximum rainfall intensity ($y = 19.98x + 12.89$; $R^2 = 0.34$; $p<0.01$).

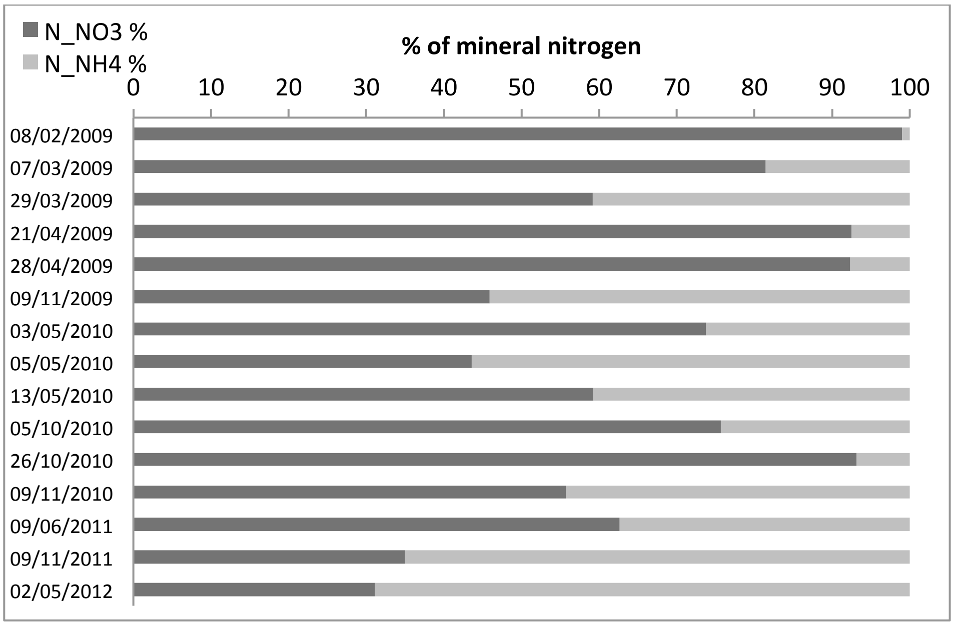


Figure 3.1. Percentage of ammonia nitrogen (N_NH_4) and nitric nitrogen (N_NO_3) in respect to the mineral nitrogen moved by surface runoff.

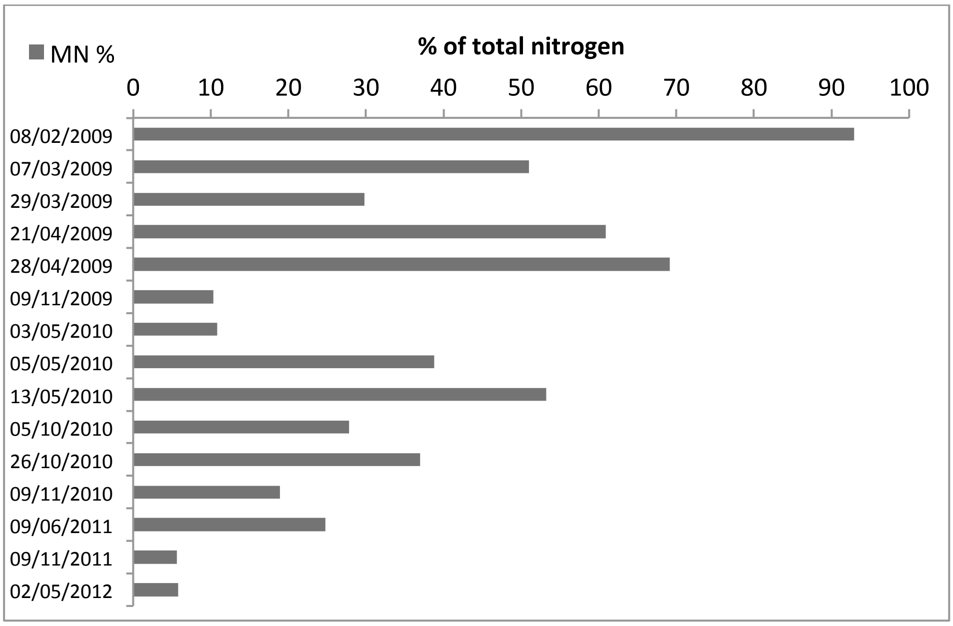


Figure 3.2. Percentage of mineral nitrogen (MN) in respect to the total nitrogen loaded in every runoff event.

Also another various studies conducted in Italy (Acutis et al., 1996, Papini et al., 1997, Balestra et al., 2001) and abroad (Sharpley and Smith, 1995, Heathwaite and Johnes, 1996, Sharpley, 1997, Udawatta et al., 2004, 2006) refer highly variable concentrations of N and P depending on the type of the soil, the use of fertilizers and their doses and, more generically, depending on the management.

3.5. Conclusions

Erosion process in this vineyard of the Oltrepò Pavese, produce low runoff rates and the soil losses are lower than the soil loss tolerance.

Therefore we conclude that this soil is not susceptible to erosion because this management is not harmful.

Sediment concentration in runoff is very variable from a rainfall event to another. Soil losses are related with runoff amount. TP is related with the maximum runoff rate.

Only few samples have TN greater than 10 mg l^{-1}. We therefore believe that N does not pose an immediate threat to the aquatic system but the amount of TP losses could have effects on eutrophication, contributing to increase the non point sources of pollution.

Chapter 4

Particle size distribution of eroded material during runoff events.

Bernardoni Ettore, Acutis Marco

Keywords: PSD, Particle Size Distribution, Laser Granulometry

4.1. Abstract

In this paper, particle size distribution (PSD) of eroded material was investigated for different runoff erosion event on a field plot. The study was carried out in an experimental filed located in a hilly area, where vineyards are the typical cultivation.

Sediment samples were collected for four years, after every runoff event through a multislot runoff sampler.

The PSDs of eroded material were determined using a laser particle size analyser, after dispersion of the samples. For each soil, PSD frequency curves of eroded sediments and parent soils were generally of a similar shape. The texture of the sediment was in general similar to that of the parental soil but there is an evident depletion in clay and sand and an enrichment in silt indicating the existence of transport selectivity.

A ratio between PSD of the transported material with that of the parental soil provided a measure of the particle size selectivity of the transported sediments. The ratio it’s on average 1.21 for the silt particles, 0.76 for the sand and 0.55 for the clay.

4.2. Introduction

Loss of soil is a worldwide problem because a non renewable resource is being lost and also because eroded material are potentially a source of pollution and could degrading water in river systems and sea (Young and Onstad, 1978; Ghadiri and Rose, 1993).

Soil erosion by water is a natural process that influences the origin and dynamics of landscapes and therefore plays an important role in the ecosystems evolution (de Lima et al., 2008). Moreover soil erosion has several adverse effects on soil fertility (Pimentel et al., 1976; Morgan, 1986). Understanding the factors affecting water erosion is of fundamental importance for the planning and designing of measures for the soil conservation, particularly where the intensive use of soil has been degrading land and water. Erosion of soil by water is caused by the combined and the simultaneous effect of the processes of soil aggregates breakdown by the impact of rain drops and then the transport of the eroded material by runoff (e.g., Römkens et al., 1997; Meyer, 1980). Any factor that influences runoff characteristics consequently affects the erosion of soil by water. (de Lima et al., 2008).

In detail the phenomenon involves two main processes: first the detachment of soil particles and aggregates (or the results of their breaking) from parental soil by the effect of raindrop or runoff shear; and second the transport of the material by raindrop splash effect and flowing runoff.

Usually soil particle sizes are selectively eroded. Erosion often causes selective loss of fines particles, encouraging the development of a coarsening skeletal soil, with reduced moisture retentive properties (Lewis, 1981; Frost and Speirs, 1984).

The detachment of soil material and the aggregates breakdown are mainly influenced from the typology of soil cover. In fact the kinetic energy of raindrops is much larger than that of surface flow, than in bare soil the most important component of detachment is due to the raindrop effect (Hudson, 1971). Erosion is also intensified on sloping land, where more than 50% of the soil contained in the splashes is transported downhill (Pimentel, 1995). However the movement of the detached soil is mainly due by surface overflow (Young and Wiersma, 1973) witch increase sharply with slope and when rilling is initiated (Warrington et al., 1989; Shainberg et al., 1992).

These processes have been extensively studied using rain simulators (Arnaez et al., 2007; Franklin et al., 2007; Pérez-Latorre et al., 2010) and most of these studies used constant rainfall intensities, because the primary objective in this sense is to collect measurable and constants data, and not to mime the effect of natural events (Dunkerley, 2008). In fact simulated rain differing significantly from the characteristics of natural rainfall, which is very variable in intensity, distribution, size and kinetic energy of the drops, temporal and spatial variability (Sharon, 1980; Helming, 2001; Willems, 2001). The spatial and temporal distribution of rainfall is one of the main factors affecting runoff on slopes (de Lima et al., 2008).

Soil particle-size distribution (PSD) is one of the most important physical attributes because of its great influence on soil properties related to water movement, productivity, and soil erosion (Huang and Zhang, 2005; Montero, 2005). The land use largely influence PSD by helping or hindering the soil erosion processes (Martínez-Casasnovas and Sánchez-Bosch, 2000; Erskine et al., 2002; Basic et al., 2004). In this sense, characterization of PSD may be a promising indicator to reveal the influence of land use on soil properties (De Wang et al., 2008).

In order to assess the effects of the erosion process, it is important to quantify PSD of the eroded sediments along with the total amount of soil material lost. Clay is generally considered the size fraction of the sediment that is most important in the transport of adsorbed chemicals in the soil (Young and Onstad, 1978). It is well know that the finer material, in general, can travel greater distances before being deposited, than an understanding of the PSD of eroded material is essential to accurately predict where soil components will be deposited, and how the PSD of the eroded sediment may vary depending on soil type, texture and management practices. Several studies have tried to characterize eroded sediments in terms of their primary PSD, determined following complete dispersion of the eroded material, and to comparing it with those of the parent soil. The results are various. Some studies reported that sediments from interrill erosion were enriched in sand to the detriment of the silt and clay size fractions (Young and Onstad, 1978; Alberts et al., 1980). In other studies, conversely, it was observed that clay, and not sand, was enriched in the eroded sediment (Monke et al., 1977, Alberts et al., 1983, Warrington et al., 2009). It was also been observed that the composition of sediments changes during the rainfall event; at the beginning sediments had finer material than that of the parent soil, but in the course of the event the PSD of the sediments become comparable to that of the parent soil (Gabriels and Moldenhauer, 1978; Mitchell et al., 1983,). These differences between PSDs of eroded materials and their parent soils results from differences in their soil properties (texture, clay content), the existing conditions at the soil surface before a rainfall event, as well as the characteristics of the precipitation event itself (intensity, raindrop size and energy, and duration).

PSD of eroded material provides basic information about erosion processes and may be useful for controlling the effect of sediments when they reach surface waters (Meyer et al., 1980). Furthermore information about the particle size distribution of the runoff eroded material is necessary for developing improved erosion and sediment models for soil loss predictions (Young, 1980).

The main objective of the study was to characterize, in natural conditions, the distribution of sediment grain-size transported by rainfall runoff generated in a vineyard hill.

4.3. Material and methods

4.3.1 Runoff plot and study area

A runoff plot of about 686 m^2, located in a 9-year-old vineyard at the "Centro Vitivinicolo Riccagioia", Torrazza Coste country, (latitude 44°58'40"44 N, longitude 09°5'4"56 E, 159 m a.s.l.) was used for the study. The plantation consists of single Guyot trained vines, at 2.5 m × 1.0 m pattern, which run along the maximum slope degree direction. The plot includes four rows (three in-row), 88 meters long; the slope is about 17%. This plot is used in a study in which runoff data, soil and nutrient losses have been recorded since December 2008. The plot is equipped with a collection systems composed by a multislot divisor and a collection tanks with a level reading systems. This instrumentation is used to measure soil losses and runoff at the lower end of the plot. A meteorological station was located near the plot, and through a data logger data was stored at a 1-minute intervals.

Sediments sampler were collected from the tanks after fourteen runoff event and taken to the laboratory.

4.3.2 Particle size distribution determination

Particle size measurements were performed by means of laser diffraction technique using a granulometric analyser, after soil dispersion by Na-hexametaphosphate.

We decided to use the laser diffraction technique for PSD determination because soil materials in runoff samplers were usually present in low concentrations, would have made it necessary to sample and drying large quantities of sample to obtain a quantity of soil for the classic analysis methods. Furthermore the laser granulometer use dispersed granular material in water, condition in which the samples are already found.

Another advantage using this technique is given by the fact that this method provides a continuous PSD rather than an arbitrary division of the particles between a limited number of size fractions (as determined by conventional methods based on sedimentation and/or sieving) and permits a more detailed analysis of a desired size range, especially in the clay size fraction (Eshel et al., 2004).

We decided to disperse the sediment eroded and to study only the primary PSD rather than examining the PSD of the non-dispersed sediment samples. This is because there was some concern that during the procedure for PSD determination of the non-dispersed samples, further breakdown of aggregates could be induced leading to erroneous results and conclusions (Warrington et al., 2009).

A Mastersizer 2000 laser diffraction granulometer units manufactured by Malvern Instruments Ltd was used to perform the granulometric analysis. This laser diffraction particle size analyser performed measuring particle sizes between 0.02 to 2000 µm, using both blue (488.0 µm wavelength LED) and red (633.8 µm wavelength He-Ne laser) light dual-wavelength, single-lens detection system. The light energy diffracted by the dilute suspension circulating through a cell is measured by 52 sensors. The light intensity adsorbed by the suspended material is measured as obscuration and indicates the amount of sample added in the dispersant liquid. Light scattering data are classified in 100 size fractions class, which are analysed at 1000 readings per second, and compiled with the Malvern's Mastersizer 2000 software by using the Mie diffraction theories or the Fraunhofer Approximation (de Boer et al., 1987). The Fraunhofer Approximation represents the easiest model, in contrast to Mie Theory, it does not require to provide any optical property information. However, its use can lead to significant errors due to the assumptions it makes regarding the nature of the materials being measured. The Mie theory, utilizes the refractive index (RI) and absorption (ABS) of the dispersed granular material, and RI of the dispersant liquid. This theory is based on some assumption: i) particles are mineralogically homogeneous; ii) particles are spherical; iii) the optical properties of particle and dispersion medium are known; iv) suspension dilution guarantees that light scattered by one particles is measured before being-re-scattered by other particles.

The use of laser method for measuring particle size have been widespread in recent decades in all areas in which those measures are relevant (Black et al., 1996) and a number of reports have proposed that recently developed laser diffraction instruments show potential for automating the measurement of particle size distributions in soil and related materials (Kowalenko and Babuin, 2013). However does not yet exist, particularly in soil science, official or standard methods that delineate unambiguously and defined procedures. Therefore, the procedure of analysis and parameters setting of the laser used for the determination of particle size of the samples of this work, were determined on the basis of past experience of analysis with this instrument at the CNR ISAFoM (De Mascellis and Basile, 2012; De Mascellis et al., 2009). Following this procedure the samples were previously subjected to chemical-physical dispersion through the addition of a solution of 50 g l^{-1} sodium hexametaphosphate, in variable amounts depending on the amount of the volume of the sample, but such as to maintain a ratio of 2.5:1 between liquid and dispersant solution. The samples were then subjected to agitation with an automatic vertical agitator for one night. Finally, we proceeded to the determination of particle size through the laser granulometer, preceded by a mechanical dispersion by ultrasonication for a period of 2 minutes.

For each of the samples analysed, were performed six readings of the duration of 1 minute each. The theory of calculation for the processing of data in the diffraction particle size analysis was the Mie, whereas the RI of the suspension amounted to 1.33, RI of the particles was set to 1.9 and ABS index was equal to 0.5. With this configuration, the indexes indicative of a good approximation of the measured data with respect to the theoretical model of the Mie have given excellent results.

4.3.3. Transport selectivity

Comparison of the PSD of the eroded sediments with that of the parental soil provides a measure of the selectivity of sediments transported during runoff events. The enrichment ratio (ER), as defined by Massey and Jackson (1952), is an important term and give an index of erosion selectivity.

$$\text{ER} = \frac{\text{percentage of particles in a given size class in surface runoff}}{\text{percentage of particles in a given size class in matrix soil}}$$

A value of ER greater than 1 represent an enrichment, a given class forms a greater proportion of the transported load in runoff than in the matrix soil. ER value less than one represent a depletion, a given class forms a greater portion in the matrix soil than in the transported sediment.

4.4. Results and discussion

4.4.1. Soil characteristics

The soil in the field under investigation is classified as a fine silty Typic Calciusteps mixed superactive mesic for the USDA (2010) classification or an Hapli-Hypocalcic Calcisol (Siltic) for the WRB (2006) classification (Table 4.1).

Table 4.1: Soil profile characteristics.

Horizon	Depth (cm)	Texture (%)			pH		$CaCO_3$ total	OC	OM	cation exchange (meq/100g)			
		Sand	Silt	Clay	(H_2O)	(KCl)	%	%	%	CSC	Ca+Mg	K	Na
Ap1	30	13.5	47.4	39.1	8.1	7.0	14.7	1.1	1.9	22.4	20.2	2.06	0.19
Ap2	60	14.0	57.0	29.0	8.2	6.9	14.6	0.6	1.0	21.2	19.6	1.43	0.19
Bw	80	13.5	63.5	23.0	8.2	6.9	17.3	0.5	0.8	19.9	18.4	1.37	0.12
Bk	120	15.6	70.5	13.9	8.3	6.8	20.8	0.1	0.2	26.4	24.4	1.68	0.31
BC		12.3	59.8	27.9	8.3	6.8	10.2	0.2	0.3	23.7	22.0	1.31	0.44

4.4.2 Particle size distribution (PSD) analysis

The texture of the eroded material is in general silty loam then the texture of the upper soil horizon (Figure 4.1).

The percentage of silt (2-20 μm) in parental soil account for 47.4% while in average sediments was principally composed of silt which accounts on average the 57% of the total eroded material. In the dispersed soil parental material, particles > 250 μm (medium and coarse sand) represent the 6.24% of the soil; in dispersed eroded material this value range between 0.08 to 6.85% (mean 3.67%).

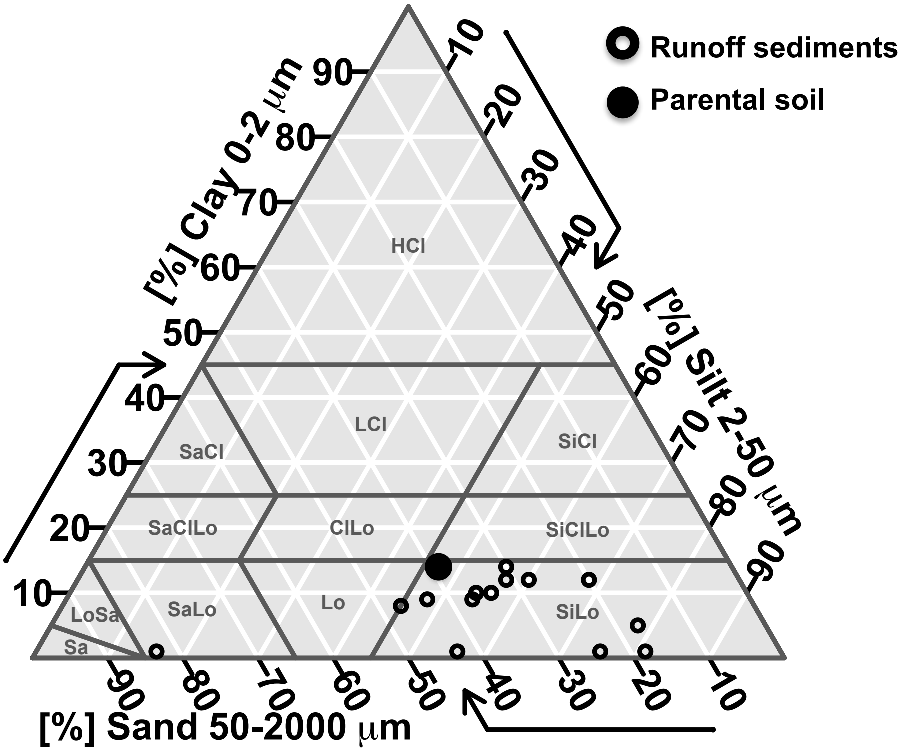


Fig 4.1: Texture of matrix soil and sediments for all the events, represented in a ISSS texture triangle.

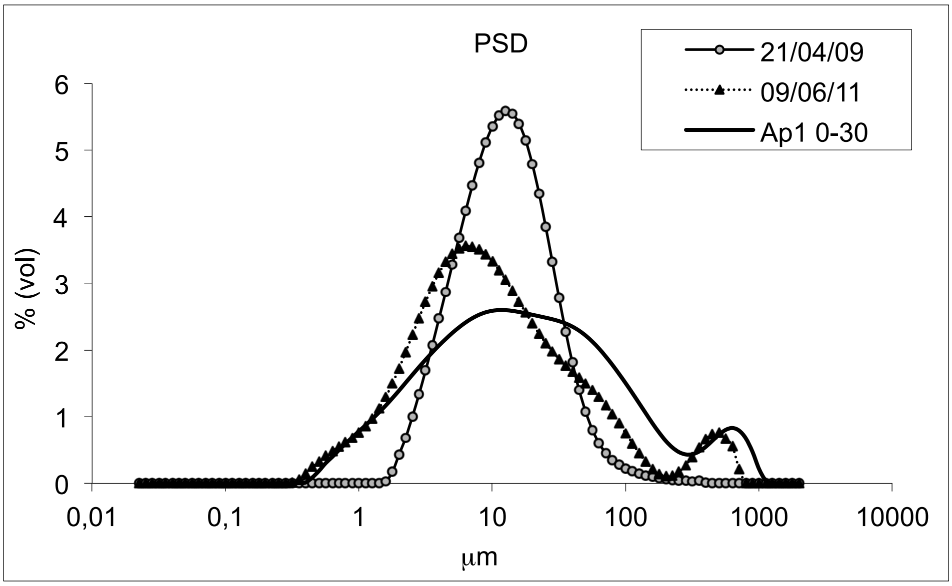


Fig 4.2: An example of the particle size distribution between the first soil horizon (Ap1) and two samplers of runoff.

According to Young (1980) soils with more than 33% of silt content (as in this case) usually generate sediments in the silt-size range (mostly in the range 20–35 µm). He also suggested that the most erodible size ranges include particles and aggregates between 20 and 200 µm in silty soils. The author postulated that particles with a size larger than 200 µm have enough mass to limit their movement, whereas for particles below 20 µm, cohesive forces impede particle detachment. Therefore, according to Meyer et al. (1981), Young (1990) and Asadi et al. (2011), soil texture is the main factor behind differences in sediment size distribution. In fact comparing the particle size distribution of the parental soil with that of the eroded material (Table 4.2) we note that the distributions of the soil particles in runoff samplers were significant correlated ($p<0.01$ for all) to that of the matrix soil.

Table 4.2: Coefficient of determination (r^2) between the particle size distribution of the matrix soil and the eroded samplers based on % of volume in 100 class of diameter. All the distribution are statistically correlated ($p<0.01$).

Event	r^2
07/03/09	0.94
23/03/09	0.68
21/04/09	0.70
28/04/09	0.77
09/11/09	0.68
03/05/10	0.25
05/05/10	0.95
13/05/10	0.81
05/10/10	0.95
26/10/10	0.96
09/11/10	0.95
09/06/11	0.90
09/11/11	0.89
02/05/12	0.95

The PSD curves of the parental soil present two main peak. A major peak which occurred in the region of the silt, and a minor peak that occur in the region of the sand. Also the PSD curves of the eroded material generally presents two main peak, the major peak in the region of the silt (about 15 µm) and the minor peak in the region of the medium-coarse sand (about 500 µm).

Loch and Donnollan (1983) and Asadi et al. (2007) also found that different sediment sizes is distributed bimodally. They theorize that the bimodal distribution of sediments resulted from the different transport mechanisms of suspension, saltation and rolling. Warrington et al. (2008) found the same bimodal distribution strictly dependent to the characteristic of parental soil. There are still some contrasting and unexplained results regarding sediment sorting in erosion processes.

Sediment size distributions seem to depend on many factors such as rainfall characteristics, vegetation cover, hydraulic flow type (sheet or rill), soil properties and slope (Shi et al., 2012).

4.4.3. Transport selectivity

A general enrichment was observed for the silt fraction and is an indicator of the transport selectivity (Figure 4.4). This is because aggregates with a high silt content have lower density than others, and are easily transported (Young, 1990).

The clay fraction in eroded material had an ER of 0.55 on average, while a values of mean ER of 1.22 and 0.89 was found respectively for silt and sand.

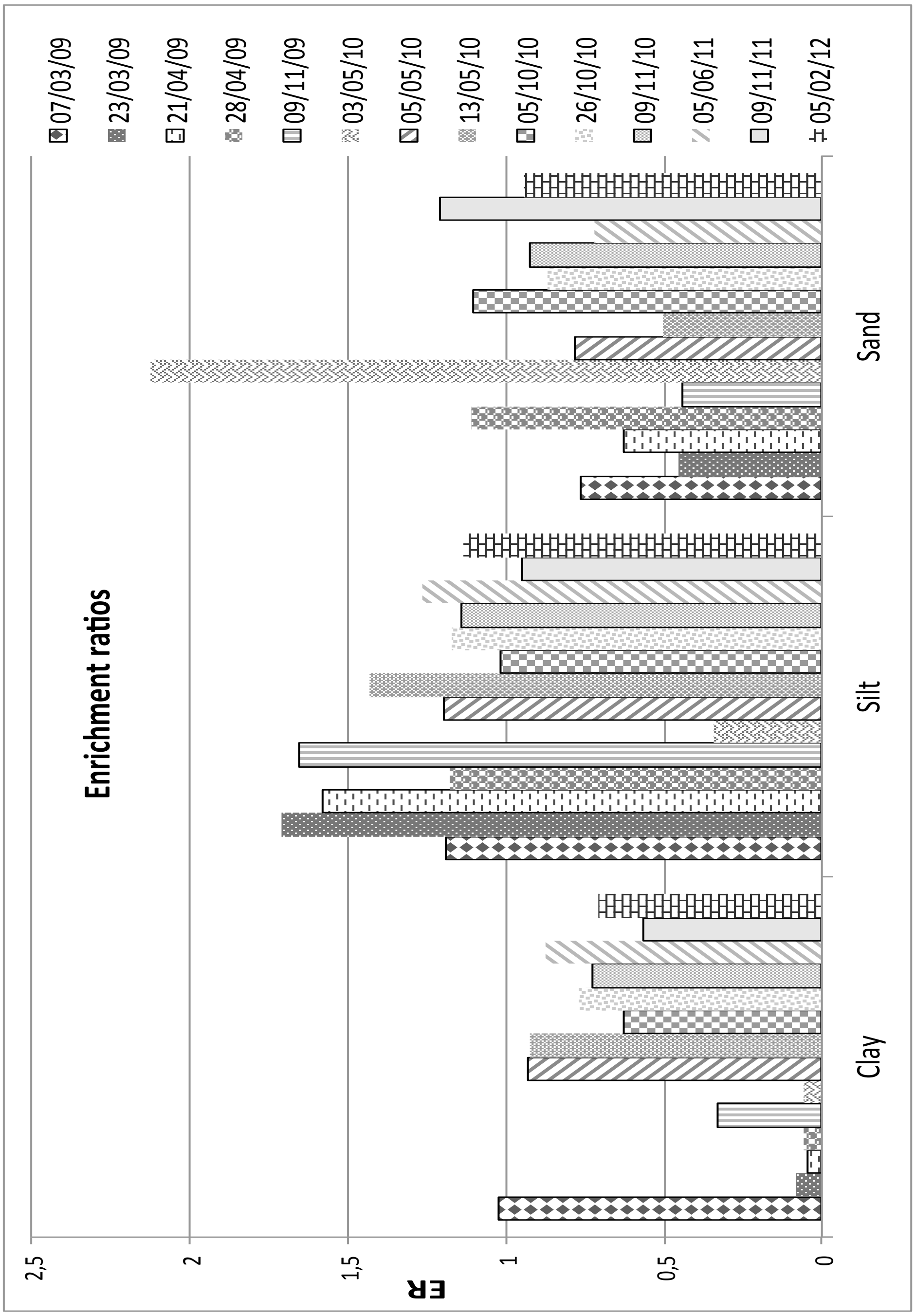


Figure 4.5: Enrichment ratio (ER) of the sediments.

A significant positive correlation between ER-clay and mean rainfall intensity (p<0.01) was found (Figure 4.5). Martinez-Mena et al. (1999) found that clay is mainly transported as aggregate. In general aggregates are to heavy to be transported and detached and Durnford and King (1993) reported that when rainfall energy is high enough to break soil aggregates, clay became available for transport, result confirmed by Shi et al. (2012).

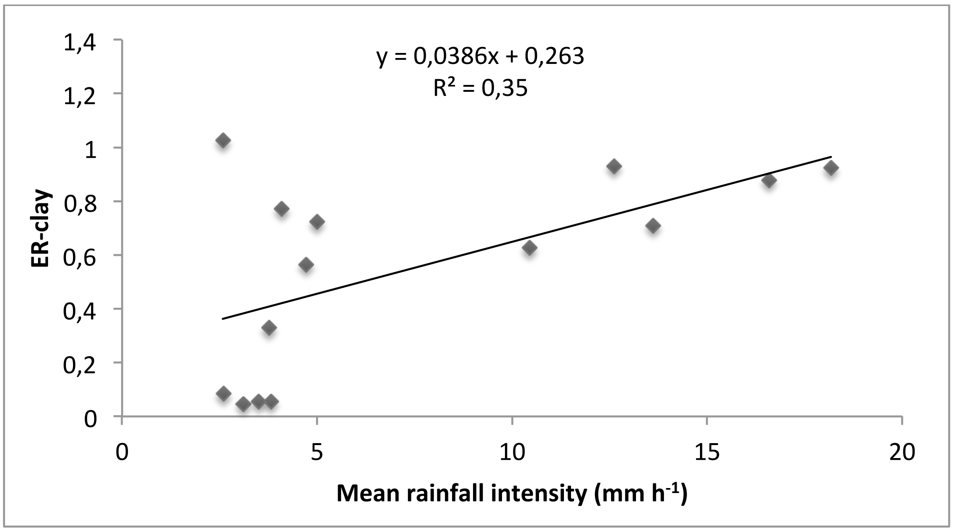


Figure 4.5: Relationship between enrichment ratio (ER) of clay fraction in sediments and mean rainfall intensity.

4.5. Conclusions

The laser granulometer has allowed to obtain information rarely available. This type of information are necessary if we are to understand the relation between erosion and soil degradation.

Characterization of the PSD of eroded sediments from an experimental plot in a vineyard, under natural condition, showed that in transport selectivity there is a general depletion of clay and sand and a consequently enrichment in silt material in the eroded material in respect to parental soil. Clay is positive correlated to the mean rainfall intensity, showing that the transport of clay is driven by the energy of the rain to transport/break aggregates containing clay.

Because of the effect of the soil erosion process can cause a variety of negative environmental and agronomical effect, such as loss of top soil and fertility, depletion in soil nutrient, we must be addressed by varying soil management and introducing conservation practices.

Acknowledgements

Authors are grateful to ISAFoM CNR and to Dr. Roberto De Mascellis for the laser granulometric analysis.

Appendix

Practices that reduce runoff.

The principle of these practices is to increase water intake and storage, minimize the concentrations of nutrients and soil in the runoff and to slow down the flow velocity, allowing the time to water to penetrate into the soil, limiting its capacity to transport soil particles and reducing its ability to cause erosion.

Mulch Farming

Mulch farming is a system in which, maintaining a permanent or semi-permanent protective cover with vegetative residues (straw, maize stalks, stubbles) on the soil surface, will limit the loss of soil by erosion. The system is particularly useful when a satisfactory vegetation cover cannot be established at the time of year when there is greater risk of erosion. The beneficial effects of mulching include the protection of the soil surface against raindrop impact, reducing the detachment from rain impact, decrease the flow velocity by increasing the roughness, and improve infiltration capacity. In some cases it also enhances the activity of some species of earthworms (Lal, 1976) which increase transmission of water through the soil profile (Aina, 1984), reduces surface crusting and improves soil moisture storage in the root zone. These effects have been widely reported. The mulch effect in reducing soil loss has been shown in both field (Borst and Woodburn, 1942; Lal, 1976) and laboratory (Lattanzi et al., 1974) studies. Lal (1976) reports an annual saving of 32% of rainfall in water runoff from mulching. Roose (1988) reports drastic reductions in runoff and erosion from a mulched field on a 20% slope.

Cover crop

Cover crops are crops with the primary purpose of cover and protect the soil. Using appropriate cover crops, it’s possible to improve also the efficiency of water use, weed control and soil organic matter. The benefits are similar to the mulch, cover crop are in general seeded when the soil is bare and could be harvested before the primary culture.

Alley cropping

Alley cropping is a system in witch arable crops are seeded in spaces between rows of planted trees. The crops growing simultaneously with the long-term tree crop and provide annual income while the tree crop matures. The trees are typically pruned minimizing shading to the crops.

No-tillage farming

No-tillage is a method of seeding on no tilled soil, through a crop residue mulch. It operates by opening a narrow slot in the soil for seed placement without mechanical or secondary tillage operations. Chemical weed control is in generally required. The beneficial effects of no-tillage in soil include soil moisture conservation due to reduction in rainfall detachment and runoff shear, improved infiltration capacity and enhanced earthworm activity. It also maintains organic matter content at high levels. Reduction in runoff has been reported under no-tillage practices compared to conventional tillage (Lal, 1976). The effectiveness of no-tillage farming in soil conservation is improved when used in association with planted cover crops.

Contour Farming.

Contour farming involves the alignment of plant rows and tillage lines with right angles to normal flow direction of runoff. It creates detention storage in the soil surface horizon and slows down the runoff thus giving the water the time to infiltrate into the soil. The efficiency of the contour farming in water and soil conservation depends not only on the design of the system but also on soil characteristics, climatic condition, slope and land use. The beneficial effect is less pronounced on compact or slowly permeable soils because these become saturated quickly compared to highly permeable soil.

Strip Cropping.

This is a kind of agronomical practice of sloping land, in which ordinary crops are planted in alternate contoured strips .These strips are so arranged that the strip crops should always be separated by strips of close growing and erosion resistance crop. The strips are aligned at right angles to the direction of natural flow of runoff. The close growing strips have a function of slow down the runoff and filter the soil washed from the land in the intertilled crop. Usually, the close growing and intertilled crops are planted in rotation. Strip cropping provides effective erosion control against runoff on well-drained erodible soils on 6 to 15% slopes. The width of the strips is varied with the erodibility of the soil, and slope steepness. Generally the use of strip cropping practice for soil conservation is decided in those areas where length of slope is not too longer and in the area where terraces are not practically feasible due to the fact that the length of slope is divided into different small segments.

Ridge and Mound Tillage.

The ridge furrow tillage system is commonly used physical practice conservation tillage. When the ridge furrows are aligned parallel to the contour lines have the dual effects of erosion control and surface drainage. Their advantages are greater, the less steep is the ground and the more permeable is the soil. Mounds and tied mounds are also effective in conserving water and reduce soil erosion. The effectiveness of ridges and mounds depends on soil, slope, rainfall and design characteristics. These systems on clay soils may induce waterlogging which may be followed by mass movement (Gray and Brenner, 1970). In severe storms, poorly designed ridge furrow systems may fail, the row catchments can over-top and the water flow freely goes down the slope with the danger of it accumulating enough energy to detach and transport soil.

Terrace Farming.

Terrace farming involves the creation of embankments built at right angles to the steepest slope, and made excavating a channel on the uphill side of a slop, the spoil resulting from the digging forms a bank on the downhill side. With this method it’s possible to converts a slope into a series of steps with horizontal shelves and vertical walls made of stone, brick or timber, supporting the embankment. There are several varieties of terraces, built by various techniques and called (according to method of construction) bench terraces (Orlandini and Zanchi, 2005); Mangum diversion terraces; Nichols terraces; broad-based and narrow-based types; channel terraces; retention terraces etc.

Buffer strips

The buffer strips are areas of planted or natural vegetation which are able to filter sediments and their attached nutrients and pollutant from agricultural water runoff. Numerous studies demonstrating the effectiveness of buffers of different types and widths. Many factors can affect buffer performance such as the slope and the soil type, whether the area has been tilled or not, and the intensity of rainfall events that cause runoff. Buffer strips are not very effective in trapping sediments and nutrients in situations of concentrated flow and therefore are effectively used where the source area has a moderate slope and produces runoff in the form of sheet flow (Lee et al., 2000). Many researchers have concluded that the width of the buffer is the most important factor that influence the amount of total phosphorus (TP) removed from runoff (Lee et al., 2000; Dillaha et al., 1989). Wider buffers are able to retain more particles of sediment, especially of small dimension (Lee et al., 2000). The capacity of a buffer strip to decrease sediment transport, in particular of small particles, greatly affects the amount of TP that a buffer is able to retain from the runoff, because most of the TP eroded from cultivated lands is linked to the sediments.

Some study have found that the solids previously trapped in the buffer strips could be released from the buffer, making the buffer as a source of pollution. This problem can be partially solved by increasing the width buffer, and harvesting or cutting the buffer vegetation.

References

Acutis, M., Argenti, G., Bersani, L., Bulletta, P., Caredda, S., Cavallero, A., Giordani, C., Grignani, C., Pardini, A., Porqueddu, C., Reyneri, A., Roggero, P.P., Sulas, L., Talamucci, P., Zanchi, C., 1996. Effetti di tipologie di suolo e colture foraggere sulle perdite per ruscellamento di azoto, fosforo e potassio in differenti areali italiani. Rivista di Agronomia 3: pp. 329-338.

Aina, P.O. 1979. Soil changes resulting from long-term management practices in Western Nigeria. Soil Sci. Soc. Am. J. 43: pp. 173-177

Alberts, E.E., Moldenhauer, W.C. and Foster, G.R. 1980. Soil aggregates and primary particles transported in rill and interrill flow. Soil Science Society of America Journal, 44: pp. 590–595.

Alberts, E.E., Wendt, R.C. and Piest, R.F. 1983. Physical and chemical properties of eroded soil aggregates. Transactions of the American Society of Agricultural Engineers, 26, 465–471.

Alfsen, K.H., De Franco, M.A., Glomsrød, S., Johnsen, T., 1996. The cost of soil erosion in Nicaragua. Ecological Economics 16, 129–145.

Arnaez J., Lasanta T., Ruiz-Flano P., Ortigosa L., 2007. Factors affecting runoff and erosion under simulated rainfall in Mediterranean vineyards. Soil Till. Res. 93, 324–334.

Asadi, H., Ghadiri, H., Rose, C.W., Yu, B., Hussein, J., 2007b. An investigation of flowdriven soil erosion processes at low stream powers. J. Hydrol. 342, 134–142.

Asadi, H., Moussavi, A., Ghadiri, H., Rose, C.W., 2011. Flow-driven soil erosion processes and the size selectivity of sediment. J. Hydrol. 406, 73–81.

Balestra, L., Toderi, M., Roggero, P.P., 2001. Sistemi colturali e qualità delle acque in un'area collinare delle Marche in emergenza nitrati. In: Biondi E., Segale A. (ed.), Pianificazione e gestione delle aree protette: analisi dell'ambiente e biodiversità, biomonitoraggio, agricoltura sostenibile. Il Lavoro Editoriale Università, Ancona, 137-168.

Basic, F., Kisic, I., Mesic, M., Nestroy, O., Butorac, A., 2004. Tillage and crop management effects on soil erosion in central Croatia. Soil Tillage Res. 78:pp. 197-206.

Bazzoffi P., Chisci G. 1999. Tecniche di conservazione del suolo in vigneti e pescheti della collina cesenate. Riv Agron 3:pp. 177-184.

Bernardoni E., Carozzi M., Acutis M., 2012. Technical approach for the measurement of surface runoff. Italian Journal of Agrometeorology, 1:pp. 29-34.

Black D.L., McQuay M.Q., Bonin M.P., 1996. Laser-based techniques for particle-size measurement: A review of sizing methods and their industrial applications, Progress in Energy and Combustion Science 22, (3): pp. 267-306.

Bonilla C.A., Kroll D.G., Norman J.M., Yoder D.C., Molling C.C., Miller P.S., Panuska J.C., Topel J.B., Wakeman P.L., Karthikeyan K.G., 2006. Instrumentation for Measuring Runoff, Sediment and Chemical Losses. Journal of Environmental Quality, 35:pp. 216–223.

Borst, H.L. and Woodburn, R. 1942. The effect of mulching and methods of cultivation on run-off and erosion from Muskingum silt loam. Agricultural Engineering 23:pp.19-22.

Butler D.M., Franklin D.H., Cabrera M.L., Risse L.M., Radcliffe D.E., West L.T., Gaskin J.W., 2010. Assessment of the Georgia Phosphorus Index on farm at the field scale for grassland management. Journal Soil of Water Conservation, 65: 200–210.

Brakensiek D.L., Osborn H.B., Rawls W.J., 1979. Field manual for research in agricultural hydrology. USDA Agricultural. Handbook 224. USDA, Washington DC, pp. 547.

Casali J., R. Gastesi R., Alvarez-Mozos J., De Santisteban L.M., Del Valle de Lersundi J., Gimenez R., Larranaga A., Goni M., Agirre U., Campo M.A., Lopez J.J., Donezar M., 2008. Runoff, erosion, and water quality of agricultural watersheds in central Navarre (Spain). Agricultural water management 95, pp. 1111-1128.

Chiaudani, T., Premazzi, G., 1998. Environment and quality of life. Water Quality Criteria in Environmental Management. Rep. EUR 116387. Commission of European Communities, Luxembourg.

Clark, E. H., Haverkamp, J. A. and Chapman, W. (1985) Eroding Soils - The Off-Farm Impacts. The Conservation Foundation, Washington, DC.

Corell, D.C., Thomas, E., Jordan, E., Weller, D.E., 1999. Precipitation effects on sediment and associated nutrient discharges from Rhode river watersheds. Journal of Environmental Quality 28, 1897– 1907.

Daniels, T.C., Sharpley, A.N., Lemunyon, J.L., 1998. Agricultural phosphorus and eutrophication: a symposium overview. J. Environ. Qual. 27, 251–257.

de Boer, G. B. J., de Weerd, C., Thoenes, D., and Goossens, H. W. J.: Laser diffraction spectrometry: Fraunhofer diffraction versus Mie scattering, Particle Characterization, 4, 138–146, 1987.

De Mascellis R., Basile A., (2012). New tecniques for soil particle size analysis: advancements and problems, in EUROSOIL 2012 - Soil Science for the benefit of mankind and environment, Bari (IT), 2-6 Luglio 2012.

De Mascellis R., Impagliazzo A., Basile A., Minieri L., Orefice N., Terribile F., (2009). Methodological issues concerning the application of reliable laser particle sizing in soils, in General Assembly of European Geosciences Union, Vienna, 14-19 aprile, 2009.

de Lima, J. L. M. P., Souza, C. S., and Singh, V. P.: Granulometric characterization of sediments transported by surface runoff generated by moving storms, Nonlin. Processes Geophys., 15, 999–1011, doi:10.5194/npg-15-999-2008, 2008.

De Wang, Fu B., Zhao W., Hu H., Wang Y. Multifractal characteristics of soil particle size distribution under different land-use types on the Loess Plateau, China (2008) Catena, 72 (1) , pp. 29-36.

Dillaha, T.A., R.B. Reneau, S. Mostaghimi, and D. Lee. 1989. Vegetative filter strips for agricultural nonpoint source pollution control. Transaction of the American Society of Agricultural Engineers 32:513-519.

Douglas, C.L., King, K.A., Zuzel, J.F., 1998. Nitrogen and phosphorous in surface runoff and sediment from a wheat-pea rotation in north-earstern Oregon. Journal of Environmental Quality 27, 1170– 1177.

Dunkerley D.L. 2008. Rain event properties in nature and in rainfall simulation experiments: a comparative review with recommendations for increasingly systematic study and reporting. Submitted to Hydrological Processes 22, 4415-4435.

Durnford, D., King, P., 1993. Experimental study of processes and particle size distributions of eroded soil. J. Irrig. Drain. Eng. 119, 383–398.

Ekholm, P., 1994. Bioavailability of phosphorus in agriculturally loaded rivers in southern Finland. Hydrobiologia 287, 179–194.

Ellison W.D. 1944. Studies of raindrop erosion. Agric. Eng. 25: 131-181.

Erskine, W.D., Mahmoudzadeh, A., Myers, C., 2002. Land use effects on sediment yields and soil loss rates in small basins of Triassic sandstone near Sydney, NSW, Australia. Catena 49 (4), 271–287.

Eshel, G., Levy, G.J., Mingelgrin, U. & Singer, M.J. 2004. Critical evaluation of the use of laser diffraction for particle size distribution analysis. Soil Science Society of America Journal, 68:pp. 736–743.

Evans, R. 1981. Potential soil and crop losses by erosion. Proceedings, SAWMA Conference on Soil and Crop Loss: Developments in erosion control. National Agricultural Centre, Stoneleigh.

Franklin D.H., Cabrera M.L., Steiner J.L., Endale D.M., Miller W.P., 2001. Evaluation of percent flow captured by a small in-field runoff collector. Transaction of ASAE 44:pp. 551–554.

Franklin D.H., Truman C, Potter T, Bosch D, Strickland T, Bednarz C., 2007. Nitrogen and phosphorus runoff losses from variable and constant intensity rainfall simulations on loamy sand under conventional and strip tillage systems. J. Environ. Qual. 7, 36 (3):pp. 846-854.

Frost, C.A. and Speirs, R.B., 1984. Water erosion of soils in southeast Scotland-a case study. Res. Dev. Agric., 1: 145-152.

Gabriels, D. and Moldenhauer, W.C. 1978. Size distribution of eroded material from simulated rainfall – effect over a range of texture. Soil Science Society of America Journal, 42, 954–958.

Gao, Q. Z., Tao, Z., Xie, M., Cui, K. and Zcng, F. (2003) Effects of hydrological processes on the chemical composition of river in suspended sediment in the Zhujiang River, China. Hydrol. Processes 17, 2365-2373.

Geib H.V., 1933. A new type of installation for measuring soil and water losses from control plots. Journal of American. Society of Agronomy 25: 429–440.

Ghadiri, H. and Rose, C.W. 1993. Water erosion processes and the enrichment of sorbed pesticides: part 2. Enrichment under rainfall dominated erosion process. Journal of Environmental Management, 37, 37–50.

Gilliam, J.W., J.L. Baker, and K.R. Reddy. 1999. Water quality effects of drainage in humid regions. In: Agricultural drainage, Skaggs, R.W., and J. Van Schilfgaarde (eds). Agronomy, monongrah 38:801- 830. Academic Press, New York

Gray, D.H. and Brenner, P.R. 1970. The hydrology and stability of cutover slopes. In: Proceedings, Symposium on Interdisciplinary Aspects of Watershed Management, Montana State University. Bozeman, ASCE. pp. 295-326.

Guy, H. P. and Ferguson, G. E. (1970) Stream sediment: an environmental problem. J. Soil Water Conserv. 25(6), 217-221.

Gunatilake, H.M., Vieth, G.R., 2000. Estimation of on-site cost of soil erosion: a comparison of replacement and productivity change methods. Journal of Soil and Water Conservation 55, 197–204.

Hall, G.F., Logan, T.J., Young, K.K., 1985. Criteria for determining tolerable erosion rates. In: Follet, R.F., Stewart, B.A. (Eds.), Soil Erosion and Crop Productivity. American Society of Agronomy, Madison, WI, pp. 173–187.

Hansen, L.T., Breneman, V.E., Davison, C.W., Dicken, C.W., 2002. The cost of soil erosion to downstream navigation. Journal of Soil and Water Conservation 57, 205– 212.

Heathwaite, A. L.; Johnes, P. J., 1996. Contribution of Nitrogen Species and Phosphorus Fractions to Stream Water Quality in Agricultural Catchments. Hydrological Processes, vol. 10, 7, 971-983

Heckrath, G., Brookes, P.C., Poulton, P.R., Goulding, K.W.T., 1995. Phosphorus leaching from soils containing different phosphorus concentrations in the broadbalk experiment. J. Environ. Qual. 24, 904–910.

Helming K., 2001. Wind speed effects on rain erosivity. Sustaining the Global Farm, 771-776.

Huang, G.H., Zhang, R.D., 2005. Evaluation of soil water retention curve with the pore–solid fractal model. Geoderma 127, 52–61

Hudson, N. 1971. Soil Conservation. Cornell University Press, Ithaca, New York

Hudson N.W, 1993. Field Measurement of Soil Erosion and Runoff. FAO Soils Bulletin No. 68. FAO, Rome, pp 139.

Hussein M.H., Hussein A.J., Awad M.M., 1999. Phosphorus and nitrogen losses associated with runoff and erosion on an Aridisol in northern Iraq. Hydrological Science-Journal-des Sciences Hydrologiques, 44(5), October 1999.

Isermann, K., 1990. Share of agriculture in nitrogen and phosphorus emission into the surface water of Western Europe against their background of eutrophication. Fertil. Res. 26, 253–269.

ISTAT (Istituto Nazionale di Statistica), 2010. 6° Censimento generale dell'agricoltura 2010.

Johnson, H.P, J.L Baker, W.D. Schrader, and J.M. Laflen. 1979. Tillage system effects on sediment and nutrient in runoff from small watersheds. Transactions of the ASAE 22(5):1110-1114.

Kosmas, C., Danalatos, N., Cammeraat, L.H., Chabart, M., Diamantopoulos, J., Farand, R., Gutierrez, L., Jacob, A., Marques, H., Martinez-Fernandez, J., Mizara, A., Moustakas, N., Nicolau, J.M., Oliveros, C., Pinna, G., Puddu, R., Puigdefa´bregas, J., Roxo, M., Simao, A., Stamou, G., Tomasi, N., Usai, N., Vacca, A., 1997. The effect of land use of runoff and soil erosion rates under Mediterranean conditions. Catena 29, 45–59.

Kowalenko C.G., Babuin D., (2013). Inherent factors limiting the use of laser diffraction for determining particle size distributions of soil and related samples, Geoderma, 193–194:pp. 22-28.

Lal, R. 1976. No-tillage effects on soil properties under different crops in western Nigeria. Soil Sci. Soc. Am. J. 40: 762-768.

Lal, R. 1976. Soil erosion problems on an Alfisol in Western Nigeria and their control. IITA Monograph No. 1. Ibadan, Nigeria.

Lal, R., 1995. Erosion crop productivity relationships for soils of Africa. Soil Science Society of America Journal 59, 661–667.

Laly, R., 1988. Erodibility and erosivity. In: Lal, R. (Ed.), Soil Erosion Research Methods, pp. 141–162.

Lattanzi, A.R., Meyer, L.D. and Baumgardner, M.F. 1974. Influences of mulch rate and slope steepness on interrill erosion. Proc. Soil Sci. Soc. Am. 38:946-950.

Lee, K-H., T.M. Isenhart, R.C. Schultz, and S.K. Mickelson. 2000. Multispecies riparian buffers trap sediment andnutrients during rainfall simulations. Journal of Environmental Quality 29:1200-1205.

Legg, J.O., and J.J. Meisinger. 1982. Soil nitrogen budgets. In: Nitrogen In Agricultural Soils, ed. A.L. Page, 503-566. Madison WI: American Society of Agronomy.

Lewis, L.A., 1981. The movement of soil materials during a rainy season in Western Nigeria. Geodetma, 25: 13-25.

Loch, R.J., Donnollan, T.E., 1983. Field rainfall simulator studies on two clay soils of the Darling downs, Queensland. II. Aggregate breakdown, sediment properties and soil erodibility. Aust. J. Soil Res. 21, 47–58.

Lopez A., Garcia J., 2007. Nitrate content of soil solution in vineyard under different soil maintenance systems. En: Bosch Serea, A.D., Teira Esmatges, M.R., Villar Mir, J.M. (eds). Towards a better efficiency in N use, pp. 111-113.

Lü Y., Fu B., Chen L., Liu G. and Wei W., 2007, Nutrient transport associated with water erosion: progress and prospect. Progress in Physical Geography 31(6), pp. 607–620.

Mariani, L., 2008. Il clima dell'Oltrepò, in Guida all'utilizzo della denominazione di origine Pinot Nero in Oltrepò Pavese. Pavia, Consorzio Tutela Vini: 15–20.

Martínez-Casasnovas, J.A., Sánchez-Bosch, I., 2000. Impact assessment of changes in land use/conservation practices on soil erosion in the Penedès–Anoia vineyard region (NE Spain). Soil Tillage Res. 57, 101–106.

Martinez-Mena, M., Alvarez Rogel, J., Albaladejo, J., Castillo, V.M., 1999. Influence of vegetal cover on sediment particle size distribution in natural rainfall conditions in a semiarid environment. Catena 38, 175– 190.

Matos A. T., Pinho A. P., Costa L. M., Morris L. A., 2008. Streamside Management Zone (SMZ) Efficiency in Herbicide Retention from Simulated Surface Flow. Planta Daninha, 26, 131-142.

Massey, H.F., Jackson, M.L., 1952. Soil. Science Society of American Journal 16, 353–356.

McCormack, D. E., K. K. Young, and L. W. Kimberlin. 1982. Current criteria for determining soil loss tolerance. Chapter 9 in Schmidt, B. L., R. A. Allmaras, J. V. Mannering, and R. 1. Papendick, editors, Determinants of Soil Loss Tolerance, ASA Special Publication No. 45, Am. Soc. Agr., Madison, W1 53711.

Meyer, L.D., 1981. How rain intensity affects interill erosion. Trans. Am. Soc. Agr. Eng. 23 (4), 527–544.

Meyer, L.D., Harmon, W.C., McDowell, L.L., 1980. Sediment sizes eroded from crop row side slopes. Transactions of the ASAE 23, 891–898.

Mitchell, J.K., Mostaghimi, S. & Pond, M.C. 1983. Primary particle and aggregate size distribution of eroded soil from sequenced rainfall events. Transactions of the American Society of Agricultural Engineers, 26, 1773–1777.

Montero, E., 2005. Rényi dimensions analysis of soil particle-size distributions. Ecol. Model. 182, 305–315.

Morgan, R.P.C., 1986. Soil degradation and soil erosion in the loamy belt of northern Europe. In: G. Chisci and R.P.C. Morgan (Ed%), Soil Erosion in the European Community: Impact of Changing Agriculture. A.A. Balkema, Rotterdam, pp. 165-172.

Monke, E.J., Marelli, H.J., Meyer, L.D. and Dejong, J.F. 1977. Runoff, erosion, and nutrient movement from interrill areas. Transactions of the American Society of Agricultural Engineers, 20, 58–61.

Ng Kee Kwong, K.F., Bholah, A., Volcy, L., Pynee, K., 2002. Nitrogen and phosphorous transport by surface runoff from a silty clay loam soil under sugarcane in the humid tropical environment of Mauritius. Agriculture, Ecosystems and Environment 91, 147– 157.

Ongley, E. D. (1996) Control of Water Pollution from Agriculture. Irrigation and Drainage Paper 55. FAO, Rome, Italy.

Ongley, E. D., Bynoe, M. C. and Percival, J. B. (1981) Physical and geochemical characteristics of suspended solids, Wilton Creek, Ontario. Can. J. Earth Sci. 18, 1365-1379.

Ongley, E., Krishnappan, B. G., Droppo, I., Rao, S. and Maguire, R (1992) Cohesive sediment transport: emerging issues for toxic chemical management. Hydrobiologia 235/236, 177-187.

Ohno, T., and L.M. Zibilske. 1991. Determination of low concentrations of phosphorus in soil extracts using malachite green. Soil Sci. Soc. Am. J. 55:892–895.

Orlandini, S. and Zanchi, C. 2005. Primi risultati idrologici ed erosivi in due sistemazioni idraulico agrarie del Chianti. Atti XXVI Convegno della Società Italiana di Agronomia, Foggia 20-22 settembre 2005, p. 454-455

Ortega-Achury S.L., Martínez-Rodríguez G.A., Sotomayor-Ramírez D., Muñoz-Muñoz M., 2007. Nutrient concentrations in runoff from different manure amended fields of the tropics under natural rainfall conditions. J. Agric. Univ. P.R. 91: 101-115

Ottone C., Rossetti R., 1980. Condizioni termo-pluviometriche della Lombardia, Atti dell'Istituto Geologico dell'Università di Pavia, 29: pp. 27–48.

Pansak W., Kongkeaw T., Hilger T.H., Cadish G., 2005. Nitrogen Losses by erosion and leaching in hillside cropping systems of northeast Thailand as affected by soil conservation measures: a case study. Conference on International Agricultural Research for Development. Tropentag 2005, Stuttgart-Hohenheim, October 11-13, 2005.

PAP/RAC, 1997. Guidelines for Mapping and Measurement of Rainfall-Induced Erosion Processes in the Mediterranean Coastal Areas. PAP-8/PP/GL.1. Priority Actions Programme Regional Activity Centre (MAP/UNEP), with the cooperation of FAO, Split, pp. 70.

Papini R., Bazzoffi P., Pellegrini S. et al., 1997. Perdite di nutrienti per ruscellamento da suoli argillosi marginali a diversa utilizzazione nella Val d’Era. Agricoltura Ricerca, n°170, pp. 21-32.

Pérez-Latorre F., de Castro L., Delgado A., 2010. A comparison of two variable intensity rainfall simulators for runoff studies. Soil and Tillage Research 107 (1):pp. 11-16.

Pieri L., Bittelli M., Hanuskova M., Ventura F., Vicari A., Pisa P.R.. 2009. Characteristics of eroded sediments from soil under wheat and maize in the North Italian Apennines. Geoderma 154(1-2):pp. 20-29.

Pierzynski, G.M. (ed.). 2000. Methods for phosphorus analysis for soils, sediments, residuals, and waters. Southern Cooperative Series Bulletin No. 396, 110 pages.

Pimentel D., Harey, C., Rososudarmo, P., Sinclair K., Kurz, D., Mcnair M., Christ S., Shpritz, L. Fitton L., Saffouri R., Blair R.; 1995. Environmental and economic costs of soil erosion and conservation benefits. Science, 267: pp. 1117–1123.

Pimentel, D., Terhune, E. C., Dyson-Hudson, R., Rochereau, S., Samis, R., Smith, E. A., Denman, D., Reifschneider, D. and Shepard, M., 1976. Land degradation: effects on food and energy resources. Science, 194: 149-155.

Foy, R.H., Smith, R.V., Jordan, C., Lennox, S.D., 1995. Upward trend in soluble phosphorus loadings to Lough Neagh despite phosphorus reduction at sewage treatment works. Water Res. 29 (4), 1051–1063.

Pinson W.T., Yoder D.C., Buchanan J.R., Wright W.C., Wilkerson J.B.,2004. Design and evaluation of an improved flow divider for sampling runoff plots, Applied Engineering in Agriculture 20 (4): 433–438.

Poesen, J., Hooke, J.M., 1997. Erosion, flooding and channel management in the Mediterranean environments of southern Europe. Progress in Physical Geography 21, 157– 199.

Portielje, R. and D. van der Molen, 1999. Relationships between eutrophication variables: from nutrient loading to transparency. Hydrobiologia, 408/409: 375–387

Ramos, M.C., Martínez-Casasnovas, J.A., 2004. Nutrient losses from a vineyard soil in North eastern Spain caused by an extraordinary rainfall event. Catena 55, 79– 90.

Ramos, M.C., Martínez-Casasnovas, J.A. 2006. Nutrient losses by runoff in vineyards of the Mediterranean Alt Penedès region (NE Spain). Agriculture, Ecosystems and Environment, 113, 356-363.

Ramos, M.C., Porta, J., 1994. Rainfall intensity and erosive potentiality in the NE Spain Mediterranean area: results on sustainability of vineyards. Il Nuovo Cimento 17, 291– 299.

Rayan K.T., 1981. Sediment measurement techniques used by the Soil Conservation Service of New South Wales, Australia. Proceedings of the Florence Symposium: Erosion and Sediment Transport Measurement. Florence June 1981. IAHS publication n. 133: 151–157.

Reichert, J.M., Norton, L.D., Huang, C., 1994. Sealing, amendment and rain intensity effects on erosion of high clay soils. Soil Sci. Soc. Am. J. 58, 1199–1205.

Reyes M.R., Gayle G.A., Raczkowski C.W., 1999. Testing of a multislot divisor fabricated from plastic. Transaction of the ASAE 42 (3): 721–723.

Reposa J.H., Pandit A., 1994. Inorganic nitrogen, phosphorus and sediment losses from a citrus grove during storm water runoff. Florida Institute of Technology.

Römkens, M. J. M., Prasad, S. N., and Gerits, J. J. P.: Soil erosion modes of sealing soils: a phenomenological study, Soil Technol., 11, 31–41, 1997.

Roose, E.J. 1988. Soil and water conservation lessons from steep-slope farming in French-speaking countries of Africa. In: Conservation Farming on Steeplands. W.C. Moldenhauer and N.W. Hudson (eds.) pp. 129-139. SWCS, Ankeny, IA.

Roose, E., 1996. Land Husbandry: Components and Strategy. 70 FAO Soils Bulletin. Food and Agriculture Organization of the United Nations, Rome.

Shainberg, I., Warrington, D. And Laflen, J.M. 1992. Soil dispersibility, rain properties, and slope interaction in rill formation and erosion. Soil Science Society of America Journal, 56, 278–283.

Sharon, D.: The distribution of hydrologically effective rainfall incident on sloping ground, J. Hydrol., 46, 165–188, 1980.

Sharpley A.N., 1997. Rainfall frequency and nitrogen and phosphorus runoff from soil amended with poultry litter J. Environ. Qual. 26,1127-1132

Sharpley A.N., Smith S.J., 1992 Prediction of bio available phosphorous loss in agricultural runoff. J. Environ. Qual. 21: 32–37

Sharpley, A. N., Smith, S. J., 1995 Nitrogen and phosphorus forms in soils receiving manure. Soil Sci. 159,253-258.

Sheridan, J. M., Lowrance R. R., Henry H. H., 1996. Surface flow sampler for riparian studies. Applied Eng. in Agric. 12(2): 183-188.

Sheridan J. M., Lowrance R. R., Bosch D. D., 1999. Management effects on runoff and sediment transport in riparian forest buffers. Transactions, American Society of Agricultural Engineers 42:55–64.

Shi, Z. H., Fang, N. F., Wu, F. Z., Wang, L., Yue, B. J., and Wu, G. L.: Soil erosion processes and sediment sorting associated with transport mechanisms on steep slopes, J. Hydrol., 454–455, 123–130, 2012.

Sistani K.R., Brink G.E., Oldham. J.L., 2008. Managing broiler litter application rate and grazing to decrease watershed runoff losses. J. Environ. Qual. 37:718–724.

Smith, R.E., Goodrich, D., and Quinton, J.N. 1995. Dynamic, distributed simulation of watershed erosion: The KINEROS2 and EUROSEM models. Journal of Soil and Water Conservation.

Sombatpanit S., Jai-Aree S., Sermsatanasusdi P., Hirunwatsiri S., Poonpanich C., 1990. Design of a double-split divisor for runoff plots. In: Boardman J., Foster I.D.L, Dearing J.A., Soil Erosion on Agricultural Land. John Wiley and Sons. Chichester, pp 687.

Soil Survey Staff. 2010. Keys to Soil Taxonomy, 11th ed. USDA-Natural Resources Conservation Service, Washington, DC.

Sotomayor-Ramírez D., Ramírez-Avila J., Mas E., Martínez G., 2008. Erosion and nutrient loss reduction with an alternative planting method for coffee (Coffea arabica). J. Agric. Univ. P.R. 92: 153-169.

Spann, W.P., Sikking, A.F.S., Hoogmoed, W.B., 2005. Vegetation barrier and tillage effects on runoff and sediment in an alley crop system on a Luvisol in Burkina Faso. Soil Tillage Res. 83, 194–203.

Speth, J.G.: 1994, Towards an Effective and Operational International Convention on Desertification, New. York, United Nations, International Convention on desertification

Stutter, M.I., Langan, S.J., Cooper, R.J., 2008. Spatial and temporal dynamics of stream water particulate and dissolved N, P and C forms along a catchment transect, NE Scotland. J. Hydrol. 350, 187–202.

Toy T.J., Foster G.R., Renard K.G., 2002. Soil erosion: Processes, prediction, measurement, and control. John Wiley and Sons, New York, pp 352.

Tropeano, D., 1983. Soil erosion on vineyards in the Tertiary Piedmontese basin (north western Italy): studies on experimental areas. Catena Suppl.4, 115–127.

Udawatta, R.P., Motavalli, P.P., Garrett, H.E., 2004. Phosphorus Loss and Runoff Characteristics in Three Adjacent Agricultural Watersheds with Claypan Soils. Journal of Environmental Quality 33, 1709-1719.

Udawatta R. P., Motavalli P.P., Garrett H.E., Krstansky J.J., 2006, Nitrogen losses in runoff from three adjacent agricultural watersheds with claypan soils, Agriculture, Ecosystems and Environment 117, 39–48.

United States Department of Agriculture, 1986. Urban hydrology for small watersheds. Technical Release 55 (TR-55) (Second Edition). Natural Resources Conservation Service, Conservation Engineering Division, Springfield, pp 164.

US EPA, 1986. Quality Criteria for Water. Office of Water Regulation and Standards. EPA-440/586-001.

Usón, A., 1998. Medidas de control de la erosión en suelos de vinã de las comarcas Anoia–Alt Penedès (Barcelona): Efectividad y viabilidad. PhD Thesis, University of Lleida, Lleida, p. 260.

Valderrama, J.C. 1981. The simultaneous analysis of total nitrogen and total phosphorus in natural waters. Mar. Chem. 10: 109-122.

Verstraten, G., Poesen, J., 2002. Regional scale variability in sediment and nutrient delivery from small agricultural watersheds. Journal of Environmental Quality 31, 870– 879.

Verstraeten, G., Poesen, J., Govers, G., Gillijns, K., Van Rompaey, A., VanOost, K., 2003. Integrating science, policy and farmers to reduce soil loss and sediment delivery in Flanders, Belgium. Environmental Science and Policy 6, 95– 103.

Wainwright, J., 1996. Infiltration, runoff and erosion characteristics of agricultural land in extreme storm events, SE France. Catena 26, 24–47.

Warrington, D., Shainberg, I., Agassi, M. and Morin, J. 1989. Slopeand phosphogypsum’s effects on runoff and erosion. Soil Science Society of America Journal, 53, 1201–1205.

Warrington, D.N., Mamedov, A.I., Bhardwaj, A.K., Levy, G..J.,2009. Primary particle size distribution of eroded material affected by degree of aggregate slaking and seal development. European Journal of Soil Science, 60: 84-93.

Water National Quality Inventory, http://www.epa.gov/OWOW/NPS/facts/point1.htm, 1994.

White W. J., Pinho A., Morris L.A., Jackson C.R.,2003. Proceedings of the 2003 Georgia Water Resources Conference, held April 23-24, 2003, at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

Wicherek, S., 1991. Viticulture and soil erosion in the north of Parisian Basin. Example: the Mid Aisne region. Z. Geomorph. N.F., Suppl.-Bd.83, 115–126.

Willems, P.: A spatial rainfall generator for small spatial scales, J. Hydrol., 252, 126–144, 2001

Woodward, D.E., 1999. Method to predict cropland ephemeral gully erosion. Catena 37, 393– 399.

WRB (World reference base for soil resources) 2006.World Soil Resources Reports No. 103. FAO, Rome.

Young, R.A., 1980. Characteristics of eroded sediment. Trans. ASAE 23 (1139–1142),1146.

Young, R.A. and Onstad, C.A. 1978. Characterization of rill and interrill eroded soil. Transactions of the American Society of Agricultural Engineers, 21, 1126–1130.

Young, R.A. andWiersma, J.L. 1973. Role of rainfall impact in soil detachment and transport. Water Resources Research, 9, 1629–1636.

Xue L., Huo T., Zhang R., Li D., 2008. The distribution of nitrogen in soil and rainfall intensity on nitrogen infiltration flux influence in partly saturated soil. Bioinformatics and Biomedical Engineering, 2008. ICBBE 2008.

Zeng, S.C., Su, Z.Y., Chen, B.G., Wu, Q.T., Ouyang, Y., 2008. Nitrogen and phosphorus runoff losses from orchard soils in South China as affected by fertilization depths and rates. Pedosphere 18 (1), 45–53.

Zhang, G.L., Yang, J.L., Zhao, Y.G., 2003. Nutrient discharge from a typical watershed in the hilly area of subtropical chain. Pedosphere 13 (1), 23–30.

Curriculum vitae

Ettore Bernardoni was born in Voghera on March 19, 1982. In 2001 he obtained a diploma of secondary school from the Istituto TecnicoAgrario Statale "Carlo Gallini" with a vote of 90/100. He frequented the University of Milan, Faculty of Agriculture. He graduated in Agricultural Sciences and Technologies (1st Level Degree Course) with 105/110 marks, on February 2006. On April 2008 he graduated in Agricultural and Environmental Sciences (2st Level Degree Course) with 108/110 marks. After degree, he started to carry out research in the Department of Plant Production. In March 2008 he obtained a bursary at the Department of Plant Production at the University of Milan. In March 2011 he obtained a research grant at the Department of Plant Production at the University of Milan. In October 2012 he stated to work for ERSAF (Ente Regionale Servizi Agricoltura e Foreste) at the Department of Agricultural Services, division of Services Networks, Research and Experimentation.