Cultural practices and risks of runoff and interrill erosion under vineyard (Ardèche, Southern France)

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Introduction

As they cover poorly the soil surface during the whole year, vineyards involve weeds and erosion problems, particularly on the steep hillslopes of Mediterranean areas of France where rainstorms can be dangerous. This danger is important not only for wine quality but also for landscape evolution and floods over the plains. Last 20 years, many catastrophic floods were observed in southern France.

In Ardèche country, many circumstances increase the erosion risks. The Cevenols rains in autumn may be very intensive (100 mm/hour) and abundant (120 mm/day). Lithosols are poor and superficial on steep slopes (Maillo,1999). Land use has changed last 30 years increasing environmental risks. To improve the wine quality, vineyards have been moved on the hillslopes but soils are compacted by tractors, which can move only up and down, and herbicides degraded the topsoil structure so that runoff increased significantly (Léonard, 2003).

To evaluate the possibility to decrease these runoff and erosion problems, 36 rainfall simulator tests where used to compare the efficiency of six cultural practices on a calcareous Lithosols with 40% of topsoil surface covered by stones on a 12% slope vineyard.

Material and Methods

The experimental vineyard is situated on the old farm of Olivier de Serres, at Pradel (44°35 N, 4° 30 E, 285 m alt.) on a hillslope situated between the Rhone valley and the volcanic Coiron Mountains. The marno-calcareous rocks are covered by 0.4 to 1 m colluvium with a loamy-clay brown soil, 2% of organic matter, and 40% of calcareous and basaltic stones. Rainstorms are particularly aggressive in autumn and spring and attain 1000 mm a year because the proximity of Mediterranean Sea and the Cevennes Mountains. Vineyard (Syrah cepage) is 24 years old and is still well producing: it is planted along the slope each 1 m in the rank and 2.2m between ranks in order to allow the mechanization (Maillo, 1999).

In the spring 1999, four usual cultural practices have been introduced between 3 ranks along the slope:
i) Chemical clean weeding (DCT) corresponding to the presently most frequent practice;
ii) Conventional tillage at 10 cm depth, the preceding system, leaving a soil surface covered by stones at 40% (SARC40); iii) a mulch of 25 t/ha of straw over the tilled surface (PAIL); iv) a graminacea seeding with 30% of Ray-grass (*Lolium perenne*) and 70% of *Festuca rubra.* Locally on 1m² plots, two additional treatments were developed: v) a clean weeding + tilling with manual extraction of stones down to 30% of the surface (SARC 30), vi) after tilling a manual addition of stones up to get 80% of covered surface (SARC 80). These treatments are common on some stony soils of the vineyards in France or in Switzerland (Nachtergaele et al., 1998).

Each cultural practice has been tested by two simulated rains and three repetitions on 1 m² in June 1999: a 30 minutes rain 60 mm/hour on "dry soils" without any natural rain for 5 days at least, and after 15 minutes and the end of the possible runoff, a one hour rainfall of 60 mm/hour "on very wet soils" conditions, similar to the rainstorms falling during the autumn. For each simulation, various parameters were observed in order to explain the differences of runoff and erosion: Hp% = previous soil moisture on 10 cm depth; Pi 1 and 2 = prepounding rain amount (mm), KR 1 and 2= runoff rate (%) for the first and second rains; INF 1 & 2 = final infiltration rate (mm/h) after rains 1 & 2; TURBIM 1 & 2 = Runoff turbidity (g/l) at the end of each rain ; surface status : open surface (%) (aggregates, fauna holes, fissures) and covered surface (%) by litter, stones and weeds (Roose, 1996). They were estimated at 192 points of observation on lines crossing the microplots. Soil samples were collected near the microplots at 0 - 5 cm depth to determine the carbon content, texture and structural stability (Le Bissonnais, 1996). All the variables were analyzed for the second rain but some were not for the first rain because no runoff was observed after 30 minutes. In order to classify the treatments a note was attributed to each treatment in relation to the different parameters from 1 when it is the best to 0 if the worst and 0,5 when intermediate. Statistical analysis (test Newman-Keuls for classification of treatments) was made with the logiciel Statistica V.6 (StatSoft TM).

Results and Discussion

In figure 1 and table I are presented averages and standard deviation of runoff (%) and soils losses (g/m²) of rain simulated in relation of the six treatments and their statistical analysis (test Newman-Keuls). During the first rainstorm, on dry situation (Hp = 4 to 10% in 0 to 5 cm depth), prepounding rain (Pil) is significantly higher under mulch (Pail) and tilled plots (SARC 80-40-30) than under chemical weeding and grass seeding (DCT and ENH): the runoff % is always higher on those last treatments. During the second rain, on

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moist soil (Hp = 11 to 20 %), the runoff rate are higher than during the first (KR1= 0 to 27% ; KR2 = 5 to 78%). Mulching (addition of straw or stones on the soil surface) gave better results than the other treatments : highest prepounding rain, (Pi=23 to 35mm), highest infiltration rate (INF = 41 & 55 mm/h instead <39 mm/h), lowest runoff (KR2 = 5 to 12%), lowest turbidity (TURBIM <2.2 g/l instead 5 to 8 g/l for tilled plots) and lowest soil losses (MES = 2 to 12 g/m² while up to 105 and 309 g/m² under chemical weeding and tillage with clearing of stones).

The semi-automatic classification of the six cultural practices allowed getting a general view on the interest of each treatment. After this classification (table 1), with a general note of 0.93, mulching with straw or stones are the best cultural practices. In opposite, tillage with taking stones off the field and chemical weeding got the worse notes (0.29) and accumulated maximal runoff and soil losses inconvenients. We noted that getting grasses was giving relatively poor classification index (0.36 against 0.71 for the conventional mechanical weeding). This was due to high runoff which happens with grasses *Festuca rubra* sewed 3 months before only.

To explain variations of runoff and soil losses observed, we analyzed their relations with parameters depending on local variability (slope, topsoil texture and moisture) and with parameters a priori in relation to cultural practices (soil organic carbon, soil structure stability, soil surface features like % of the surface covered by litter, rocks and weeds, and % of the surface closed by sealing crust, rocks included in the soil or in the crust and compacted areas) (Roose, 1996).

At the 1m² scale there is no relation between slope % (10 to 16%) and erosion or runoff rate (Roose, Cavalié, 1988). We found no correlation between texture (clay, sand %), or soil moisture of the topsoil (0 to 5 or 10 cm) and runoff or erosion parameters, probably because the variations between treatments are not great enough (Blavet et al., 2004; Lelong et al., 1993).

But we found significant correlations (p = 90 %) with the stability of the structure (MWD) and the increase of prepounding rain of 1rst and 2d rain, or the decrease of the runoff rate of each rain and the stable infiltration rate of the second rain (De Noni et al., 2002. There is a good correlation between the carbon rate and the structure stability of the topsoil (Barthès et al., 1998; De Noni et al., 2002). There are also strict correlations between soil losses (Turbim & MES) and the covered surface %. When the topsoil is covered it is protected against the drop energy : here the treatments mulched (with straw or stones) have the best cover % and the worse are tilled with stone clearing (SARC30%)(Gril, 1984; Roose et Cavalié, 1988; Arshad et al., 1999).

Considering all cultural practices, there is no significant correlation between soil covered % and runoff parameters because soil surface could be open or closed on the same level of surface cover. But considering a same surface features (ex tilled weeding) with different cover surfaces, a correlation between various cover % and runoff parameters could appear: so the % of stones can improve the prepounding rate and the final infiltration rate (Poesen, Torri, Bunte, 1994). That means that stones on the open soil surface protect the soil structure against the rainfall energy. But if stones are included in the sealing crust or in the soil, the infiltration rate will decrease. Finally there are interactions between the closed surface and the cover %: the closed surface increased faster if the soil is poorly covered during the rains (r = - 0, 754*).

Thus, considering the treatment classification and the explaining factors, cover % is mainly explaining soil losses and detachment, while closed soil surface % would regulate runoff and final infiltration rate. It appears also that soil structure stability in relation to carbon content of the 10 cm topsoil can influence the runoff rate from the first rain on the dry condition (Barthès et al., 1998).

Conclusion

This study shows that mulching with straw (100% surface) and stones (80%) best covering inter rows of vineyard can reduce runoff and erosion significantly because their protection of the open surface against drop and runoff energy, aggregates breaking up and soil porosity closing. The worst cultural techniques are chemical weeding (presently the most frequently used) and tillage weeding with stones clearing (still frequently used). Seeding with grasses practice, not very efficient in our experiments, remains questionable because it was too recently installed (3 months) on previously herbicided soils: it could reduce rapidly soil losses, but more time is necessary to verify it can also reduce runoff.

It seems also useful to verify later the influence of these treatments on the soil properties modifying the soil behavior against erosion. Finally, it appeared that an inquiry must confirm that mulching is acceptable for the winegrowers in term of cost and painful labor.

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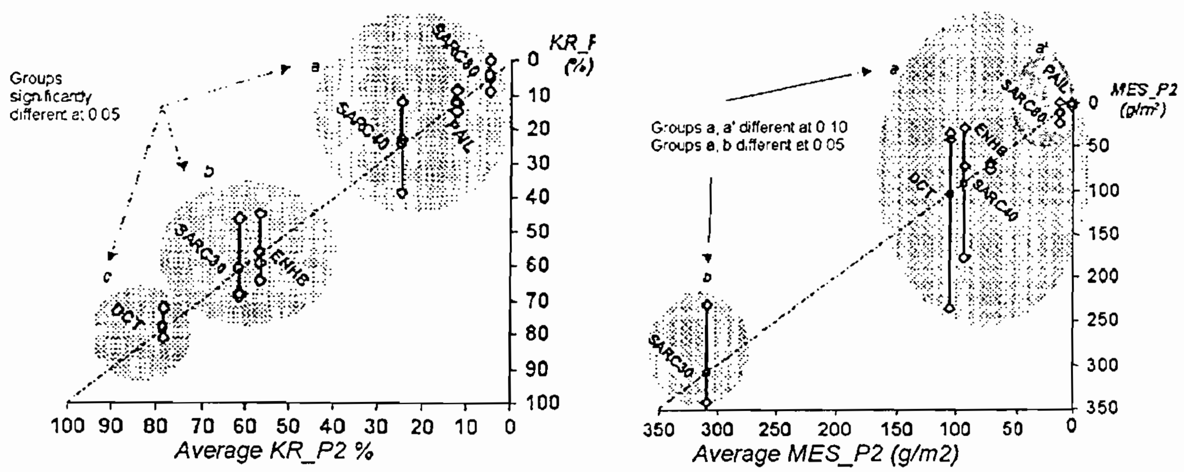

1.a.Runoff rate, in % of the rainfall (coefficient KR 2). 1.b.Exported matter in suspension in g/m2 (variable MES 2).

Figure 1. Runoff rate and exported materials by suspension during the second simulated rainfall following the different cultural practices (individual data and means).

Table 1. Average runoff and soil losses under rainfall simulations, with statistical grouping of means and semi-automatic classification of the cultural practices

Variables of runoff and soil losses	Cultural Practices											
	DCT		SARC30		ENIIB		SARC40		SARC80		PAIL	
Pi 1 : Prepounding rain during the first rain (mm)	9,8 ± 3,1 c	0	19,8 ± 4,8 b	0,5	9,3 ± 4,2 c	0	23,8 ± 5,1 a	1	30 ± 0,5 a	1	30 ± 0,8 a	1
KR 1 Runoff rate during the first rain (%)	27,5 ± 7,2 b	0	8,9 ± 7,3 a	1	17,9 ± 8,6 b	0	4,2 ± 5,8 a	1	0 ± 0 a	1	0 ± 0 a	1
Pi 2 : Prepounding rain during the second rain (mm)	1,2 ± 0,4 b	0	1,1 ± 0,6 b	0	1,6 ± 0,2 b	0	4,8 ± 4,0 b	0	35,6 ± 23,1 a	1	22,7 ± 2,2 a	1
KR 2 : runoff rate during the 2d rain (%)	78,2 ± 5,1 c	0	61 ± 12,9 b	0,5	56,4 ± 9,8 b	0,5	24,5 ± 13,3 a	1	4,8 ± 4,6 a	1	12,2 ± 3,1 a	1
INF 2 : stable infiltration at the end of the 2d rain (mm / h)	8,3 ± 3,9 c	0	13,5 ± 8,1 c	0	18,5 ± 5,9 c	0	38,2 ± 8,1 b	0,5	55,3 ± 3,3 a	1	41,8 ± 9,3 b	0,5
TURBIM 2 : Runoff Turbidity a t the end of the 2d rain (g / /L)	2,2 ± 2,3 a	1	8 ± 0,3 c	0	2,1 ± 0,3 a	1	5,6 ± 1,7 b	0,5	5 ± 0,5 b	0,5	0,2 ± 0,3 a	1
MES 2 : Suspension matter during the 2d rain (g/m²)	105,3 ± 113,2 a	1	309,4 ± 67,8 b	0	71,6 ± 4,2 a	1	93 ± 78,0 a	1	12,2 ± 12,0 a	1	1,6 ± 1,9 a	1
Average note for each cultural practice	0,29		0,29		0,36		0,71		0,93		0,93	

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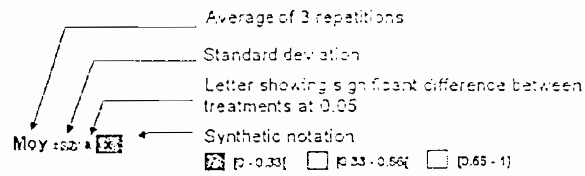

Table 2. Linear correlations between i) the Mean Weight Diameter, the Soil Organic Carbon, ii) the soil cover rate and soil surface closing rate and iii) the runoff and soil losses variables

Field variables	Runoff variables					Soil losses variables	
	First rain		Second rain			Second rain	
	Pi 1	KR 1	Pi 2	KR 2	INF 2	TURBIM 2	MES 2
1. MWD µm (0 - 5 cm)	0,82* n=5	-0,81* n=5	0,49 n=5	-0,71 n=5	0,57 n=5	-0,31 n=5	-0,33 n=5
2. SOC g/kg (0 – 5 cm)	0,88** n=5	-0,96*** n=5	0,46 n=5	-0,76 n=5	0,66 n=5	0,27 n=5	-0,06 n=5
3. Soil cover rate on all situations	0,13 n=17	-0,13 n=17	0,43 n=17	-0,40 n=17	0,40 n=17	-0,77** n=17	-0,75** n=17
4. Soil cover rates on tilled situations with stone cover	0,82** n=9	-0,67** n=9	0,63 n=9	-0,72** n=9	0,75** n=9	-0,70** n=9	-0, 82** n=9
5. Initial closing rate at the beginning of the first rain	-0,55** n=14	0,66** n=14	-0,13 n=14	0,43 n=14	-0,32 n=14	-0,68** n=13	-0,30 n=14
6. Final closing rate at the end of the second rain	-0,79** n=14	0,79** n=14	-0,74** n=11	0,97*** n=11	-0,94** n=11	-0,22 n=11	0,44 n=11

**Significatives correlations at p > 95 %., ** significative at >99%, n= repetitions number*

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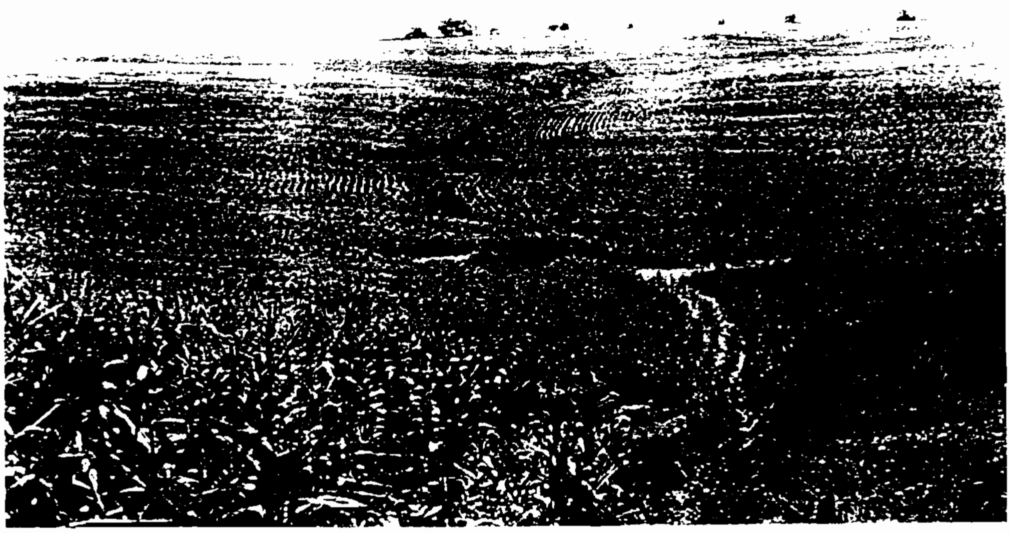

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