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The cropping pattern and its role in determining erosion risk: experimental plot results from the Mugello valley (central Italy)

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Abstract The evaluation of soil loss related to different crops is of primary importance, since biological measures are often the only applicable conservation practices on hilly lands. Runoff and soil loss data collected since 1979 to 1987 from nine experimental plots (20 m length, 5 m width, 14% slope) with three different crops (wheat, corn, pasture) are reported. The results put in evidence the remarkable efficacy of pasture in reducing runoff and soil loss in comparison with that recorded from corn and wheat plots. The experimental values of the cover and management factor are in accordance with those derived from Wischmeier & Smith's tables. The results also indicate that, in some Italian environments, it may be possible to utilize the Universal Soil Loss Equation which provides a useful tool for planning agricultural systems to conserve the soil fertility.

Les cultures et leur rôle dans la détermination des risques érosifs: résultats sur parcelles dans la vallée de Mugello (Italie centrale)

Résumé L'évaluation des pertes en sol relatives à différentes cultures revêt une grande importance si l'on considère que les mesures biologiques de conservation sont en général les seules pratiques de conservation qui peuvent être appliquées en milieux de collines. Les résultats du ruissellement et des pertes en sol presentés dans cette communication, ont été obtenues de 1979 à 1987 sur neuf parcelles expérimentales (longues de 20 m, larges de 5 m, avec une pente de 14%) avec trois cultures différentes (blé, maïs, prairie). Les résultats mettent en évidence combien la prairie facilite la réduction du ruissellement et des pertes en sol par rapport aux parcelles de maïs et de blé. Les valeurs expérimentales du facteur cultural ont été identiques aux valeurs déduites des tables de Wischmeier & Smith. Les résultats indiquent qu'il est possible d'utiliser, même dans certains milieux italiens, l'Equation Universelle des Pertes de

Sol, utile dans la planification des systèmes agricoles pour conserver la fertilité des sols.

INTRODUCTION

Structural modifications such as the enlargement of fields without taking into account conservation practices, and the intensification of the cropping pattern, to optimize the cost-benefit ratio, have caused an acceleration of erosion processes with a consequent degradation of soil productivity in the hilly areas of Italy characterized by physical, pedological and morphological limitations on land use. This impact is particularly serious because the effects can be masked for some time by a progressive increase in the use of fertilizers, pesticides, etc., by improvements in crop varieties and by the use of modern technologies which can maintain high crop yields. However, the progressive increase of these means of maintaining production cannot be supported indefinitely and the degradation of the soil ecosystem could become evident only in its advanced stage and recovery could prove difficult. Furthermore, although the demand for food is increasing, there has been a progressive reduction of the best agricultural areas as a result of urbanization and industrialization. It is therefore important to maintain soil fertility and to preserve its productive potential, particularly in these hilly areas. This aim can be achieved both through the application of appropriate tillage, residue mulches and careful choice of crops, and through the introduction of mechanical conservation practices. The choice between these various methods of soil conservation, which will reflect the erosion risk, generally favours biological techniques (crops and crop management) rather than the mechanical measures which require earth movement and are therefore more costly and demanding.

The evaluation of the degree of soil loss associated with different crops is consequently of primary importance, particularly when it is recognized that biological measures are often the only available conservation practice on Italian hilly lands. The aim of the present research is to quantify the soil losses associated with the more common crops in these hilly areas in order to assist in the choice and management of crops, and in the application of the most appropriate crop schedules for soil fertility conservation.

METHODOLOGY

The study has been carried out using nine plots located in the Fagna experimental station (Scarperia-Firenze) on typical Eutrocrepts soil which originated on the silty-clayey sediments of the ancient lacustrine deposits of the Mugello valley. The plots are located on a slope with a uniform steepness of 14%. The main characteristics of the surface horizon (*Ap*), with a thickness of about 40 cm, are reported in Table 1.

Each plot has a dimension of 5 × 20 m, and is arranged with the major axis in the direction of the maximum slope. The lateral and upslope

Table 1 *Physico-chemical characteristics of the surface horizon (Ap, 0–40 cm)*

Clay (%)	Silt (%)	Sand (%)	pH	$CaCO_3$ (%)	Organic Matter (%)
52	35	13	7.8	14	2

boundaries are delimited by borders of galvanized sheet-iron fixed into the soil to a depth of about 15 cm, and protruding 20 cm above ground. On the lower side of the plot a trough has been installed to collect all the runoff. This is then sent through a pipe to a divisor which allows a storage tank to collect only 20% of the runoff from the plot. After each rainfall event, the volume of runoff is measured and samples of runoff are taken in order to establish the concentration of eroded soil.

The crop treatments, replicated three times, are represented by wheat, corn and pasture which represent the major crops in this area. The cultivation of the slopes has been carried out using traditional methods for the area, which include soil tillage up and down the slope in the summer for the wheat and in the spring for corn, and seed bed preparation up and down the slope.

RAINFALL AND EROSIVITY

The rainfall regime of the study area is typical of the Appenine region, with a summer minimum in July and two winter maxima in November and February. The average rainfall for the period 1979–1986, recorded by a raingauge located near the experimental plots, was 1000 mm. This is similar to the 50 year average (1924–1970) observed at the neighbouring station of Borgo S. Lorenzo (1045 mm).

The rainfall data have been analysed to calculate the rainfall erosivity, using the methodology reported by Wischmeier & Smith (1978). The relative annual values for 1979–1986 are 2601.2, 1385.8, 2597.1, 2809.8, 1320.3, 3961.0, 1949.0, 2434.7 MJ ha^{-1} $year^{-1}$ respectively. The erosivity values for each month have been used to derive the cumulative percentage erosivity curves for each year and an average curve for the period (1979–1986) (Fig. 1).

These curves may be used to define the period of the year with the maximum rain erosivity and to relate the pattern of erosivity to the characteristics of the cover provided by various crops during different vegetative stages. From the trend of this curve it is possible to select the crops and the crop management most suitable for reducing erosion.

RESULTS AND DISCUSSION

The results of soil loss and runoff measurements undertaken between January 1979 and May 1987 for 418 rainfall events are reported. It should be noted

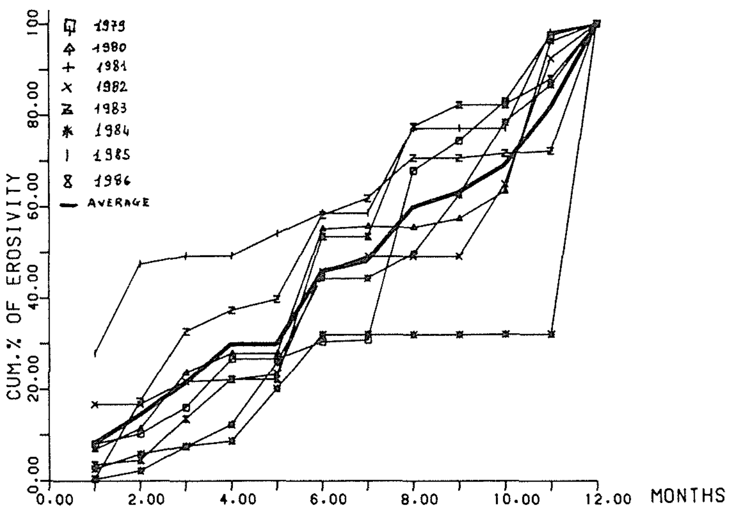

Fig. 1 *Cumulative percent erosivity curves of the period 1979–1986.*

that in the plots where wheat is cultivated, soil loss and runoff were not collected during the following months: between August and November 1979; between September and November 1981, between part of August and part of November 1982; between part of August and November 1983; September and October 1984; between July and part of November 1985; and between part of August and November 1986. For this crop a complete annual data set is only available for 1980 when it proved possible to measure all rainfall events. For the corn plots, soil losses and runoff were not collected during following periods: April 1982, between March and May 1983, between March and June 1984, between November 1985 and May 1986 and from December 1986 to May 1987. During these periods the plot borders had been removed to permit soil tillage and seed bed preparation. For the pasture plots all data have been continuously gathered starting from May 1979 when the grass was sown.

The average annual runoff for the three replicates and the runoff coefficients, related to the rainfall recorded during those periods during which the plots were functioning, are reported in Table 2.

Because of the limited data for the wheat plots indicated above, it is only possible to compare the runoff from this crop with that from the other crops for the year 1980. Similarly, a comparison between the runoff data collected from the corn and pasture plots is only possible for the years 1979–1982. The results obtained demonstrate the remarkable effectiveness of the pasture in reducing runoff in comparison to that recorded from the corn and wheat plots, even though the comparison with the latter is only possible for the year 1980. The reported values of the runoff coefficient for the three cropping treatments have been calculated taking into account only the rainfall falling in the period during which the plots were functioning. These coefficients are not completely comparable.

The average annual soil losses for the cropping treatments are reported

Table 2 *Annual runoff and runoff coefficients for the study plots*

Year	*Wheat*		*Corn*		*Pasture*	
	Runoff (mm)	*Runoff coeff. (%)*	*Runoff (mm)*	*Runoff coeff. (%)*	*Runoff (mm)*	*Runoff coeff. (%)*
1979	*405.83*	*58.06*	*206.08*	*38.13*	*193.41*	*28.36*
1980	*580.36*	*58.55*	*585.58*	*59.09*	*385.48*	*38.89*
1981	*441.68*	*63.55*	*659.33*	*66.32*	*441.73*	*44.43*
1982	*359.70*	*46.59*	*784.96*	*78.46*	*484.93*	*47.45*
1983	*364.88*	*46.02*	*202.53*	*33.10*	*324.87*	*37.36*
1984	*444.36*	*54.97*	*621.15*	*84.03*	*670.80*	*56.41*
1985	*78.08*	*18.60*	*172.73*	*31.77*	*94.49*	*14.25*
1986	*200.73*	*34.34*	*80.54*	*21.38*	*316..66*	*39.87*
1987	*105.05*	*38.17*			*119.16*	*43.29*

in Table 3. The effectiveness of the pasture cover in limiting soil losses to below the maximum level of soil erosion tolerance, which for this soil is about 7 t ha^{-1} $year^{-1}$, should be noted. This soil loss tolerance level is greatly exceeded by the corn plots and to a lesser extent by the wheat plots. For the latter crop the reported soil loss values are underestimates, since soil loss data are lacking for October and November, as pointed out above. During these months the erosion risk for this crop is at its highest because of the sparse, vegetative cover. This affords limited protection to the soil which is particularly prone to erosion as a consequence of the seed bed preparation. In this context a rainfall event occurring during December 1981 is particularly illuminating. It was characterized by a rainfall depth of 39.2 mm, of which 38.4 mm fell in 1 h, and by an erosivity of 443 MJ ha^{-1} h^{-1}. The soil loss recorded for this event represented 64.3% of the total recorded for the year. For the wheat plots the majority of the soil loss occurs between November and February, representing about 76% of the total amount measured, as average for the period 1979–1986. Although the winter months also evidence the highest erosion risk for the other crops, the experimental results indicate another dangerous period for corn in May–June, related to the stage which immediately follows sowing. During this period the soil losses from the corn plots are very high. A rainfall event which occurred in June 1986 provides a good example of this problem. It was characterized by a rainfall depth of 40.2 mm and ny an erosivity of 514.21 MJ ha^{-1} h^{-1}. The corresponding soil loss of 9.99 t ha^{-1} represented 90% of the annual loss. The considerable soil loss recorded from the corn plots in 1982 was due to above-average erosivity value and to the poor soil cover provided by a low density of plants (*c.* 0.5 plants m^{-2}).

The cover and management factor, *C*, of the Universal Soil Loss Equation (Wischmeier & Smith, 1978), was derived utilizing the cumulative percentage of erosivity and the soil erodibility value (Zanchi, 1988) as well as the amount of soil loss and the topographic factor value. Mean annual values of the cover and management factor were estimated at 0.13, 0.37, 0.03

Table 3 Annual soil loss (t ha^{-1}) as an average of three replicates for the period 1979–1987

Crop soil loss in:	1979	1980	1981	1982	1983	1984	1985	1986	1987*
Wheat	8.504	6.073	10.113	17.818	4.024	2.081	0.537	3.163	0.365
Corn	17.988	23.651	46.753	81.407	4.300	9.054	4.266	11.051	-
Pasture	5.844	3.292	2.815	6.359	2.602	2.054	0.536	1.009	0.189

*Until May 1987.

respectively for wheat, corn and pasture. These experimental values for corn and pasture are in close agreement with those tabulated by Wischmeier & Smith (1978). The experimental value for wheat is, however, less than that derived utilizing the Wischmeier and Smith tables. The difference can be at least partly accounted for by the fact that soil loss data for wheat plots are lacking during the time of highest erosion risk. The cover and management factor value reported above for wheat is therefore undoubtedly an underestimate. Furthermore, on the basis of the experimental results, it is important to note that, in order to maintain the erosion within the admissible soil loss tolerance, corn would need to follow five years of pasture. To compare directly runoff and soil loss from the three different cropping treatments, only the data relating to the rainfall events when all plots were working contemporaneously have been used. The results are reported in Table 4.

Table 4 *A comparison of runoff and soil losses for rainfall events when all plots of the three crops were working simultaneously*

Years	Wheat Runoff (mm)	Wheat Soil loss (t ha^{-1})	Corn Runoff (mm)	Corn Soil loss (t ha^{-1})	Pasture Runoff (mm)	Pasture Soil loss (t ha^{-1})
1979	96.2	4.218	91.90	10.156	74.9	3.744
1980	580.0	6.073	585.7	23.651	385.5	3.292
1981	441.7	10.113	548.3	41.892	368.2	2.630
1982	359.7	17.818	508.4	48.281	344.4	4.106
1983	124.6	2.134	198.7	4.236	128.9	1.766
1984	299.3	1.375	487.9	7.485	338.9	1.214
1985	76.4	0.529	169.2	4.102	89.2	0.522
1986	27.1	2.654	62.4	10.329	37.8	0.515
Mean	250.6	5.614	331.5	18.767	220.9	2.224

These data indicate that runoff from the wheat and corn plots exceeds that from the pasture plots by 1.13 and 1.5 times respectively. The erosion losses from the wheat and corn plots exceed those from the pasture plots by 2.5 and 8.4 times respectively.

CONCLUSIONS

The results shown above demonstrate that the utilization of this hilly area for intensive cultivations is, from a conservation point of view, generally risky. Corn crops in particular, at least with the management techniques normally utilized in this area, cause a noticeable acceleration of the erosion process. Such row crops can only be cultivated on hilly slopes by employing a rotation involving a high percentage of conservation crops, such as pasture, or by adopting suitable supporting practices such as conservation tillage, mulching, etc or mechanical conservation techniques.

Even from the wheat plots, the soil losses are frequently higher than the maximum level of soil loss tolerance. This is due to the high percentage of the annual erosivity that is concentrated between October and February, when the soil is more susceptible to erosion because of either the sparse vegetative cover, or as a consequence of seed bed preparation. The experimental results have confirmed the effectiveness of pasture in reducing erosion in an area potentially very prone to erosion, and in limiting soil losses to values lower than the maximum acceptable level.

Furthermore, it seems important to highlight the close accordance between the experimental values of the cover and management factor and the values derived from the tables reported by Wischmeier & Smith (1978). This implies a possibility of utilizing such tables in applying the Universal Soil Loss Equation, to evaluate erosion risks. Such potential is also indicated by previous work by the author (Zanchi, 1978) which suggests that the equation may be used to predict the long-term soil loss in environments, such as the Italian one, which are different from those for which it was originally developed. This reflects considerable practical potential because this equation can provide useful assistance in the choice of crops, crop management and eventually conservation practices, which will allow erosion rates to be maintained at an acceptable level and the soil fertility to be conserved.

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