Istituto Sperimentale per lo Studio e la Difesa del Suolo

International Conference

Sustainable Soil Management for Environmental Protection Soil Physical Aspects

Field Guide

Florence, Italy 2-7 July 2001

Organized by

Istituto Sperimentale per lo Studio e la Difesa del Suolo

International Union of Soil Science

Società Italiana della Scienza del Suolo

EurAgEng - Field of interest on Soil and Water

International Commission of Agricultural Engineering

Under the high patronage of

Ministero delle Politiche Agricole e Forestali

Comune di Firenze

With the contribution of

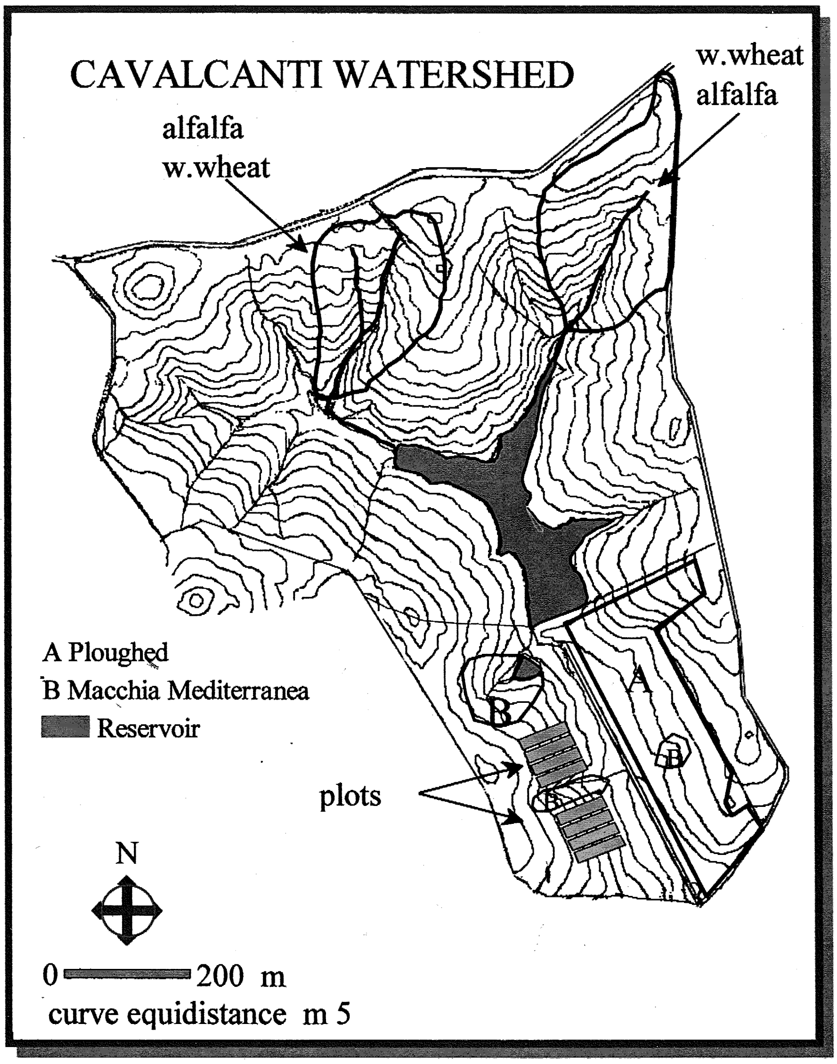
European Commission
Fifth Framework Programme for RTD "Quality of life and Management of Living Resources"

European Soil Bureau
European Commission JRC - S.A.I.

Ministero delle Politiche Agricole e Forestali
Istituto Sperimentale per lo Studio e la Difesa del Suolo
Piazza M. D'Azeglio, 30 – Firenze

EXCURSION TO VICARELLO EXPERIMENTAL CENTRE (VOLTERRA - TUSCANY)

P. Bazzoffi, S. Pellegrini, R. Papini, E.A.C. Costantini
and
A. Rocchini, O. Grasselli, M. Morandi, G. Brandi, L. Gabellini



Guide content:
- Erosion forms in the Volterra area
- Soil-landscape relationships in the Volterra area
- Experimental layout
- Mono-crop watersheds
- Experimental plots area
- Meteorological station
- Reservoir and water-level recorder
- Main results
- References

1. EROSION FORMS IN THE VOLTERRA AREA *(R. Mazzanti & G. Rodolfi, from Bazzoffi et al., 1997)*

The Pliocene sedimentary cycle, in the area around Volterra, is characterized by the stratigraphic superposition of the following formations:

- Argille azzurre marine (Marine blue clays, Lower Pliocene), lying concordantly on an upper Miocene formation, deposited in a fresh water or hypo-haline environment (gypsum, clays, sands, conglomerates); they are of considerable thickness (about 1000 m) and can be separated into two members (lower and upper) as a result of the intercalation of a conglomerate level:
- Argille sabbiose e sabbie delle Case Cafaggiolo (Case Cafaggiolo sandy clays and sands),which mark the beginning of the middle Pliocene transgression;
- Sabbie a *Flabellipecten* (*Flabellipecten* sands), with intercalations of arenaceous limestones, which close the sedimentary cycle with a thickness of about 200 m.

There is a close relationship between the physical-mechanical features of the Pliocene sediments and the forms which characterize the Val d'Era landscape . The latter can all be well observed from the top of the *Balze* di Volterra (Volterra Crags). From the base of the series on up, they correspond as follows:

- Lower Blue Clays => *biancane*
- Upper Blue Clays => "B" type *calanchi*
- Sandy Clays and Sands => "A" type *calanchi* and "small *balze*"
- *Flabellipecten* Sands => *balze* di Volterra

For definitions of these forms refer to the exhaustive literature on the matter (Rodolfi and Frascati, 1979; Mazzanti and Rodolfi, 1988)

2. SOIL-LANDSCAPE RELATIONSHIPS IN THE VOLTERRA AREA *(L. Lulli, from Bazzoffi et al., 1997)*

With the exception of some residual limbs of paleosols, the soils in the area around Volterra are generally Entisols, affected to varying degrees by vertic phenomena. Inceptisols are also present. They are generally deeper and are characterized exclusively by the formation of a cambic horizon with carbonate segregation and tendentially dark brown in colour. Inside the basin we have considerable differences in the granulometric composition of the sediments, which are associated with different forms and soils (Lulli et al., 1980).

Starting with the finer sediments of the Lower Blue Clays we find deposits with almost no sand which are associated with decidedly compact soils, with no deep water circulation, which are subjected to erosion, above all in the upper zone disturbed by tillage. The passage between soil and bedrock is sharp. The dominant clay is vermiculite. In these sediments, which behave like a compact mass, we have decidedly rounded erosion forms, with decortication of the surfaces and incisions located along the fractures. This gives rise to a *mammelloni* (knoll) landscape. The soils (*Lischeto* series of the Vertic Xerorthents) are always thin, massive and not very evolved. The most evident erosion forms are deep incisions with well defined edges. Actual fans of muddy material (mud flows) often form at the base of the slopes.

Again clayey materials, where montmorillonite is dominant (20%) and with a sand content of around 10% (Upper Blue Clays) develop soils, the main characteristic of which is that they produce cracks which are deep enough to affect horizon C and sometimes pass through it (*Mattaione* series of the Vertic Xerorthents). Hydromorphic features are found in the deep levels. Amphitheatre-like *calanchi* (type "B", Rodolfi and Frascati, 1979) , which evolve mainly because the soil slips over its substratum, form in these environments.

On the sandy clay and sandy deposits of Case Cafaggiolo the sand content increases while the montmorillonite content is reduced to about 8%, even if the tendency to cracking remains well expressed. In this case the "knife-edged" *calanchi* forms (type "A", Rodolfi and Frascati, 1979) appear when there is greater relief energy or greater cohesion in the sediment. In the presence of even more resistant levels *balze* form, but with escarpments which are not very high (small *balze*). The soils (*Renaglio* series of the Aquic Xerorthents) show a certain capacity to sustain trees. When the sand content reaches levels of up to 50% (*Flabellipecten* sands), the landscape changes completely in that the soils (*Renaglio* series) are able to sustain trees: well structured woods, olive groves and vineyards. The surfaces become rounded, similar to the surfaces of clayey-silty deposits from many points of view.

3. EXPERIMENTAL LAYOUT

This guide presents a study carried out on the hilly clayey watershed "Cavalcanti" near Volterra, in the Era Valley (Pisa). This watershed has a surface of 85 hectares and drains in the homonymous ephemeral torrent.

Following Pinna (1977) the climate of the station is classified as Csa (mesothermic, humid, mediterranean). The average temperature is 12.7°C, ranging between extreme values of -10°C and +40°C. The average yearly rainfall is 678 mm; rainfall is concentrated in spring and autumn. ETP, following Thornthwaite, is 569 mm.

Soils have a clay texture, and are classified by Soil Taxonomy as Vertic Xerorthent and Vertic Xerochrept. They derived from pliocenic clayey marine deposits and can be placed in the family of clayey-fine, mixed calcaric mesic soils. Two soil series are present: 1) Lischeto (Vertic Xerorthent), which cover 66.5% of the area and 2) Pegolina (Vertic Xerochrept), spread over 33.5% of the surface (Delogu and Lulli, 1982). Main soil characteristics are reported in Table 1 (Mbagwu and Bazzoffi, 1987).

Sand (2-0.02 mm) ($g\ kg^{-1}$)	200
Silt (0.02-0.002 mm) ($g\ kg^{-1}$)	380
Clay (<0.002 mm) ($g\ kg^{-1}$)	420
pH (H_20)	8.2
Liquid limit %	51.5
Plastic limit %	23.2
CEC (meq/100g)	25.2
Organic matter ($g\ kg^{-1}$)	5
Ca CO_3 total ($g\ kg^{-1}$)	128
Ca CO_3 active ($g\ kg^{-1}$)	83
N total ($g\ kg^{-1}$)	1.0
P total ($g\ kg^{-1}$)	0.6
P available ($\mu g\ g^{-1}$)	5.8
K ($\mu g\ g^{-1}$)	173.7

Tab. 1. Main soil characteristics.

Shrinking and swelling phenomena dominate the hydrological behaviour of soils. In winter they present a very low infiltration capacity, with maximum runoff coefficient of 0.85. In summer, on the contrary, cracks determine high infiltration capacity, and runoff coefficient approaches to 0.

The aims of the experiments carried out at Vicarello experimental station are: 1) to quantify the influence of different soil uses on runoff and soil erosion; 2) to increase knowledge on the influence of soil use on the acceleration or reduction of flood events; 3) to study nutrient dynamics. These studies are conduced at different scales inside Cavalcanti watershed.

In the upper part, 62.4 hectares of the watershed lead water to a reservoir of 189000 m^3 capacity, whose dam was built in 1954. The average slope of this part of the watershed is 23.9% and 53.8% of the surface has slope classes ranging between 20% and 50% (Fig. 1) (Bazzoffi and Panicucci, 1983).

In this more elevated part of the catchment, studies were carried out since 1970, and a lot of data are available, on: 1) soil characteristics, 2) hydrology, 3) soil erosion, 4) sedimentation, 5) radionuclides dynamics and 6) nutrient balance. Inside this part, two sub-catchments of about 5 ha size are monitored with a flume, electronic water level detector ISCO and automatic sampler. These two small catchment are monocrop cultivated (durum wheat and alfalfa, see cover illustration), with the aim of detecting difference in hydrology and soil erosion at this scale (Bazzoffi et al., 1997).

In the body of the reservoir, several survey have been performed for measuring settled sediment, Cs137 radio nuclide stratification and water quality (Bazzoffi and Panicucci, 1983).

Down the dam, the watershed is studied at field scale by data collection on two randomized blocks of 4 plots 75 m long and 15 m wide. Each plot is equipped with an electronic Fagna-type hydrological unit, for runoff measurement and sampling (Bazzoffi, 1994). This new device allows very precise measurements and the analysis of runoff dynamics. In the experimental centre an electronic meteo-station every hour collects data of rain, radiation, humidity, temperature and wind velocity and direction. Another electronic tipping bucket raingauge collects data of rainfall with a resolution of 0.2 mm. All the electronics devices in the watershed are synchronised.

In the plot experiment we compared four treatments: 1) durum wheat, 2) continuous harrowed surface, 3) alfalfa and 4) grazing shrubs (*Atriplex halimus* L.).

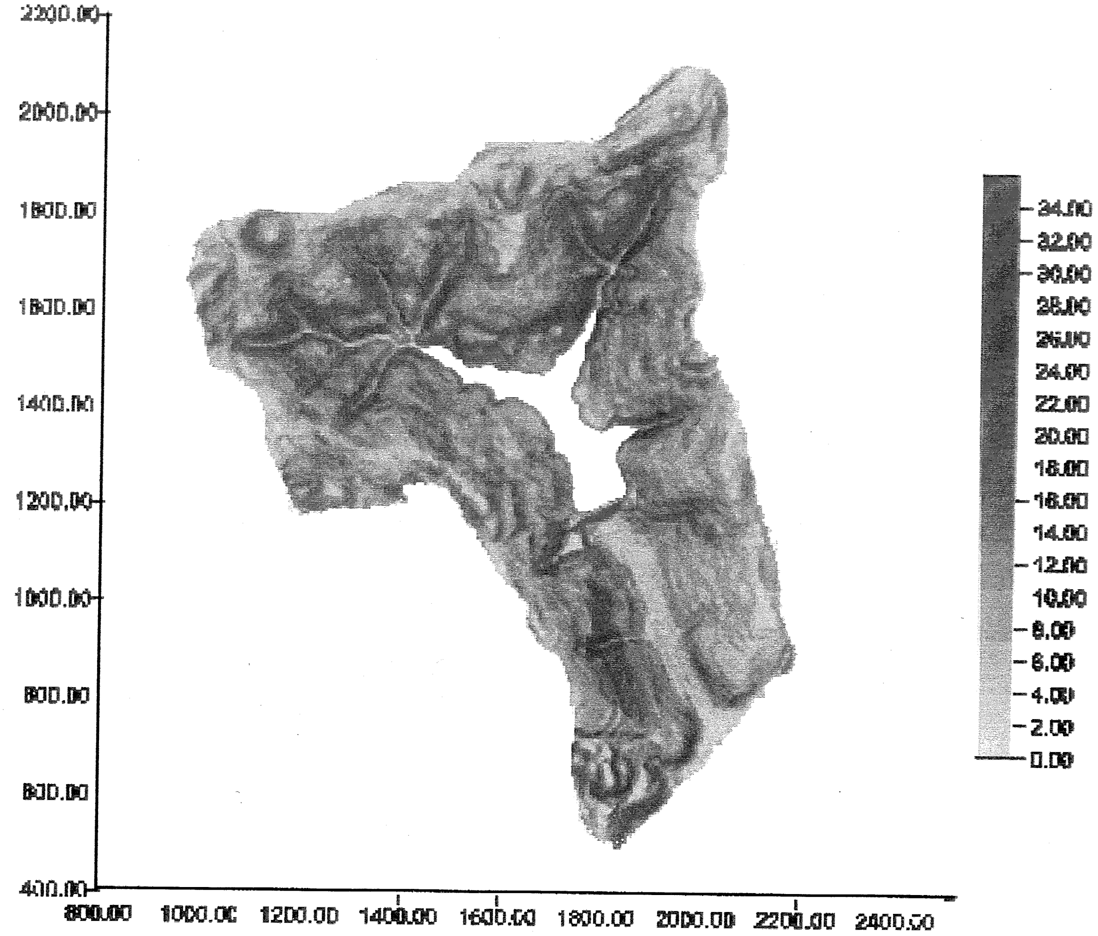
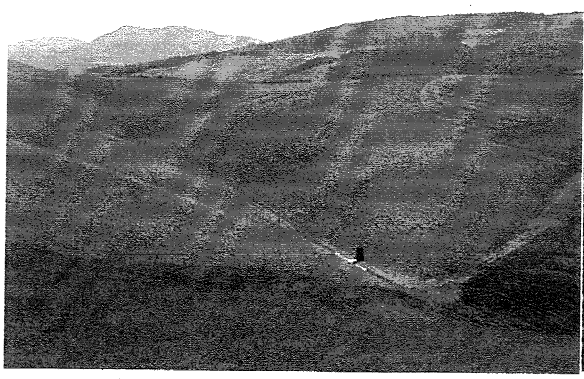


Fig. 1. Slope map of the Cavalcanti watershed (sexagesimal degrees)

4. MONO-CROP WATERSHEDS



The hydrological station is composed by:

- metal box.
- data logger ISCO 3210 with three channels: rainfall, runoff, sampling.
- modified mechanic raingauge.
- ultrasounds water-level meter.
- runoff sampler activated by the data-logger.
- standard V notch channel.

Main characteristics

- The data-logger could work in two modality:
  - A) Rollover: when memory is full it writes the new data on first data.
  - B) Slate: when memory is full it stops recording.
- The data-logger could activate the partitions in different ways:
  - A) when runoff volume is higher than a pre-set value.
  - B) after a determined quantity of rain.
  - C) at pre-set time intervals.
- The data-logger uses a software that can recognise and eliminate anomalous recordings.
- The recorded level value is the mean value on measures detected in the pre-set interval.
- Runoff volume is determined by selected equations or by manual calibration. In the latter modality, used here, the flow table is computed by the data logger digitising, on its front panel, some values of flow (l/sec) and related water levels in the channel.
- The data logger is synchronised with those of the plots and with the meteo-station.

The actual configuration of the data-logger is the following:

Partition raingauge:
- Slate modality, it activates the recording after 0.2 mm of rain and it records a date each 2 minutes.

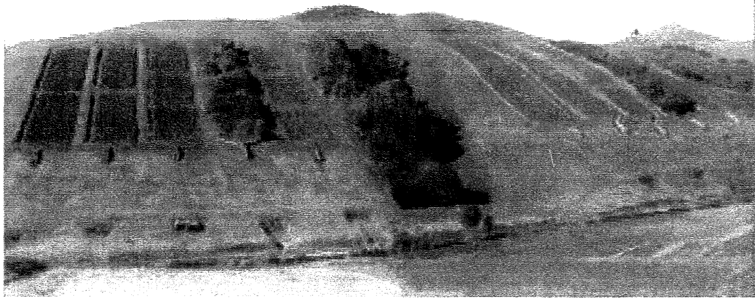
Partition runoff:
- Rollover modality, it records the level in the channel each 2 minutes.

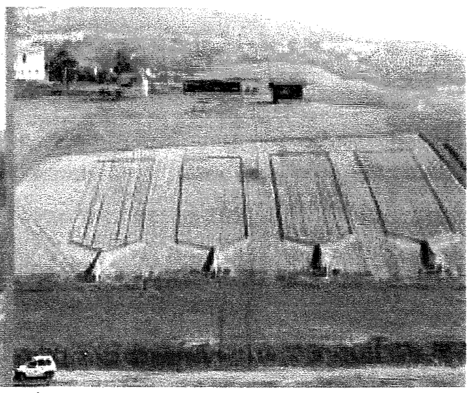
Partition sampler:
- Rollover modality, it records the time to which the sampling happens.

The sampler:
- ISCO Model 2910, with a bottle of 9.4 litres.
- it allows the collection of an integrated sample.
- the operation of collecting consists of 3 phases:
  1) Cleaning of the sampling tube, through air flux.
  2) Water aspiration.
  3) Second cleaning of the sampling tube, through air flux.
- If used without the data-logger it allows the acquisition of a sample to intervals of pre-set time.
- Currently the quantity of sampling is 5cc each 10 m^3 of runoff.

Channel characteristics:
- right basin: runoff passes through a trapezoidal channel and outflows through a composed trapezoidal + V-notch weir.
- left basin: runoff passes through a rectangular open channel.

5. PLOT AREA AND FAGNA-TYPE UNIT FOR MEASUREMENT AND SAMPLING OF RUNOFF WATERS





Left: testing agricultural CAP measures for erosion. Right: Soil erosion on compaction-affected plots

5.1. Fagna-type unit

Its name derives from the Fagna Experimental Centre of the Istituto Sperimentale per lo Studio e la Difesa del Suolo of Florence, where this unit was planned and tested on 12 experimental plots for monitoring soil erosion and nutrients losses (Bazzoffi, 1994).

The working principle is simple: waters from superficial runoff to be measured are conveyed through pipes or flumes in a sedimentation container, where the coarse materials, that creep and hop at the bottom of the flume, are forced to settle.

The sedimentation container separates the transported material in two parts: the creeping and the suspended ones. The knowledge of the quantity of creeping sediment is important. In fact, the attempt to maintain the eroded soil in the field, using conservation measures, is specially applied to this component. This coarse part of the sediment is also more subject to settling inside the watershed when the slope steepness decreases.

The settling container also avoids the plugging of the sampling system and loss of the measurement.

Runoff waters, thus cleaned of the coarser materials, come out of the tank and fall on a revolving pot.

The support frame of the pot has two U-shaped forks with two coaxial pivots at the sides of the pot, therefore enabling it to turn completely upside down.

In such a way the pot is simply supported and easily removable. When empty, the mouth of the pot is turned up.

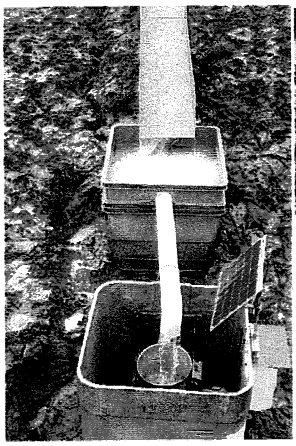
As the water falls into the pot, it reaches neutral equilibrium followed by unstable equilibrium with the upsetting and discharge of the water and the immediate return to the vertical position.

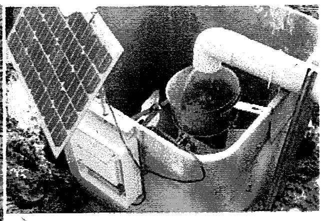
The discharged flux is then intercepted by a sampling hole in such a position as to enable a few cubic centimetres of runoff to enter when the water violently falls on it.

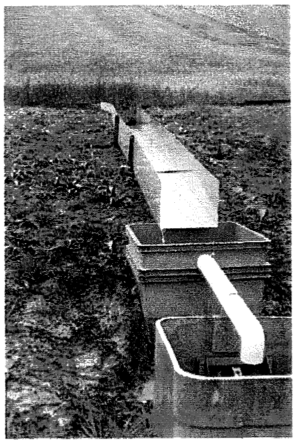
This sample is then conveyed, through a small plastic pipe, to a tank below the level of the hole. Since every pot discharge is sampled the same way, at the end of the runoff event the tank will contain an integrated and representative sample of the total turbid runoff.

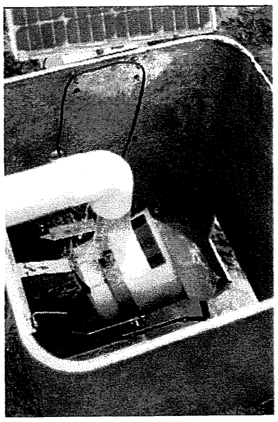
The measurement of the material deposited in the settling container before the mechanism, is carried out by putting the sediment in suspension inside the container and taking a sample with a large-mouthed bottle.

From the total volume of the sedimentation container and from the concentration of sediment content in the bottle the total amount settled is easily calculated. If the sediment is too much to be resuspended the operator will take the measurement of the depth of the surface of the sediment inside the sedimentation container (using a simple sounding-rod with a small disc at the end). From a previously-made calibration curve the quantity of material is achieved.









The Fagna-type unit is a conceptually new "total measurement station"; in fact, the new sampling methodology allows the collection of a really integrated sample. Furthermore runoff is totally measured. On the contrary, in the existing systems, the runoff is generally divided and the final quantity is considered as an integrated sample.

Such an assumption sometimes is not correct; in fact, when runoff is very feeble and protracted it is very difficult to achieve its division into equal parts, and also the sensitivity of the water level recorder is too low for a correct measurement.

The new system does not present initial inertia and is able to record and sample very small runoff fluxes. It is easier to construct and cheaper.

Another advantage of the Fagna-type unit is the facility of installation and maintenance. In the field, it is not generally necessary to prepare a supporting platform in concrete, in fact the revolving pot always equilibrates in the vertical position and works even if not perfectly centred under the water flow; furthermore the mechanism also runs perfectly after long periods of inactivity, due to drought.

An electronic recorder of the frequency of the pot discharges allows the determination of the runoff-time relationship and the automatic processing of the hydrological data.

With a PC, through serial interface, it is possible to carry out data transfer, the checking-up of the recorder and the programming of its running. The system is power supported through solar cells and battery and protects the stored data from the lack of electrical power. During the periods characterised by the absence of runoff, the clock is the only part of the system which is in operation. Whenever a tipping occurs, the rest of the system starts up and records it with an algorithm which excludes possible inaccurate recordings caused by the pot swinging when it returns to the vertical position. Once the tipping has been effected, the day and time are memorised in the space of one second.

It is also possible to programme the unit to effect the time recording only when a certain number of tippings, previously selected by the operator, have occurred. This enables the generation of lighter files without loss of information on the runoff hydrogram.

The PC needs to be simply connected to the recorder in order to gather the data and reset the clock and the memory of the unit. Once the data are collected, the watch within the system is checked (to ensure the measurements are precise) and whether any data has been completely or partially eliminated by possible electrical disturbances caused by the storm. The software also foresees both a correction in the times of the tippings if the system's clock is not precise, and a possible interpolation of the missing data. At this point, the system is ready to begin measuring once again.

Since the clock is reset to that of the PC, synchronisation of the unit is obtained when several plots are present in the experiment, each having a Fagna-type unit (Fig. 3). This enables evaluation of the influence of the various vegetal canopies on the hydrological characteristics of the flow.

5.2. Calibration and testing

The calibration of the system for the determination of the material deposited inside the sedimentation container has been carried out by putting a known quantity of sediment in the settling container.

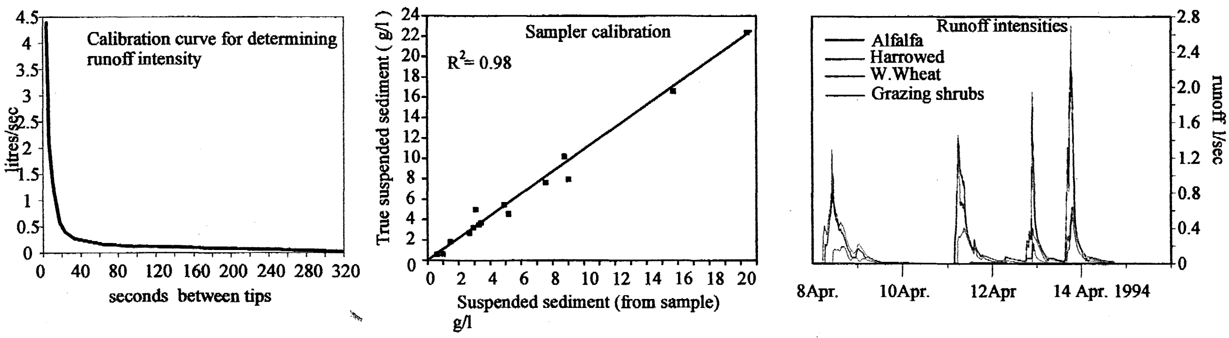
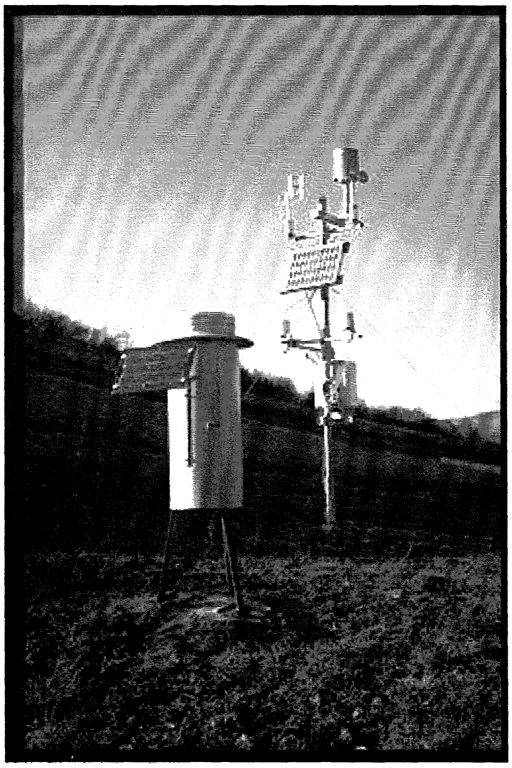


Fig. 2. Calibration curve for determining runoff intensity and suspended sediment and an example of runoff hydrogram.

We used two types of sediment (clay and sandy loam) and for everyone we ran three tests using different quantities of material and repeating the operation twice.

The calibration of the turbid sampler below the pot has been done by means of the sampling of 15 simulated runoffs. The measured turbidities of the integrated samples were practically the same as the respective total-runoff turbidity. The simple regression obtained between the solid charge of the sample and that of the runoff resulted highly significant, with $R^2 = 0.98$ (Fig. 2).

6. THE METEO STATION



Single tip recording raingauge (left). 1-hour recording station (right)

6.1. Characteristics of the single tip recording raingauge:

- The unit consists of a tipping bucket raingauge made electronic with infrared sensor.
- The electronic doesn't hinder the mechanical movement.
- It records the single tip, using the same datalogger type of the plots.
- Powered by solar cell.
- Synchronisation with the others units.

6.2. Meteorological station "Multirecorder" ETG:

1- Data-logger
2- Solar panel;
3- Tipping bucket raingauge (resolution 0.5 mm);
4- Anemometer working with opto-electronic impulses (field of measure 0- 50 m/s);
5- Gonio-anemometer;
6- Solarimeter (Si photocell -field of measure 0- 1000 W/mq);
7- Thermometer (thermoresistance, field of measure –20 / +80°C);
8- Hygrometer (capacitive sensor).

6.3. Data recordings:

The software allows:
1- Acquisition of the data each 2 minutes, validation and memorisation;
2- Elaboration and memorisation each hour;
3- Calculation of the rain intensity (mm/min);
4- Elaboration of wind direction data using the criterion of the "prevailing sector";
5- Daily memorisation of minimum and maximum: temperature, global radiation, relative atmospheric humidity, speed of the wind.

7. THE RESERVOIR AND ITS WATER-LEVEL RECORDER.

The reservoir, built in 1954, had a starting capacity of nearly 189.000 m^3 and has a high "trap efficiency" for sediments (Bazzoffi e Panicucci, 1983); therefore, by the measurement of the settled sediments, an indirect evaluation of long-term soil erosion is possible.

Following the main guidelines of the U.S. Civil Engineers Corp (USDA, 1979), the sediments deposited inside the reservoirs have been determined with the use of a sub-bottom profiler coupled with the Differential Global Positioning System (GPS). Water depth at each point of the survey was simultaneously determined by the use of the same sonar device (Fig. 4).

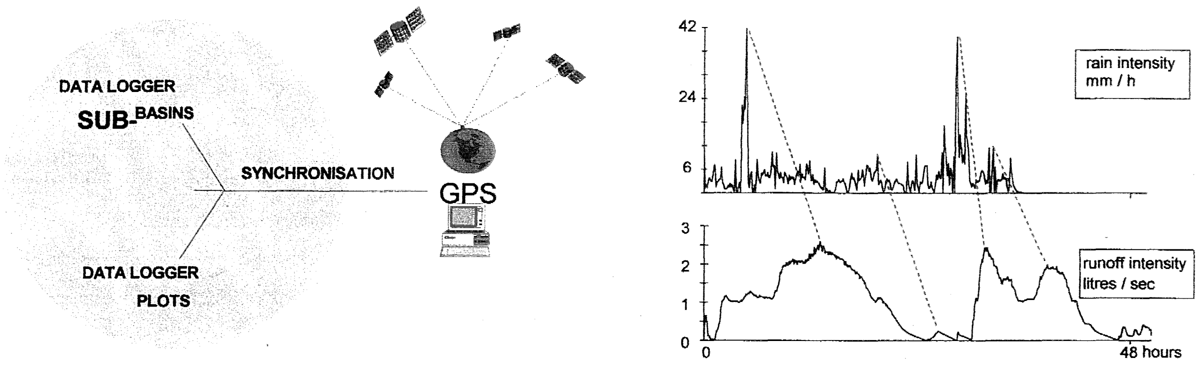


Fig. 3. Synchronisation of the different units allows the analysis of rainfall and runoff peak occurrence.

Survey points were interpolated by Kriging with the use of the surface mapping system Surfer 5.01 (Golden Software).

The sonar layout reading has been carried out by means of a field setting and of a suitable software. Afterward, files have been processed by a geostatistic analysis software in order to calculate the sediment volume and to produce the sediment thickness map (Figs. 5 and 6).

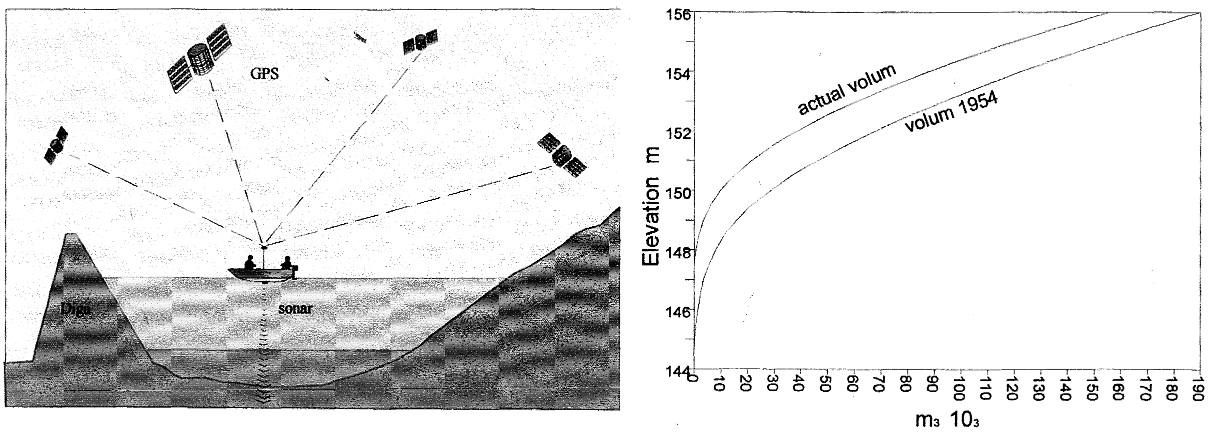


Fig. 4. Use of sub-bottom profiler and Differential Global Positioning System (GPS) for sediment thickness determination and survey point localisation. Reservoir water-volume curves.

Through the regulation curve of the reservoir and recorded water levels it is possible to calculate the watershed's runoffs and their characteristics.

A small revolving pot (the prototype of the modern Fagna-type unit) samples the water that spills through the spillway. This enable the calculation of turbidity and nutrient charge of flowing waters.

7.1. Water level recorder:

This device is composed by:

- Floating sensor connected to a band-pulley through a metal strap. The pulley transmits the movement to an horizontal bar that drives the pen on the recording paper.

- The bar is carved with a double inverted helical groove. During water rise or fall, if the pen reaches the right or the left margin of the paper strip, the helical groove inverts the movement of the pen.

7.2. GPS (Global Positioning System)

It is used for determining:

- For determining the position of the boat during sediment and water thickness survey.
- For determining the position of the boat during the sampling of water, inside the reservoir, for chemical analyses.

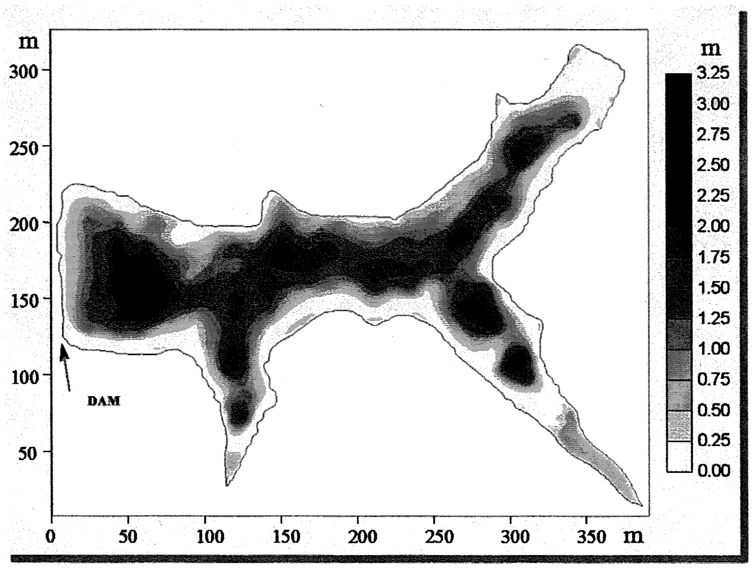


Fig. 6. Sediment localisation and thickness. Sedimentation started in 1954.

8. MAIN RESULTS

8.1. Runoff and soil erosion

A detailed analysis of rain characteristics influencing the erosive process, recorded at the Vicarello experimental centre (Volterra-Tuscany) during 1964-1990 demonstrated a dry up of climate in the short period. This trend was in terms of rain quantity and particularly from the point of view of aggressiveness. In fact, the evolution of rain events resulted towards an increasing of quantity and intensity, meanwhile an increase of the mean lag between successive events has been (Bazzoffi and Pellegrini, 1992).

At the watershed scale and on multi-decennial average, soil erosion resulted in 9.75 t/ha/year, as estimated by measurement of the sediments in the reservoir in the upper part of the watershed.

Cs137 balance in soil and sediment demonstrated that only 13.9% of total radionuclide input was removed by runoff water (Fig.7) (Bazzoffi and Panicucci, 1983).

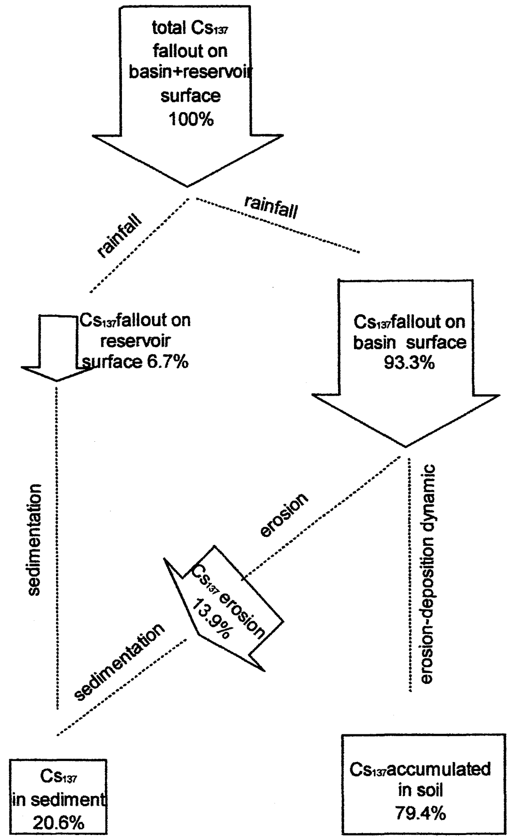


Fig. 7. Schematic drawing of the Cs137 dynamics inside the hydrographic system; Arrows and squares dimensions are proportional to the magnitude of each phenomenon.

In mono-crop watersheds both runoff volume and maximum peak flow did not differ between alfalfa and wheat land use. Differences became progressively more important when considering runoff volumes occurred on 10 and 30 minutes. In fact, they were reduced of 7% and 25% in alfalfa respect to wheat. Alfalfa was also able to increase mean duration of runoff events of about 40% (Fig. 8, Table 2).

In comparison to winter wheat, grazing shrubs drastically reduced runoff of 66% and soil loss of 93%. Respect to harrowing, shrubs reduced runoff and erosion respectively of 49% and 91%, while respect to new-planted alfalfa, grazing shrubs reductions were respectively of 77 and 94% (Table 2).

New alfalfa plantation wasn't able to protect the soil in the first year; in fact runoff volumes were 33% higher than in wheat plots, and 55% higher than in harrowed plots. Soil erosion was respectively higher of 24% and 38% (Table 2).

These findings are important in the evolution of rills in gully and possibly calanco. In fact in these clayey hilly areas, the rotation of soil use is: winter wheat, alfalfa, alfalfa, winter wheat, and soil is almost always in condition of vulnerability, specially in spring and autumn when it is bare or scarcely covered, and aggressive rains occur.

In May 1994 an intensive storm of 78 mm of rain, with estimated frequency of 6.5 years, occurred. This rainfall produced evident rills in the harrowed plots, and the estimated soil loss was 130 t/ha (Fig. 9). Total soil loss observed in the same plots during the entire 1994 was 9 t/ha. This fact demonstrates that conservation measures must be considered with respect to the risk of critical events.

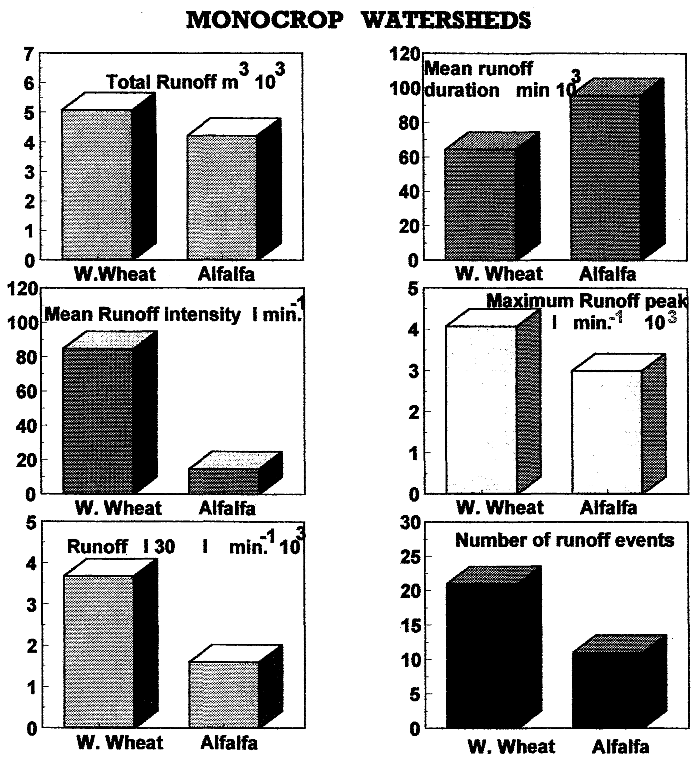


Fig. 8. Runoff characteristics observed in sub-watershed

	Runoff m^3 ha $year^{-1}$			Mean Runoff Intensity l min^{-1} $event^{-1}$			Max. Runoff Intemsity l min^{-1} $event^{-1}$			Max 10 min. Runoff Intensity l min^{-1} $event^{-1}$			Max 30 min. Runoff Intensity l min^{-1} $event^{-1}$		
monocrop sub watersheds	Diff.	Sign. level for difference (Student t)	Diff. %	Diff.	Sign. level for difference (Student t)	Diff. %	Diff.	Sign. level for difference (Student t)	Diff. %	Diff.	Sign. level for difference (Student t)	Diff. %	Diff.	Sign. level for difference (Student t)	Diff. %
Winter wheat / Alfalfa	0.83	0.46	0.00	55.6	0.01	79.2	18.4	0.16	3.3	33.6	0.92	7.0	101	0.70	24.9

Table 2. Mean differences of runoff in sub-watershed

In the plot experiment soil uses were also compared for their capability of increasing the lag time between the occurrence of maximum rainfall peak and the maximum runoff peak (Fig. 10). This hydrological parameter only relates with time, without considering the intensity of the peak. For each runoff event and for each plot, it was calculated the difference between the time of occurrence of the maximum rainfall peak and the maximum runoff peak. The averages values indicate that in the period between November and January, when soil cracks are closed, grazing shrubs elongate the lag time. Alfalfa is also capable of increase the lag time, specially in the second year from sowing, when root and canopy are more efficient in soil protection.

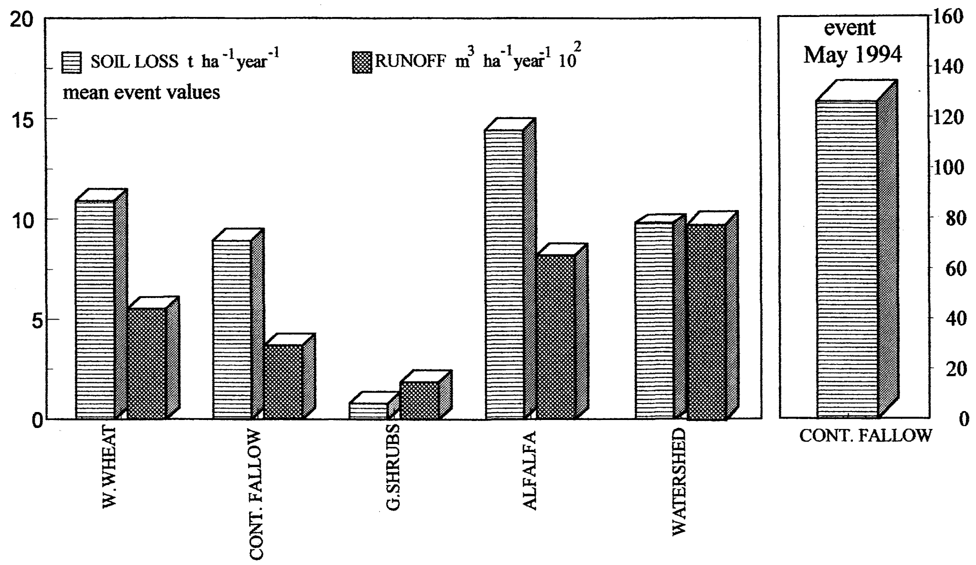


Fig 9. Runoff and erosion at watershed and plot scale.

Harrowing the soil for preparing seed-bed condition resulted in the shorter lag time, while ploughing increased water infiltration and lag time of the runoff peak respect to rainfall peak.

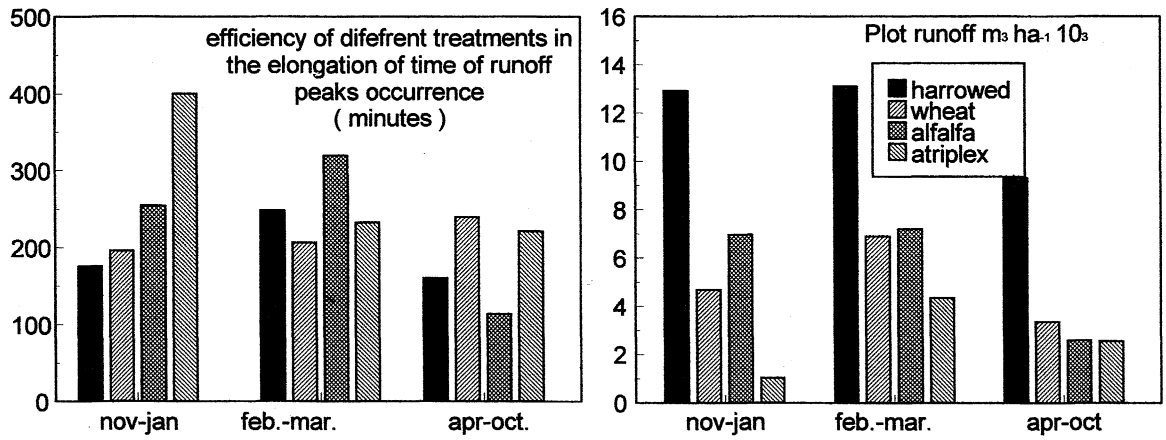


Figure 10. Effect of different soil use on runoff peak time-lag.

8.2. Nutrient dynamics

For each runoff event nitrates, ammonium and soluble phosphorus in runoff waters and total nitrogen, available, bio-available and total phosphorus in suspended sediments were determined. The higher loss of nutrients occurred in alfalfa plots in the first year, followed by cereal, continuous fallow and grazing shrubs. Nitrate loss from alfalfa, cereal and harrowed plots was respectively 12.4, 10 and 7.6 kg/ha. The loss of soluble phosphorus in all soil uses was very low and due to fertilizer application. In the sub-catchment cultivated with cereal the losses of nitrate were 10.5 kg/ha, while losses of nitrate from alfalfa sub-catchment were 0.5 kg/ha.

Seasonal nitrate dynamics and their distribution in soil profile were affected by tillage and fertilization. In fact tillage increased the summer mineralization of organic nitrogen of soil and consequently caused an high content of NO_3-N in soil in autumn. In winter, runoff and leaching determined significant losses of NO_3-N.

The application of mineral N to cereal plots, at sowing time, did not cause an increment in NO_3-N in the soil profile in December. Furthermore, since plant uptake is very low in this period, we can conclude that mineral fertilisation can cause an increase in the loss of NO_3-N, without a significant benefit for the plants (Papini et al., 1997).

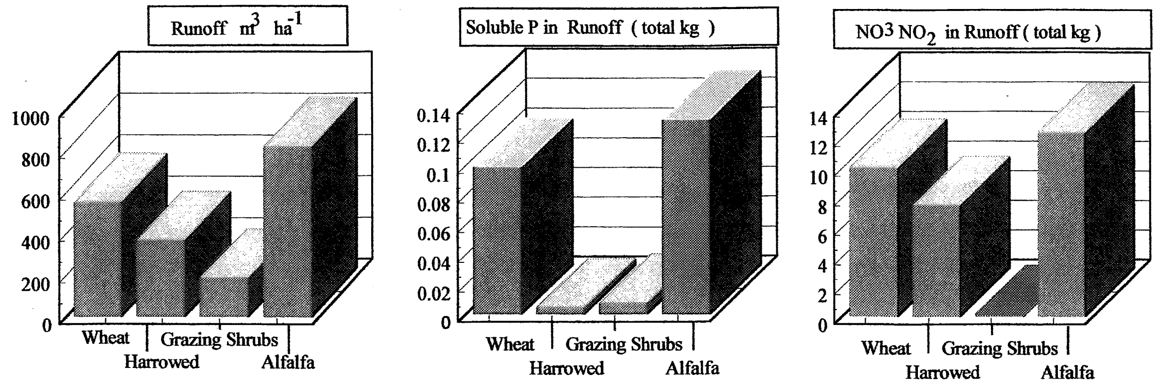


Fig. 11. Nutrients carried by runoff (plot experiment)

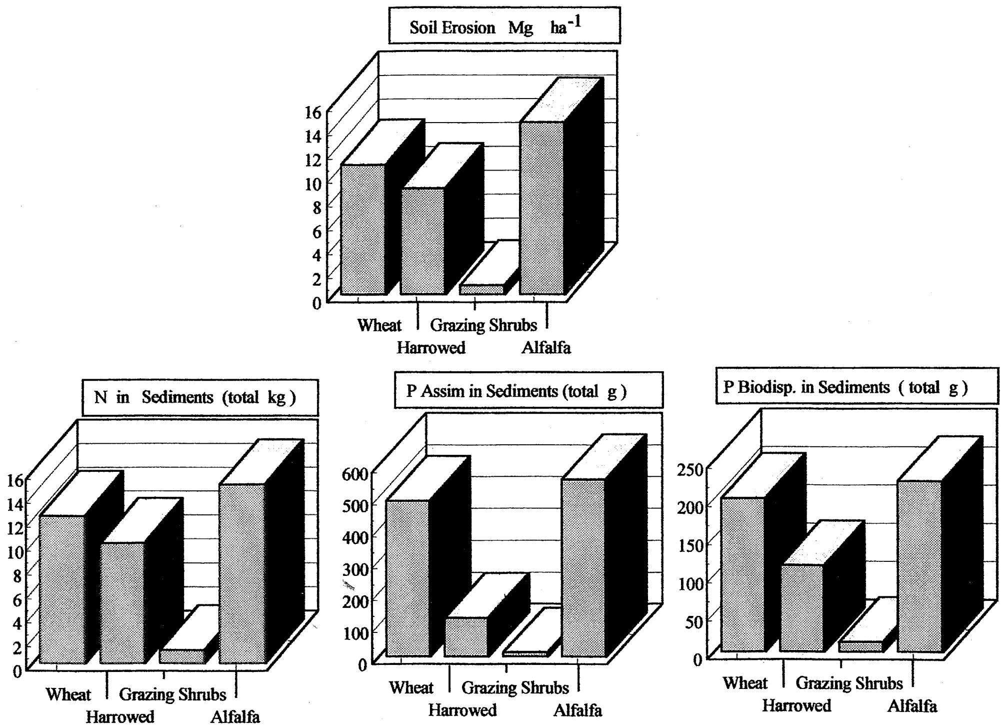


Fig. 12 Nutrients carried by sediments (plot experiment)

REFERENCES

BAZZOFFI P. (1994). *The enhanced Fagna-type hydrological unit for measurement and sampling of runoff waters*. International Workshop on Soil Erosion in Semi-Arid Mediterranean Areas. ESSC-CSEI, Taormina 28-30th Oct. 1993. CNR (ed.). pp.195-204.

BAZZOFFI P., PANICUCCI M. (1983). *Erosione sui versanti e conseguente sedimentazione in piccoli serbatoi artificiali. Nota I: Confronto fra il valore risultante dai rilievi sedimentometrici e dal bilancio del radionuclide Cs-137 da fallout derivato da esplosioni nucleari*. Annali Istituto Sperimentale per lo Studio e la Difesa del Suolo. Firenze, pp. 127-178.

BAZZOFFI P., PANICUCCI M. (1984). *Erosione sui versanti e conseguente sedimentazione in piccoli serbatoi artificiali. Nota II: Rilievi su due sistemi bacino-serbatoio dell'Italia centrale*. Annali Istituto Sperimentale per lo Studio e la Difesa del Suolo. Firenze, pp. 133-148.

BAZZOFFI P., PELLEGRINI S. (1992). *Caratteristiche delle piogge influenti sui processi erosivi nel periodo 1964-1990 in un ambiente della valle dell'Era (Toscana). Evoluzione climatica e modelli previsionali.* Annali Istituto Sperimentale per lo Studio e la Difesa del Suolo. Firenze, pp. 161-182.

BAZZOFFI P., MBAGWU J.S.C., CHUKWU W.J.E. (1995). *Statistical models for predicting aggregate stability from intrinsic soil components.* Int. Agrophysics, 9, 1-9.

BAZZOFFI P., PELLEGRINI S., CHISCI G., ROCCHINI A. (1999). Variazioni indotte sui deflussi e sull'erosione da differenti usi agricoli del suolo. In: La difesa dalle alluvioni – Convegno scientifico in occasione del trentennale dell'alluvione di Firenze (Firenze, 4-5 Novembre 1996), CNR Ed., Gruppo Nazionale per la Difesa dalle Catastrofi Idrogeologiche, Pubblicazione n. 1963, a cura di Falciai M.e Preti F., pp. 427-437.

BAZZOFFI P., PELLEGRINI S., CHISCI G., PAPINI R., SCAGNOZZI A. (1997). *Erosione e deflussi a scala parcellare e di bacino in suoli argillosi a diversa utilizzazione nella val d'Era.* Agricoltura Ricerca, 170, 5-20.

BAZZOFFI P., BOSCAGLI A., BRANDI G., BUSONI E., CALZOLARI C., CHIARUCCI A., CHIAVERINI I., CHISCI G., COLICA A., DE DOMINICIS V., DEL SETTE M., GRASSELLI O., LULLI L., MACCHERINI S., MAZZANTI R., MORANDI M., PAPINI R., PELLEGRINI S., ROCCHINI A., RODOLFI G., TORRI D., VECCHIO B. (1997). Guide for excursion "Badlands processes and significance in changing environments", Firenze-Siena, 23-28 Agosto 1997. Supplementi di Geografia Fisica e Dinamica Quaternaria, suppl. III, t. 2, 151-166.

DELOGU F., LULLI L. (1982). *Nota pedologica su cinque piccoli bacini sperimentali della Valdera (Pisa).* Annali Istituto Sperimentale per lo Studio e la Difesa del Suolo. Firenze, pp. 141-145.

LULLI L., DELOGU F., GREGORI E., MICLAUS N. (1980). Cartografia di base per la programmazione degli interventi in aree marginali (Area rappresentativa dell'alta Valdera – Botro dell'Alpino e Renaglio). Annali Istituto Sperimentale per lo Studio e la Difesa del Suolo. Firenze, pp. 33-96.

MAZZANTI R., RODOLFI G. (1988). Evoluzione del rilievo nei sedimenti argillosi e sabbiosi dei cicli neogenici e quaternari italiani. In: La gestione delle aree franose, Edizioni delle Autonomie, pp. 13-60.

MBAGWU J.S.C., BAZZOFFI P. (1987). *Estimating the consistency limits moisture retention and availability of some Italian soils from physical properties.* Annali Istituto Sperimentale per lo Studio e la Difesa del Suolo. Firenze, pp. 111-120.

PAPINI R., BAZZOFFI P., PELLEGRINI S., BRANDI G., MONTAGNA G. (1997). Perdite di nutrienti per ruscellamento da suoli argillosi marginali a diversa utilizzazione nella Val d'Era. Agricoltura Ricerca, 170, 21-32.

PINNA M. (1977). *Climatologia.* UTET, Torino.

RODOLFI G., FRASCATI F. (1979). Cartografia di base per la programmazione degli interventi in aree marginali (Area rappresentativa dell'alta Valdera). I – Memorie illustrative della carta geomorfologica. Annali Istituto Sperimentale per lo Studio e la Difesa del Suolo. Firenze, pp. 37-80.

USDA (1979). *Field Manual for Research in Agricultural Hydrology.* Handbook n.224. United States Department of Agriculture ed., Science and Education Administration, pp. 547.