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Anti-erosive effectiveness of Eucalyptus coppices through the cover management factor estimate

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Abstract:

In this paper sediment yield data, measured from 1978 to 1994 in two small Calabrian basins (W2 and W3) reafforested with eucalyptus trees (*Eucalyptus occidentalis* Engl.), and the Modified Universal Soil Loss Equation (MUSLE) applied in a distributed form are used to evaluate the anti-erosive effects of eucalyptus cover. At first step the sediment yield measurements observed in W2 basin are used to estimate a single cover management factor representative of the eucalyptus coppice and equal to the median value (0·164) of the cover management factor values calculated for each runoff event. Then, the reliability of the selected representative cover management factor is verified on W3 by comparing the cumulative distribution function (CDF) of the measured sediment yield with the CDF of the calculated one. Finally, the temporal analysis of the crop and management factor is developed searching, at monthly and annual scale, the correlation between crop anti-erosive effectiveness and rainfall erosivity index. © 1998 John Wiley & Sons, Ltd.

KEY WORDS soil erosion; cover factor; runoff; eucalyptus plantation; forest harvesting

INTRODUCTION

According to Lull and Reinhart (1972) an undisturbed and totally covered forest soil usually yields no surface runoff and it has no sheet and rill erosion.

Forest ecosystems affect both soil hydraulic properties (water retention and hydraulic conductivity) and overland flow velocity. In particular, dense forest cover normally reduces runoff at the hillslope scale and consequently determines an increase of the concentration time and a smoothing of the flood hydrograph. Therefore, forest cover modifying the hydrological hillslope processes (infiltration and runoff) is able to reduce erosion and to support sediment delivery processes. According to Wischmeier and Smith (1978) forest cover has to be considered 'the most efficacious brake to erosion'.

Forest also develops an antierosive action through the supply of organic matter, rainfall interception and reduction of rainfall kinetic energy.

Under forest cover, topsoil accumulates a high organic matter content which enhances the stability of the soil structure and reduces soil erodibility (Dissmeyer and Foster, 1981). The crop residue and biological activity of animal organisms can increase the infiltration capacity and improve macro-porosity; in fact, in undisturbed forested soil the dead and decaying root systems can create fissures in which vertical infiltration motion takes place (Kirkby, 1980).

Vegetal canopy intercepts rainfall and collects water on its foliage. At the beginning of an event the canopy catches most of the occurring rainfall and the interception goes on until the forces owing to surface tension are greater than those owing to gravity (Horton, 1919; Grah and Wilson, 1944). The percentage of intercepted water depends on wood composition (broad-leaf, coniferous, deciduous, evergreen), wood age,

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density and structure and total rainfall depth and intensity (Ausennac and Boulangeat, 1980; Ausennac *et al.*, 1982; Nizinski and Saugier, 1989; Borghetti, 1992). Some of the intercepted rainfall never reaches the ground, but it is evaporated during and after the event. Some of the intercepted rainfall reaches the ground as stemflow and it contributes to runoff. Drops falling from the canopy may be larger than the original raindrops but they fall from a low height; in other words, the energy of the drops reaching the soil surface is less than that of rainfall in non-covered areas.

The forest cover also determines the dissipation of the rainfall kinetic energy, and the brushwood and litter play an important role in providing protection able to absorb residual kinetic energy.

Some models using a process-based approach to predict erosion, like EUROSEM (Morgan, 1994) and LISEM (De Roo *et al.*, 1994), deal in turn with the interception during rainfall (Merriam, 1973; Aston, 1979), the volume of rainfall reaching the ground surface as direct throughfall and leaf drainage and the volume of stemflow.

The USLE-derived models (Bingner, 1990) introduce the crop management factor *C* into the equations used to simulate the interrill erosion (Meyer and Wischmeier, 1969; Foster *et al.*, 1977; Wischmeier, 1975). Finally the *in progress* physically based technology named WEPP (Nearing *et al.*, 1989; Laflen *et al.*, 1991) simulates the processes of detachment, transport and deposition of soil particles on interrill areas by a single equation in which a ground cover adjustment factor and a canopy cover adjustment factor are introduced.

The vegetation cover also affects both the rill pattern developing on the hillslope and the depth and velocity of concentrated flows.

Rogers (1989) carried out some experimental runs with simulated rainfalls acting on a laboratory plot (7 m wide and 6·25 m long), having a slope equal to 10 and 20%. The crop cover, having a percentage ranging from 0 to 45%, was obtained by sods.

The analysis showed that the experimental surfaces with zero cover (Figure 1a) and 10·4% cover (Figure 1b) produce a similar parallel drainage pattern. When the crop cover increases (Figure 1c) deflection of the flow by the vegetation occurs and the rill pattern of 20·9% ground cover run is more dentritic than the previously described patterns. When the crop cover increases to 45·2% (Figure 1d), a few long drainage networks dominate the surface. Comparison of drainage density, DD, with crop cover percentage, PC, shows

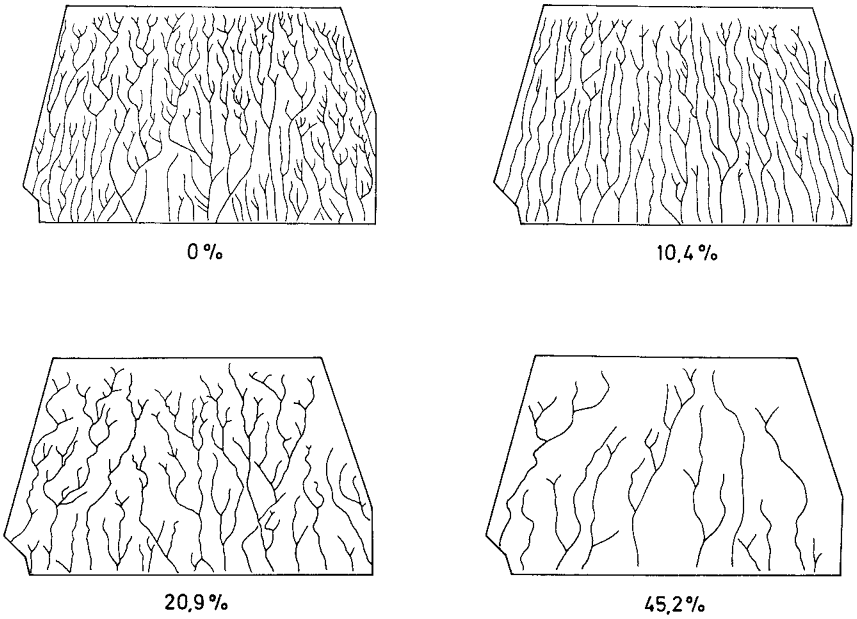


Figure 1. Influence of crop cover percentage on rill pattern

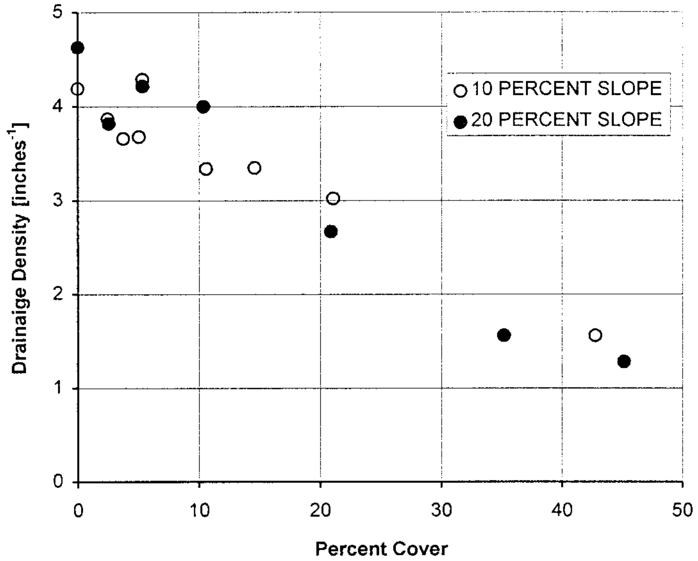


Figure 2. Relationship between drainage density DD and crop cover percentage PC

that DD linearly decreases with increasing ground cover (Figure 2). In other words, for increasing crop cover percentage values the sediment transport efficiency decreases because the probability that the eroded particles stop before arriving at the nearest rill increases (Ferro, 1997). Figure 2 also shows that DD can be considered constant for PC values less than 10%, indicating a crop cover percentage *limit* to the effectiveness of vegetation in reducing erosion.

The experimental measurements carried out by CEMAGREF in two experimental basins, located in the Alps of Upper Provence (France), having different PC values, showed significant differences in soil losses. In particular, the basin having a percentage of forested cover equal to 30% was characterized by a sediment yield greater than 75 m^3/ha per year while in the basin with 87% of area covered by *Pinus nigra* stands the sediment yield was equal to 1·24 m^3/ha per year (Buttafuoco, 1993).

Since slope instability and high soil loss are characteristic of the mountainous Calabrian region (South Italy), in 1978 the CNR 'Soil Conservation Project' equipped three small basins (W1, W2 and W3 in Figure 3) to monitor the effect of afforestation on hydrological response and sediment yield (Avolio *et al.*, 1980; Iovino and Puglisi, 1991).

In this paper the experimental data measured from 1978 to 1994 (Avolio *et al.*, 1980; Cantore *et al.*, 1994; Callegari *et al.*, 1994) in W2 and W3 basins will be used. The available sediment yield measurements and the modified universal soil loss equation (MUSLE) of Williams (1975), applied in a distributed form, will be used to evaluate the effects of the eucalyptus coppice on sediment yield

EXPERIMENTAL BASINS

The studied area is located near Crotone (35 m a.s.l., 39°09′02″N, 17°08′10″E) in the ephemeral basin of Crepacuore Stream, which drains to the Ionian Sea (Figure 3).

The basin W2 was planted in 1968 with *Eucalyptus occidentalis* and was coppiced twice in 1978 and 1990 (coppicing cycle equal to 12 years). The forest cover is discontinuous and 20% of the basin area is bare. The forest cover in the period 1978–1990 had a canopy cover increasing from year to year by up to 68%.

The basin W3 was covered with a *Eucalyptus occidentalis* high forest in the period 1968–1986. In 1986 the forest cover was coppiced. The forest cover is uniform and the percentage of bare area is equal to 3% of the total basin area. In Table I, for each investigated basin, the basin area A_w (ha), the mean altitude H_m

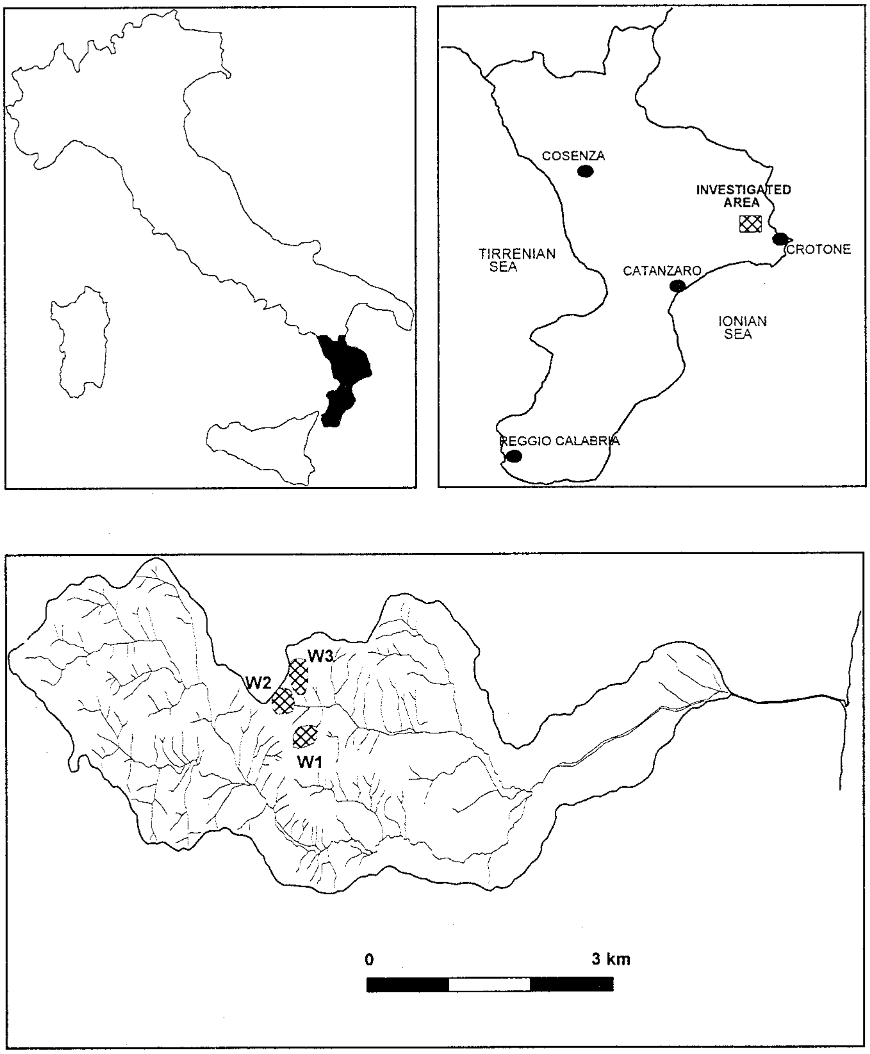


Figure 3. Experimental basins

(m a.s.l.), the minimum elevation Z_{min} (m a.s.l.), the maximum elevation Z_{max} (m a.s.l.), the mean slope s (%) and the percentage of sand, silt and clay in the soil are listed.

Each basin is monitored by an H-flume weir (Brakensiek *et al.*, 1979) and measurement of flow depth is carried out at the end of a rectangular channel by a mechanical water level recording gauge. The sampling device is constituted of a Coshocton Wheel (Parson, 1954; Carter and Parson, 1967) collecting a sample (*c.* 1/200) of the flow volume. Each collected sample flows into appropriately sized tanks. At the end of

Table I. Characteristic data of the investigated basins

Basin	A_w (ha)	H_m (m)	Z_{min} (m a.s.l.)	Z_{max} (m a.s.l.)	s (%)	Sand (%)	Silt (%)	Clay (%)
W1	1·473	155	90	122	53	14	44·5	41·5
W2	1·375	128	85	103	35	14·6	49·2	36·2
W3	1·654	114	85	98	24	20·7	45·5	33·8

each event the collected suspension is well mixed and suspension samples at different heights, of given volume (one litre), are drawn out. The suspended solid content in g of each sample is determined by oven-drying at 105 °C. The ratio between the mean value of the suspended solid content (g) and the sample volume (one litre) is assumed as the mean suspension concentration C_m (g/l). The sediment yield of each event is calculated by the product of the mean concentration C_m and the measured runoff volume.

METHODS

The analysis will be developed for 27 selected events measured at basin W2 and 33 events measured at basin W3.

A preliminary statistical analysis carried out for finding dependence between sediment yield and rainfall depth h_j, rainfall intensity I_j and runoff volume V_j produced no statistically significant correlation (Figure 4). This statistical result shows that a simple correlation between sediment yield and a *climatic* variable is not able to explain the sediment yield event variability because the combined effects of basin morphometry, soil and crop characteristics are not taken into account. Therefore, for considering all the above-mentioned variables a soil erosion mathematical model has to be applied. At present, most of the available soil erosion models, both empirical and physically based, put some USLE elementary factors (Wischmeier and Smith, 1978) into the basic equations used to estimate soil loss or to simulate the soil erosion subprocesses (Bingner, 1990; Renard *et al.*, 1991). The USLE, and its reviewed (Renard and Ferreira, 1992; Renard *et al.*, 1994) and modified (Williams, 1975) versions, is the most widely applied soil erosion model since it most likely represents the best compromise between applicability (in terms of input data) and reliability of soil loss estimates.

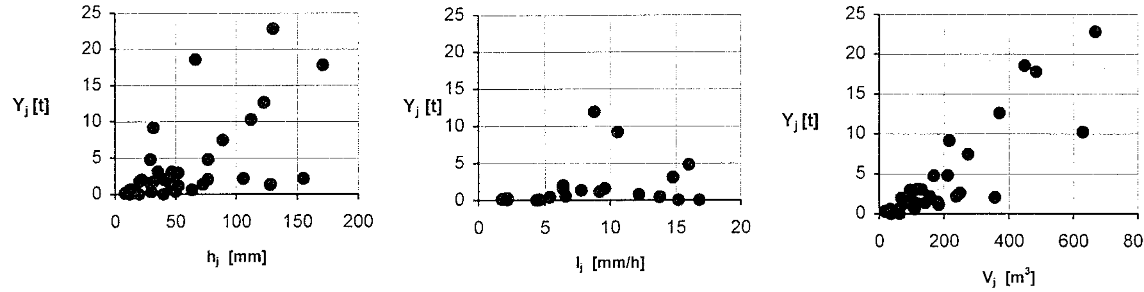


Figure 4. Correlation between sediment yield and rainfall depth h_j, and rainfall intensity I_j, and runoff volume V_j

Risse *et al.* (1993) pointed out that cover management and topographic factors had the most significant effect on the overall efficiency of USLE. This indicates that most of the research emphasis should continue to be placed on these parameters.

The need to estimate directly the basin sediment yield and the available input data measurements suggested the use of the modified universal soil loss equation (MUSLE) (Williams, 1975) whose applicability at the basin scale has already been verified in Mediterranean areas (Bagarello *et al.*, 1990, 1991). Williams (1975), by using field data and measurements carried out in 18 small American basins, having an area ranging from 1·2 ha to 17·7 km^2, proposed the following equation:

$$Y_j = R_{d,j} K \,.\, LS \,.\, C \,.\, P \tag{1}$$

in which Y_j is the sediment yield (t/ha) of each event, K is the soil erodibility factor (t h/kg m^2), LS is the topographic factor (dimensionless), C is the cover management factor (dimensionless), P is the support practice factor (dimensionless) and $R_{d,j}$ (t/ha unit of K) is the runoff factor of each event having the following expression:

$$R_{d,j} = \frac{0{\cdot}8776}{A_w}(q_{p,i}V_i)^{0{\cdot}56} \tag{2}$$

where $q_{p,j}$ is the peak flow rate of the flood event (m^3/s), V_j is the runoff volume (m^3) and A_w is the basin area (ha). According to Williams (1975) the values of the K, LS, C and P factors have to be representative of the basin.

For each investigated basin the soil erodibility factor was calculated by the nomograph of Wischmeier *et al.* (1971) by using 10 soil sample data (Avolio *et al.*, 1980). K is equal to 0·55 for W2 basin and 0·58 for W3 basin. The P factor was equal to one for each basin because no erosion control practice was adopted.

For evaluating the topographic factor the digital elevation model (DEM) of each basin was first obtained by SURFER package and a topographic map at scale 1:500 (Figure 5). The basin was rastered into cells (3 m × 3 m) and the topographic factor L_iS_i of each cell was calculated by the following equation:

$$L_iS_i = \left(\frac{\lambda_i}{22{\cdot}1}\right)^{0{\cdot}5}\left(\frac{0{\cdot}43 + 30s_i + 430s_i^2}{6{\cdot}613}\right) \tag{3}$$

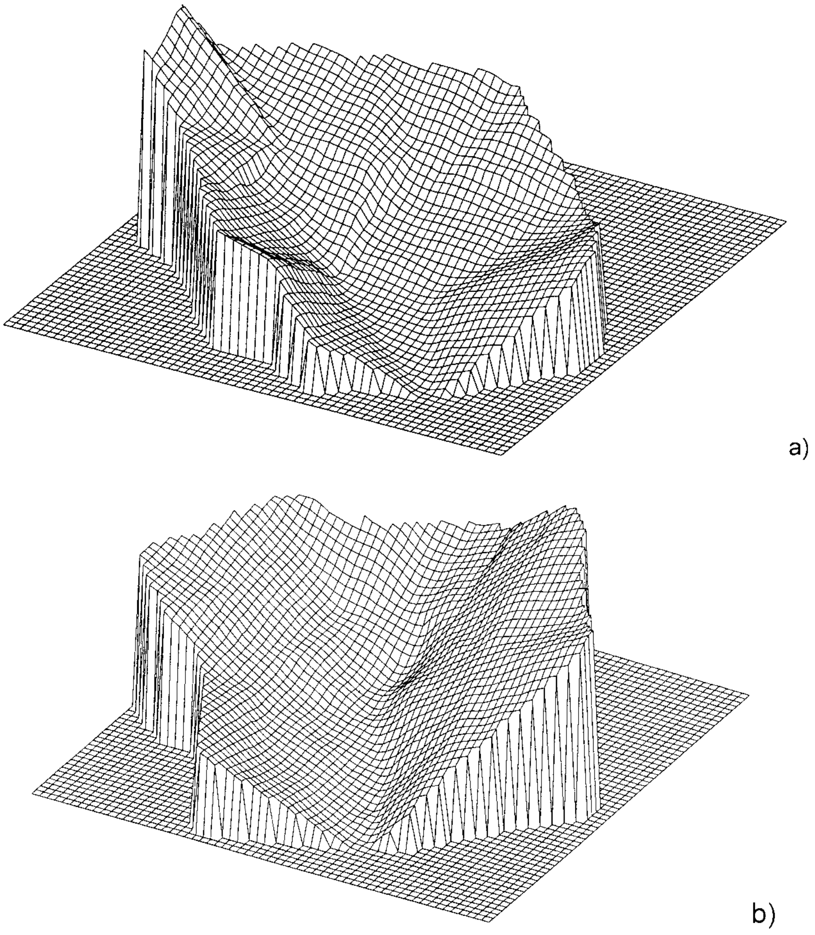


Figure 5. Digital elevation model for (a) W2 and (b) W3 basin

in which λ_i and s_i are the slope length (m) and the slope steepness (m/m) of the morphological unit, respectively.

The analysis was developed into two subsequent phases: model calibration and validation. In the calibration phase MUSLE and sediment yield measurements was used for calculating the crop management factor of each event. Then a single cover management factor value is assumed as *representative* of the forest cover (eucalyptus coppice). The discontinuity of the forest cover standing on W2 basin suggested development of the model calibration for the W2 basin and verification of the selected *representative* value of the *C* factor for the eucalyptus coppice using the sediment yield measurements carried out at the W3 outlet.

MODEL CALIBRATION

The W2 basin area constitutes vegetated surfaces, having a total area, A_v, equal to 11 053 m^2, with bare surfaces covering a total area, A_b, equal to 2693 m^2. At first the basin is divided into n_v morphological units falling into the vegetated area, and into n_b morphological units falling into the bare area. The sediment balance equation establishes that the sediment production for the basin outlet $P_s(t)$ is equal to the sediment produced by all morphological units into which the basin is divided (Ferro and Minacapilli, 1995). In particular, for the W2 basin it results in

$$P_s = P_{s,v} + P_{s,b} \tag{4}$$

in which $P_{s,v}$ is the sediment yield (t) produced from the n_v morphological units, and $P_{s,b}$ is the sediment yield (t) of the bare area.

For each event and taking into account Equation (1), the sediment balance Equation (4) can be rewritten as follows:

$$P_{s,j} = R_{d,j}K\left(C_b \sum_{i=1}^{n_b} L_i S_i A_{u,i} + C_{v,j} \sum_{i=1}^{n_v} L_i S_i A_{u,i}\right) \tag{5}$$

in which $P_{s,j}$ is the basin sediment yield of each event j measured in t, $A_{u,i}$ is the area (ha) of the i morphological unit, C_b is the cover and management factor of the bare area and $C_{v,j}$ is the C factor value of the eucalyptus coppice, which is event dependent.

By overlaying the DEM of W2 basin and the land use map, the square cells falling into the bare and vegetated area are determined and the following representative topographic factors are evaluated:

$$LS_b = \sum_{i=1}^{n_b} L_i S_i \frac{A_{u,i}}{A_b} \tag{6}$$

$$LS_v = \sum_{i=1}^{n_v} L_i S_i \frac{A_{u,i}}{A_v} \tag{7}$$

in which LS_b is the topographic factor of the bare area, equal to 8·42, and LS_v is the topographic factor of the vegetated surface which is equal to 6·60. Introducing Equations (6) and (7) into Equation (5), we obtain

$$P_{s,j} = R_{d,j}K(C_b LS_b A_b + C_{v,j} LS_v A_v) \tag{8}$$

From Equation (8), assuming $C_b = 0{\cdot}45$ which is the value corresponding to the C factor for *undisturbed land with no cover* (Wischmeier and Smith, 1978), we obtain

$$\frac{P_{s,j}}{R_{d,j}K} = 0{\cdot}45 LS_b A_b + C_{v,j} LS_v A_v \tag{9}$$

and finally

$$C_{\mathrm{v},j} = \frac{P_{\mathrm{s},j}}{R_{\mathrm{d},j} K LS_{\mathrm{v}} A_{\mathrm{v}}} - \frac{0{\cdot}45 LS_{\mathrm{b}} A_{\mathrm{b}}}{LS_{\mathrm{v}} A_{\mathrm{v}}} \tag{10}$$

For basin W2 Equation (10) gives

$$C_{\mathrm{v},j} = \frac{P_{\mathrm{s},j}}{4{\cdot}0122 R_{\mathrm{d},j}} - 0{\cdot}1399 \tag{11}$$

For basin W2, for each event Table II lists peak flow rate $q_{\mathrm{p}j}$ (m^3/s), runoff volume V_j (m^3), the measured sediment yield $P_{\mathrm{s},j}$ (t) and the crop and management factor values $C_{\mathrm{v},j}$ calculated by Equation (11). Table II also lists the rainfall erosivity factor R_j (Wischmeier and Smith, 1978) of each rainfall event.

Figure 6 shows the comparison of the empirical cumulative frequency distribution of the crop factor $C_{\mathrm{v},j}$ with a log-normal distribution (LN2) having a mean value and standard deviation equal to the sample values. According to this result the eucalyptus coppice of the W2 basin was characterized by a single *representative* crop factor C_{v} equal to the median sample value 0·164. According to Wischmeier (1975) $C = 0{\cdot}164$ belongs to 'trees with no brush, having a canopy cover ranging from 50 to 75%, and with a ground cover from 20 to 40%'.

Table II. Characteristic data of events measured at W2 basin

Event	$q_{\mathrm{p},j}$ (m^3/s)	V_j (m^3)	$P_{\mathrm{s},j}$ (t)	$C_{\mathrm{v},j}$	R_j (t/ha unit of K)
23/10/78	0·1666	449·5	18·56	0·330	
05/12/78	0·0241	97·9	1·24	0·078	
08/02/79	0·0191	71·5	1·74	0·274	
2–3/3/79	0·0268	63·2	0·70	0·007	
06/10/79	0·0215	17·0	0·47	0·093	
26/10/79	0·0169	132·4	5·22	0·805	
03/11/79	0·0241	120·8	0·92	0·004	
10–11/01/80	0·0169	239·2	2·17	0·142	
15/03/80	0·0549	252·5	4·37	0·145	
6–7/03/82	0·0095	35·7	0·39	0·063	
22/03/82	0·0080	117·5	1·32	0·247	
23/10/82	0·0549	94·8	2·98	0·196	
28/10/82	0·0129	169·1	4·78	0·738	24·99
18/12/82	0·0054	19·8	0·33	0·186	
27/12/82	0·0129	17·7	0·32	0·070	1·77
18–20/10/83	0·0841	371·1	12·62	0·382	52·76
09/03/84	0·0111	143·0	1·39	0·164	
13/11/84	0·0956	669·4	22·83	0·492	25·52
17/01/85	0·0430	629·6	10·26	0·320	14·22
08/03/86	0·0297	274·9	7·45	0·513	23·06
10/03/86	0·0638	89·3	1·80	0·053	3·39
23/02/87	0·0067	24·7	0·36	0·140	2·43
13/04/87	0·0686	68·7	2·01	0·100	13·51
29/11–2/12/90	0·0072	92·1	1·62	0·439	9·10
14–17/01/1991	0·0549	329·9	11·94	0·530	14·19
27–28/01/1991	0·0111	143·0	1·35	0·155	4·08
16–19/03/1991	0·0129	324·4	1·14	0·006	5·05

MODEL VALIDATION

The validation phase aims to verify the reliability of a crop factor C_v for the eucalyptus coppice equal to 0·164 and to study the temporal variability of the crop factor values by using the sediment yield measurements carried out for the W3 basin.

Table III, for each event, lists peak flow rate (m^3/s), runoff volume (m^3), the *measured* sediment yield $P_{s,j}$ (t) and the *calculated* one $P_{c,j}$ by Equation (8) in which $K = 0{\cdot}58$, $LS_b = 4{\cdot}68$, $LS_v = 3{\cdot}14$, $A_b = 0{\cdot}048$ (ha), $A_v = 1{\cdot}6056$ (ha), $C_b = 0{\cdot}45$ and $C_{v,j} = C_v = 0{\cdot}164$. Table III also lists the rainfall erosivity factor R_j (Wischmeier and Smith, 1978) of each rainfall event.

Figure 7 shows a good agreement between measured $P_{s,j}$ and calculated $P_{c,j}$ sediment yield; in particular, the linear correlation between $P_{c,j}$ and $P_{s,j}$ is characterized by a correlation coefficient of $R = 0{\cdot}965$ and a mean square error (MSE) equal to 26·5. Figure 8 also shows good agreement between the cumulative distribution function of the measured sediment yield [median $\mu(P_{s,j}) = 1{\cdot}15$ and standard deviation $\sigma(P_{s,j}) = 5{\cdot}43$] and the calculated one [median $\mu(P_{c,j}) = 0{\cdot}98$ and standard deviation $\sigma(P_{c,j}) = 3{\cdot}50$]. In other words, the good agreement between $P_{c,j}$ and $P_{s,j}$ values confirms the suitability of the cover and management factor value (0·164) of the eucalyptus coppice determined in the 'model calibration' phase.

Figure 9 shows, at annual (Figure 9a) and monthly (Figure 9b) time-scales, the temporal variability of the cover and management factor. Figure 9 does not show a clear time-dependent behaviour of the C_v factor; in particular, in the period 1978–1986, the expected decreasing trend of C_v values owing to coppice growth does not happen. The monthly and annual C_v values are fluctuating around the characteristic value 0·164.

The difficulties in explaining the temporal variability of eucalyptus coppice crop factor can be justified taking into account that the overall erosion-reducing effectiveness of crops not only depends on the type of vegetation and its growth but also on how much of the erosive rain occurs during the least crop protection. In other words the temporal variability of the C_v factor can be explained by the correspondence of periods of expected highly erosive rainfall with periods of poor or good plant cover and residue mulching. The interrelation between crop effectiveness and climate was studied, searching, at a fixed temporal scale (month, year), the correlation between crop factor and the corresponding rainfall erosion index. For the W3 basin, using the available rainfall event data in the period 1982–1993, the monthly and annual rainfall erosion index values were calculated according to the procedure of Wischmeier and Smith (1978).

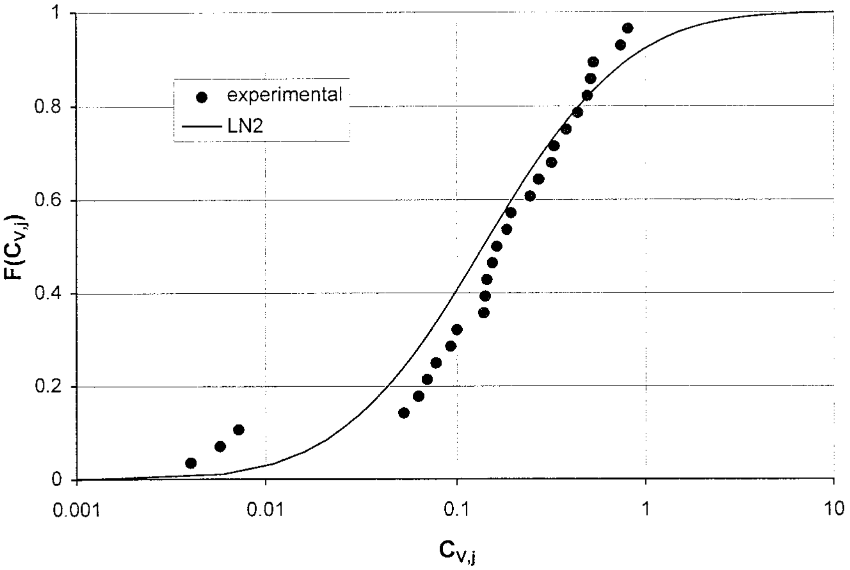


Figure 6. Comparison between empirical frequency distribution of crop factor $C_{v,j}$ and the log-normal distribution (LN2)

Table III. Characteristic data of events measured at W3 basin

Event	$q_{p,j}$ (m^3/s)	V_j (m^3)	$P_{s,j}$ (t)	$P_{c,j}$ (t)	$C_{v,j}$	R_j (t/ha unit of K)
23/10/78	0·1666	301·0	2·32	4·23	0·081	
05/12/78	0·0191	101·0	0·55	0·68	0·127	
2–3/03/79	0·0067	36·4	0·07	0·21	0·043	
11/05/79	0·0297	18·4	0·07	0·34	0·016	
03/11/79	0·0095	45·5	0·41	0·29	0·238	
10–11/01/80	0·0129	221·6	1·15	0·85	0·230	
06/03/80	0·1211	319·1	1·37	3·65	0·049	
15/03/80	0·0787	237·5	0·79	2·43	0·040	
13/11/80	0·0148	8·9	0·08	0·15	0·080	
6–7/03/82	0·0215	170·3	1·11	0·98	0·188	6·82
22/03/82	0·0169	287·7	3·14	1·14	0·484	12·91
23/10/82	0·0297	133·9	2·68	1·02	0·462	
28/10/82	0·0507	61·2	1·84	0·89	0·359	
27/12/82	0·0026	10·4	0·04	0·06	0·098	
18–20/10/83	0·0956	405·1	5·15	3·66	0·239	38·29
09/03/84	0·0148	205·0	0·35	0·88	0·053	7·25
16/04/84	0·0327	287·7	0·89	1·66	0·079	6·50
13/11/84	0·0507	272·8	3·52	2·06	0·295	20·09
08/01/85	0·0191	249·7	2·52	1·13	0·389	3·92
17/01/85	0·0686	947·5	6·92	4·89	0·240	18·84
08/03/86	0·0430	305·9	3·03	2·00	0·259	22·84
10/03/86	0·0360	135·6	1·51	1·15	0·221	2·73
23/02/87	0·0111	48·0	0·15	0·33	0·065	2·95
12–17/11/90	0·6165	1288·2	29·85	19·85	0·256	113·50
24/11/90	0·0067	125·7	1·32	0·43	0·550	2·32
29/11–02/12/90	0·0593	56·2	0·52	0·93	0·083	
05–11/12/90	0·0013	38·0	0·12	0·09	0·233	
22/12–02/01/91	0·1281	322·5	7·70	3·79	0·353	36·30
14–17/01/91	0·0638	322·5	4·79	2·57	0·323	12·72
16–19/03/91	0·0210	104·2	0·16	0·73	0·020	5·28
29–31/03/91	0·0129	90·9	0·21	0·52	0·054	2·47
25/12–05/01/93	0·0956	671·4	10·16	4·85	0·365	88·83
07/05/93	0·0180	57·9	0·17	0·48	0·043	

Figure 10 clearly shows, at monthly and annual time-scales, the correlation between the crop factor and the corresponding rainfall erosivity index. In other words, the temporal variability of the crop factor is a result of both the variability of the crop stage and the crop cover subjected to different erosive rainfall events.

CONCLUSIONS

Forest ecosystems modifying the hydrological hillslope processes (rainfall interception, infiltration, runoff) are able to reduce erosion and to support sediment delivery processes.

USLE-derived models introduce a crop management factor into the interrill erosion equation for simulating the crop influence, while physically based technology, like WEPP, uses a ground cover adjustment factor and a canopy cover adjustment factor.

The available sediment yield measurements, carried out in two little Calabrian experimental basins (W2 and W3), covered with *Eucalyptus occidentalis* forest, and MUSLE equation were used to evaluate the effects of eucalyptus coppice on sediment yield. The modified universal soil loss equation (MUSLE) was selected because its applicability at the basin scale had already been verified in Mediterranean areas and because the

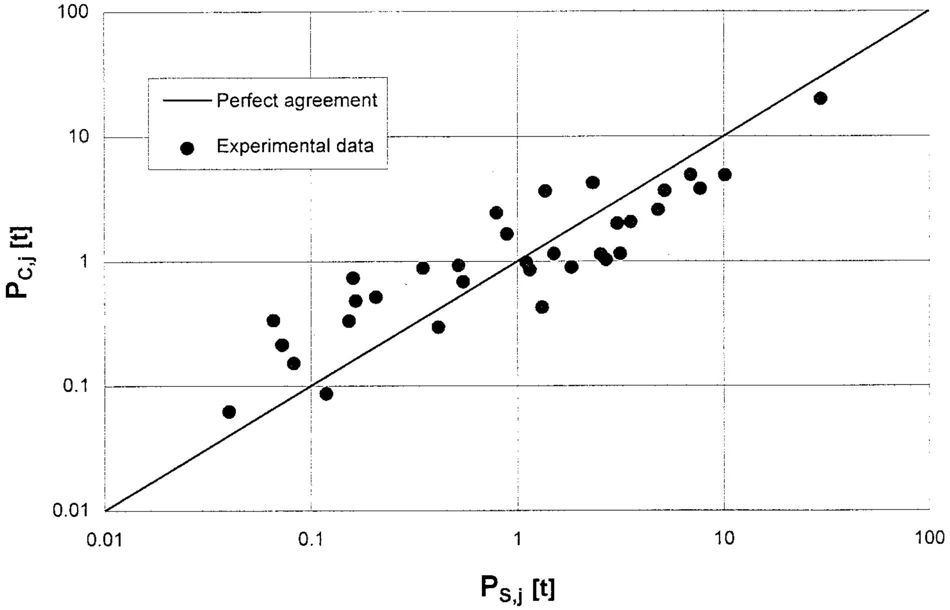


Figure 7. Comparison between measured $P_{s,j}$ and calculated $P_{c,j}$ sediment yield values

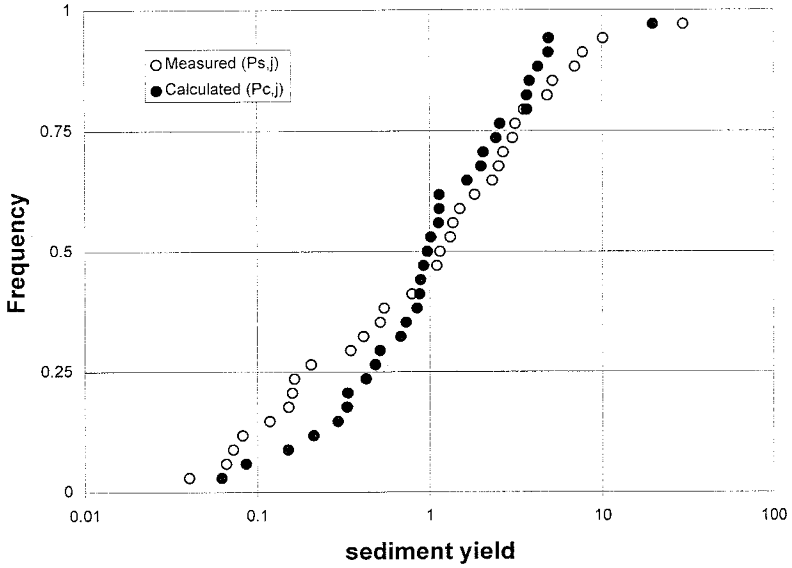
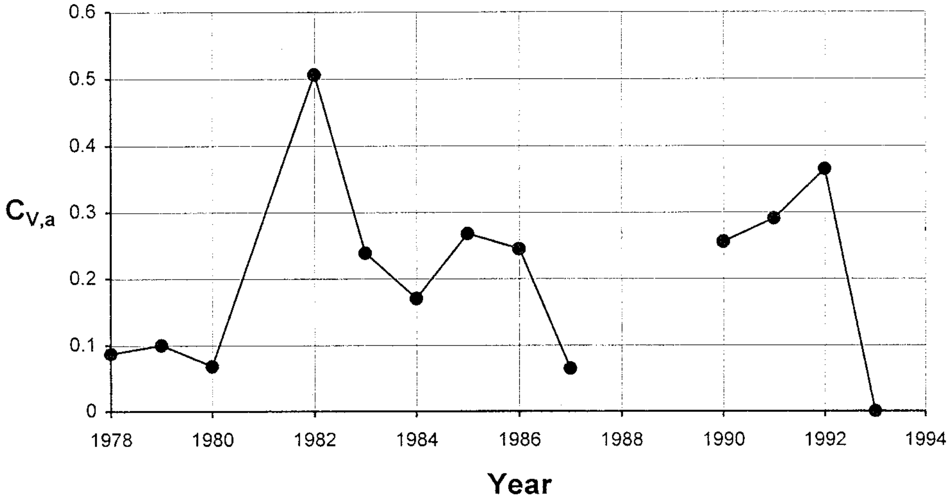


Figure 8. Comparison between the cumulative frequency distribution of measured $P_{s,j}$ and calculated $P_{c,j}$ sediment yield

available input data measurements allowed determination of the crop management factor $C_{v,j}$ for each event. The analysis was developed into two phases: model calibration and validation.

In the calibration phase MUSLE and sediment yield measurements, carried out at the W2 experimental basin, were used to estimate a single cover management factor C_v representative of the eucalyptus coppice. Since the W2 basin is covered by vegetated and bare areas, the model was applied in a distributed approach, dividing the basin area into morphological units. The analysis showed that the crop factor $C_{v,j}$ is distributed



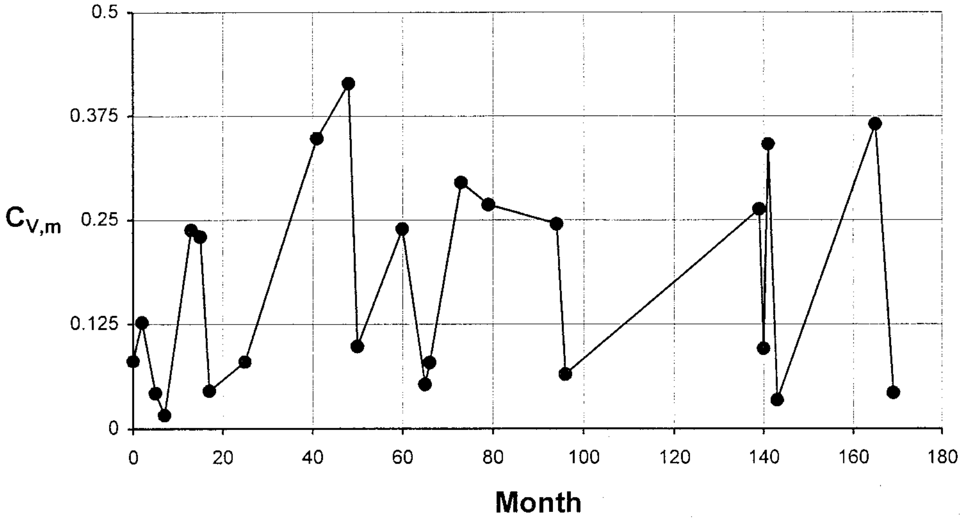
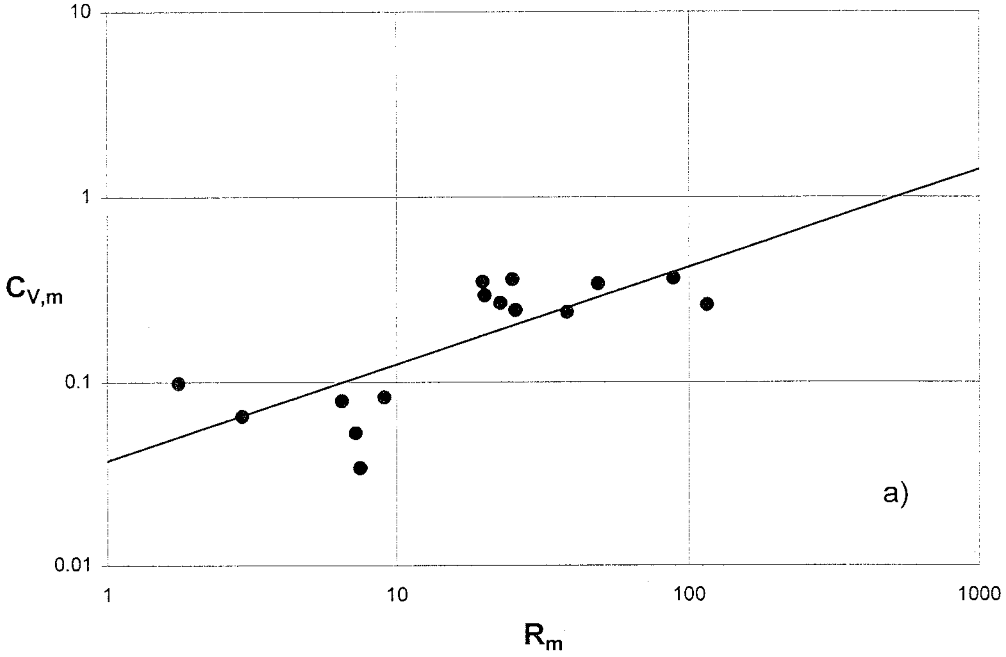


Figure 9. Temporal variability of annual and monthly crop management factor

like a log-normal distribution function and the median sample value $C_v = 0{\cdot}164$ was used as representative of the eucalyptus coppice.

The validation phase allowed verification of the reliability of the selected crop factor (0·164) of the eucalyptus coppice and study of the temporal variability of the crop factor at monthly and annual time-scales.

The suitability of the estimated C_v value was verified by comparing the cumulative distribution function of the sediment yield measured at the outlet of the W3 basin and the CDF of the calculated sediment yield. The temporal analysis of the crop management factor was studied, searching, at a given temporal scale (month, year), the correlation between crop effectiveness and rainfall erosivity index. The analysis showed that the



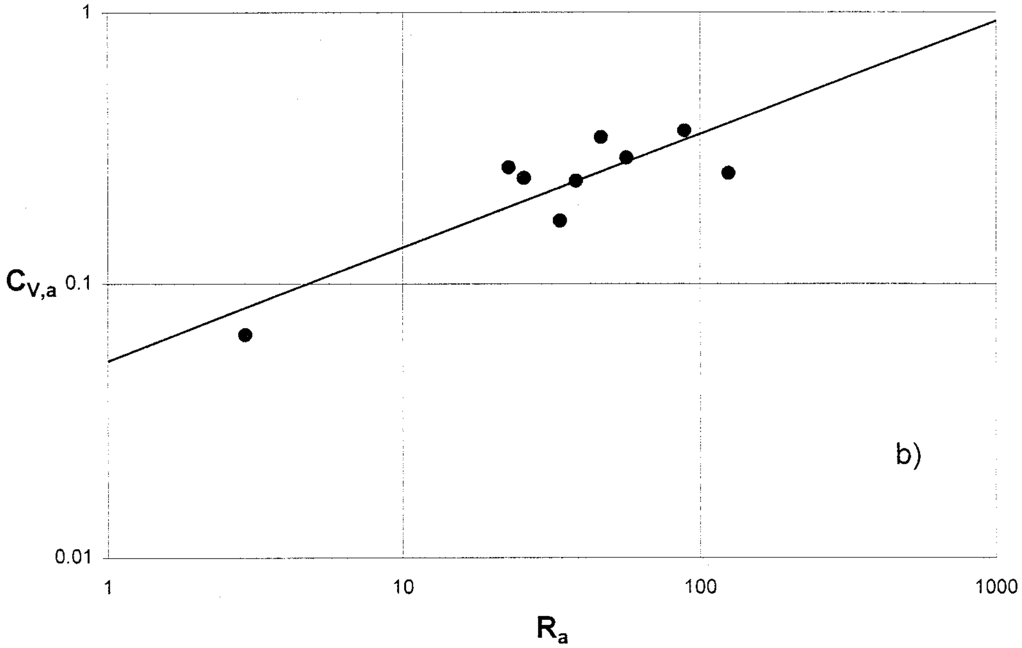


Figure 10. Correlations between crop factor and rainfall erosivity index at monthly and annual scale

temporal variability of the crop factor is a result of both the variability of the crop stage and the crop cover subjected to different erosive rainfall events.

In conclusion, the crop factor determined for eucalyptus coppice ($C_v = 0{\cdot}164$) belongs to the Wischmeier class 'trees with no brush, having a canopy cover ranging from 50 to 75% and with a ground cover from 20 to 40%'. Therefore, according to Iovino and Puglisi (1991), the eucalyptus coppice has a good anti-erosive effectiveness, which can be improved if crop cover is uniformly distributed over the area for protection and the clear-cutting residues are left on the ground for mulching.

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