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Hillslope Erosion Mitigation: An Experimental Proof of a Nature-Based Solution

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Abstract: Soil erosion during rainfall events is affected by several factors, such as topography, soil type, land management, and vegetation cover. In this study, a series of tests investigates the influence of selected perennial herbaceous plants with a deep and strong rooting system, called MC1, on runoff generation and soil erosion. The tests on the investigated nature-based solution have been performed in the Cape Fear experimental hillslope with natural and artificial rainfall and for different vegetation heights. For all the experiments, runoff, soil moisture, and erosion data were observed and collected. The results obtained in this study suggest the following conclusions: (1) MC1 is effective in terms of soil erosion reduction already with a minimum vegetation height equal to 30 cm; (2) MC1 maximum efficiency, in terms of soil loss reduction, has been reached for a vegetation height equal to 70 cm; (3) In terms of the eroded material, the use of MC1 allows for a reduction of soil loss up to 300 times higher than the bare soil condition; (4) The use of MC1 allows for a reduction in the runoff coefficient up to 1/3 of the corresponding value in the bare soil condition.

Keywords: land degradation; bioengineering techniques; soil erosion; runoff reduction; deep-roots herbaceous vegetation

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1. Introduction

Soil is a key element in preserving ecosystems and biodiversity functions [1,2]. The Soil Thematic Strategy, established in Europe in 2006, highlighted the importance of policy measures to prevent land degradation and promote soil maintenance [3,4]. Moreover, in 2012, the European Commission identified priorities and guidelines to reach "no net land take by 2050" [5]. In addition, the United Nations have often recognized the importance of soil preservation [6] and identified the sustainable development goal (SDG) target 15.3 on land degradation [7].

Soil erosion is one of the main reasons of soil degradation, and is characterized by several negative impacts, both in agricultural areas [8] and in urban and peri-urban areas [9,10]. It causes serious long-term damages to arable lands and surrounding areas, such as fertility decrease, soil filtering reduction, change in soil infiltration and water absorption, loss of mineral fertilizers, and it increases the risk of landslides and floods [11–13]. It is also well known that the soil erosion process can severely damage civil infrastructures and their environment.

Soil erosion is mainly caused by natural phenomena, but it is accelerated and/or amplified by human factors, such as incorrect land planning, absence or poor maintenance of vegetation, action of mechanical means, and choice of unsuitable crops [14]. Therefore, erosion can be defined as a process of detachment and transport of soil materials by erosive agents from any part of the Earth's surface. Commonly, natural erosion is divided into two main categories: Water erosion and wind erosion. Water erosion, investigated here, occurs as different forms of splash, sheet and interrill erosion, rill erosion, gully erosion, river banks or channel erosion, tillage erosion, and glacial erosion. Sheet and interrill erosion can be considered one of the first steps of erosion in a watershed. In particular, it is widely observed on bare soils in agricultural lands and pasture [15].

Furthermore, it is difficult to mitigate soil erosion but such an effort is needed, as soil loss causes severe economic losses, estimated at USD 44 billion/year only in the USA, and damaged soil would take several hundred years to recover naturally [2,16]. Therefore, the development of techniques to reduce soil erosion is of paramount importance.

A typical soil conservation technique to decrease the effect of soil erosion is the construction of mechanical structures, such as back-slope, hedgerows, and slow-forming terraces [17–19]. Terracing is, indeed, probably the most popular practice and a classification as a function of their slope is available in [20], while in [21] an extensive review of functions, advantages, and disadvantages is provided. However, such interventions are often costly and labor intensive.

More recently, nature-based solutions (NBS) or bioengineering techniques have been established and proved that soil conservation techniques are more effective and less expensive than terracing [22–27]. NBS are characterized by the use of natural materials, usually live material often combined with dead or inert material, and are based on design choices and technical solutions to preserve the territory, environment, and landscape.

The use of NBS techniques has become popular in several areas of Europe, China, and North America [28,29], and more recently also in developing countries [26,27,30–32]. Indeed, the use of organic and biodegradable geotextiles for soil erosion reduction, erosion control, vegetation growth, and slope stabilization is rapidly evolving [33–41]. For example, Smets et al. [42] demonstrated that palm geotextiles reduce runoff coefficients and mitigate soil erosion in hillslopes, while Gimenez-Morera et al. [38] showed that cotton palm may limit soil erosion in Mediterranean climatic conditions. In addition, Vishnudas et al. [43] studied the use of coir geotextile on hillslopes to increase soil moisture availability. Moreover, jute is a good candidate for hillslopes protection, given its high hygroscopic property as shown by Tauro et al. [44], which assessed soil erosion reduction effectiveness in a steep slope by analyzing the performances of two biodegradable geotextiles based on jute. Although NBS proved to be significantly effective in reducing soil erosion, experimental studies performed in real-life conditions to accurately assess their effectiveness are limited. Smets et al. [45] performed a review on the ability of geotextiles in reducing runoff and soil erosion, based on laboratory studies, analyzing several factors, as plot length, cover percentage, slope gradient, rainfall duration and intensity, and geotextile type. Similar field and laboratory tests have been carried out by Kalibová et al. [46,47]. Field studies on jute and jute mats have been performed by Mitchel et al. [48] to demonstrate their effectiveness for controlling erosion and runoff. The use of palm geotextile mats was investigated in field experiments by Jankauskas et al. [49], observing a reduction in soil loss of over 90%. Experimental observations coupled with soil erosion models are available in [41], which highlight the drawbacks of using laboratory tests to represent field conditions. Smets et al. [50] also implemented the effects of erosion-control blankets into the erosion numerical model using the European Soil Erosion Model [51].

A typical and more recent NBS technique consists of covering the hillslopes with specific vegetation species, which reduce the rainsplash, foster infiltration into the soil, slow down runoff, and improve the roots system to retain the soil, counteracting sliding downstream. Herbaceous vegetation guarantees optimal cover and shrub vegetation allows anchoring the soil to deeper layers. In any case, a careful evaluation of the species is required, preferring the selection of species that are compatible with the ecological characteristics of the intervention site. Indeed, autochthonous species are preferred with respect to exotic species that may alter the site ecological equilibrium [27,30]. Other than the anti-erosive and soil stabilizing actions, other benefits of the vegetation are the increase of the evapotranspiration capacity [23] and, in the case of particular plant species, the increase of soil shear strength.

While in the past grassy species have often been used and studied for the erosion control and mitigation, investigations related to the use of perennial vegetation characterized by deep-roots are limited. Such vegetation may represent an optimal, efficient solution for the soil erosion mitigation as well as for the improvement of equilibrium conditions of hillslopes [52,53]. Regarding the second point, two main effects have to be considered. The first effect concerns the positive role of roots acting as a mechanical soil reinforcement, from shallow to moderate depths. Moreover, at the ground surface, the roots provide a strong anchor for the epigeal plants portion avoiding its eradication in the case of extreme rainfall events and may reduce soil cracks. The second effect concerns the beneficial influence due to the reduction of soil water content/degree of saturation, due to the capacity of the plants to absorb water from the surrounding soil and transfer it to the atmosphere through transpiration. This mechanism, in turn, yields an increase in soil suction, in shear strength, and in soil protection against rainsplash and laminar erosion [53].

Different from trees and shrubs plantations that do not yield beneficial effects in mitigating soil erosion damage in the first few years of their growth, properly selected deep-rooting herbaceous plants are able to germinate, develop, and take roots very quickly, exhibiting their beneficial effects in a short time. In addition, these herbaceous species, mainly belonging to the botanical families of Gramineae and Leguminosae, can survive even in pedoclimatic and phytotoxic conditions prohibitive for more traditional vegetation [54].

In this paper, we present an experimental study with the aim to investigate the impact of a NBS, entailing the plantation of the deep-rooted species denoted MC1 (MC1 is an acronym. "M" stands for Macrotherma; "C" stands for C3-C4 carbon cycle; the number "1" indicates the first experimental tests held on Cape Fear with this type of plants) on runoff generation and soil erosion. The aim, in particular, is to assess the influence of MC1 height in mitigating hillslope erosion compared to the bare soil condition, and thus to identify at which height MC1 becomes efficient.

2. Materials and Methods

2.1. Cape Fear Experimental Site

The study was conducted in an experimental hillslope, named Cape Fear, located at Tuscia University in Viterbo, Central Italy. Cape Fear is a seminatural hillslope plot located in the outdoor experimental farm of Tuscia University, Viterbo, Italy (42°25′28″ N, 12°04′44″ E, 350 m a.s.l.). The plot consists of 30 m^3 of natural wedge-shaped soil (44% sand, 36% silt, 20% clay). Average values on five collected soil samples for laboratory-determined saturated water content, saturated hydraulic conductivity, organic content, and soil bulk density, are equal to 0.54 m^3/m^3, 1.49 cm/min, 0.58%, and 10.1 kN/m^3, respectively. In particular, sand, silt, and clay percentages were determined using standard laboratory techniques based on a set of sieves. The organic carbon content was determined with the dichromate method. The saturated water content was measured by the gravimetric method, whereas the saturated hydraulic conductivity was measured by the falling-head method. For a complete characterization of soil parameters, further details can be found in [55].

The wedge has a square area of 7×7 m^2, a slope of 17%, and a maximum height of 1.2 m (Figure 1). The plot rests on a containment structure of wood boards and poles on three sides, and is founded on additional 10 m^3 of soil disconnected from the underlying ground through a waterproof plastic layer. On a lateral side of the plot, a 2.5 m-long glass panel has been installed for direct observation of water infiltration. Cape Fear allows conducting experiments both with natural and artificial rainfall.

Figure 1. (**A**) Cape Fear hillslope plot: Frontal view; (**B**) glass panels.

In order to generate artificial rainfall, the plot surface hosts four pressurized nozzle rainfall simulators equipped with pressure probes [56,57]. Simulators were developed based on the prototype by Riley et al. [58]. Their structure includes a telescopic aluminum tripod connected to a steel plate. Three hoses are riveted to the plate and water is sprayed through a system of three nozzles. An HH7-M 3/4″ in nozzle is mounted on the central hose, whereas two smaller HH22-M 3/8″ in nozzles are placed onto the lateral hoses. Three cut-off valves allow for selectively activating the nozzles and controlling rainfall intensity. Rainfall intensities can be varied from a minimum of 40 mm h^{-1} using the two smaller nozzles to 140 mm h^{-1} by operating the three nozzles simultaneously. Conversely, regarding its use in natural rainfall condition, rainfall data are monitored through four SBS-500 Campbell Scientific standard rain gauges located at 30 m from the plot at the vertices of the nearby "giant-rain gauge" apparatus described in [59].

Cape Fear soil moisture is monitored through four Campbell Scientific CS615 water content reflectometers. They are located within an undisturbed 4×4 m^2 area and aligned along the downslope direction in the center of the plot. A pair of shallow reflectometers is located at 10 cm and the other deep pair at 50 cm below the soil surface.

The surface and subsurface runoff are collected in a v-shaped aluminium channel located along the downstream side of the plot. The channel pours water and solids into an aluminium tank composed of three connected partitions, where a stainless steel OBS-3+ turbidity sensor and a structural testing system (STS) strain gauge are hosted. A coarser solid material is blocked in the first partition of the tank. Flow discharge exits the tank through a v-notch weir and an output liquid discharge is computed from the water level thanks to a calibrated stage-discharge relationship. Monitored parameters are sampled at 1 Hz, then averaged at 5 min resolution, and stored on a CR10X Campbell Scientific data logger. Detailed soil characterization of the plot along with the calibration of turbidity and water level sensors are provided in [55,60].

2.2. Vegetation Cover

Graminaceous perennial deep-root species, here denoted MC1, were implanted at Cape Fear, which are non-GMO and characterized as adaptable to all soil types and extreme climatic conditions (pH 3/11; temperature −40 °C/+60 °C). Their root depth combined with the specific plants' physiology allow surviving in extreme drought conditions. Regarding the root-system features, a complete growth in 24 months and root diameters ranging from 0.1 to about 3 mm are expected.

The adopted root-system is characterized by roots with a very large tensile strength (of about tens of MPa), enhancing the increase in shear strength of the rooted soil. It is well known that this directly depends on the root area ratio (RAR), the soil friction angle, as well as a non-dimensional empirical factor [53,61–64]. The RAR quantity represents the ratio between the roots' cross section and the rooted soil cross section. The RAR ratio typically decreases with depth, this occurrence is generally verified despite the complex geometry of the root system that presents a great variability depending not only on plant species, soil properties and profile, but also on climatic and environmental conditions [65,66].

Due to such intrinsic variability, the evaluation of the RAR requires careful attention. In the past, there were experiences of plants that were introduced due to their efficacy in soil erosion control, but were then recognized as invasive, for example, see Kudzu (*Pueraria montana* var. *lobata*) in the southeastern United States [67]. For this reason, it is important to specify that, although the experimental period did not last long, the MC1 spread has not been detected next to the experimental hill. The past use of this species in Italy for the last decades supports this point.

2.3. Experimental Setup

In the first phase of research, the Cape Fear surface was in a bare soil condition, the most critical scenario in terms of soil erosion (see Figure 1). Subsequently, starting from July 2020, MC1 was sown on half of the Cape Fear surface, as shown in Figure 2. Before illustrating the tests plan, in this section, we provide a step-by-step description of the Cape Fear grassing process using MC1.

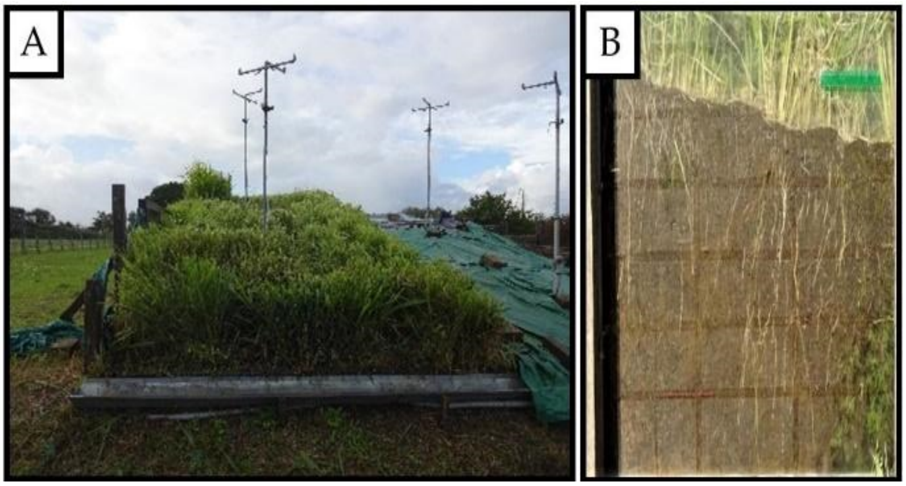

Figure 2. Cape Fear hillslope plot: (**A**) Vegetated side, (**B**) view of roots within the soil.

The preliminary step consisted of completely weeding the experimental hill. Ten days after, the half parcel (Figure 2A) was covered with a mulch cloth. In this way, the land would have not been irrigated, it would have been protected against wind and rainfall erosion, and the spontaneous vegetation growth would have been prevented.

Then, half of the Cape Fear surface was plowed and sown with MC1 (Figure 2A). During this phase, MC1 was irrigated three times for a day, for a total of about 10 l/m^2. The irrigation phase of the "cultivated land" lasted for 30 days. At the end of this phase, plants first began to sprout and the irrigation has been reduced to one time for a day, in the same amount as before. This irrigation helped promote the MC1 root vertical development. In fact, in this way, the roots are forced to seek water in depth.

After the experimental hill preparation, tests have been planned and executed. Specifically, the following four tests have been investigated: Test no. 1 corresponds to the bare soil (vegetation height, denoted with h_{MC1}, equal to zero); test no. 2 corresponds to a vegetation height of about 30 cm; test no. 3 corresponds to a vegetation height of about 70 cm; test no. 4 corresponds to a vegetation height of about 140 cm. The four tests have been investigated using natural and artificial rainfall with characteristics, as shown in Table 1.

Table 1. Rainfall characteristics during the four tests.

Test	h_{MC1} (cm)	Rainfall Type	Cumulative Rainfall Value (mm)	Max Rainfall Intensity (mm/h)	Rainfall Duration (Wet Period) (h)
No. 1	0	- Artificial	- 680	- 170	- 4
No. 2	30	Natural Artificial	121 3360	42.6 140	42.1 24
No. 3	70	Natural Artificial	70 4080	92.2 170	12.9 24
No. 4	140	Natural Artificial	110 3840	141.8 160	17.5 24

3. Results and Discussion

During the four tests, data were collected following the procedure described in Figure 3C. Here, results are illustrated focusing on the MC1 effect specifically on the rainfall-runoff hillslope response and soil erosion.

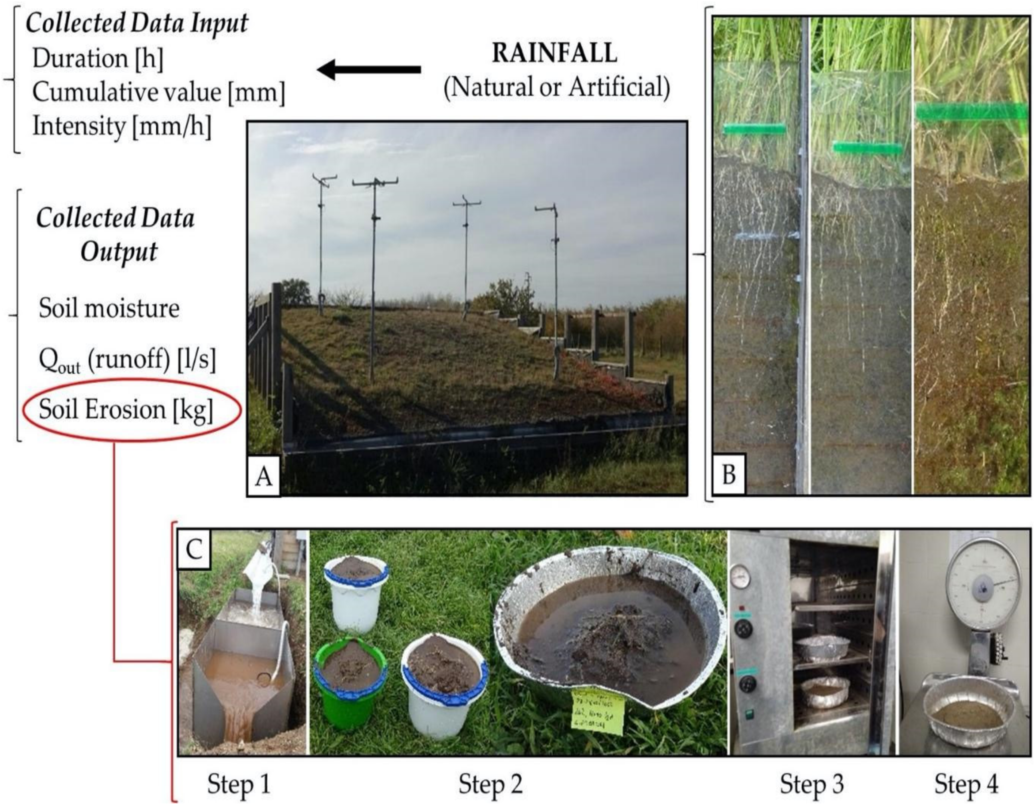

Figure 3. Description of data collection. (**A**) View of the experimental plot. (**B**) Detail of root growth monitoring. (**C**) Description of soil erosion measurements: **Step 1**: The tank for sedimentation of eroded material; **Step 2**: The eroded material; **Step 3**: Detail of drying in the oven at 110 °C for 24 h; **Step 4**: Final weighing of eroded material.

3.1. *Runoff Hillslope Response*

First, the natural rainfall condition has been analyzed. Figure 4 represents the input (natural rainfall) and output (runoff) time series that occurred in the different conditions of vegetation height. Considering the cumulative values for rainfall and runoff, the detected runoff coefficients were 0.05 (h_{MC1} = 30 cm), 0.46 (h_{MC1} = 70 cm), and 0.92 (h_{MC1} = 140 cm). From a theoretical point of view, we were expecting a lower runoff coefficient value for the increasing vegetation height. The obtained results could be due to the high values of soil moisture that were recorded in all the tests, and above all to the different rainfall intensities that occurred during the "natural" tests. Indeed, unfortunately a higher intensity was registered with a higher vegetation, and therefore, probably, mitigating the MC1 efficiency.

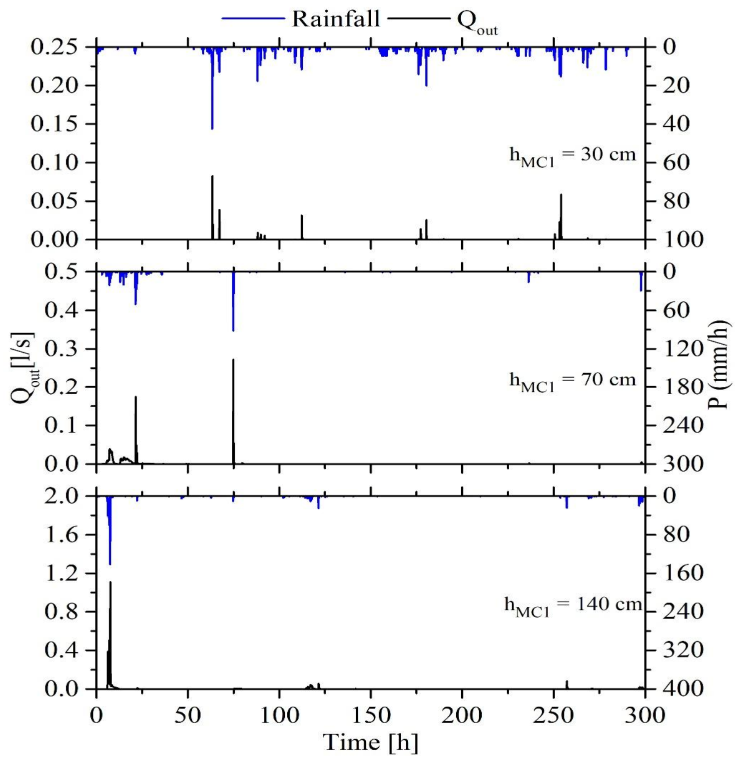

Figure 4. Natural rainfall and runoff for different MC1 vegetation heights.

In order to deeply investigate this aspect, specific rainfall events were analyzed (see Figure 5). In particular, for every test, three rainfall events have been selected from the complete timeseries shown in Figure 4, including the available maximum intensity storms (i.e., the third row in Figure 5).

As reported in Table 2, for low rainfall intensity events, MC1 may allow a relevant reduction of the runoff coefficient. For events characterized by a higher rainfall intensity (greater than 40 mm/h in terms of rainfall peak or 20 mm/h in terms of average rainfall intensity), the runoff coefficient increases and tends to 1, a circumstance that was achieved for event no. 3 with a vegetation height of 140 cm, where more than 56 mm of cumulative rainfall occurred in 2.67 h, and with a rainfall peak greater than 140 mm/h.

Table 2. Runoff coefficient during isolated natural rainfall events.

h_{MC1} (cm)	Event Number	Average Rainfall Intensity (mm/h)	Duration (h)	Cumulative Rainfall (mm)	Max Rainfall Intensity (mm/h)	Runoff Coefficient (-)	Lag Time (min)
	1	2.01	0.75	1.51	3.55	0.45	40
30	2	2.69	1.42	3.81	4.73	0.64	70
	3	6.17	1.83	11.31	42.55	0.93	40
	1	6.57	0.67	4.38	29.55	0.08	30
70	2	16.63	1.08	18.02	50.83	0.28	25
	3	22.59	0.67	15.06	92.16	0.30	15
	1	8.04	0.33	2.68	26.00	0.37	15
140	2	2.83	5.25	14.84	10.64	0.38	125
	3	21.24	2.67	56.64	141.84	1.00	20

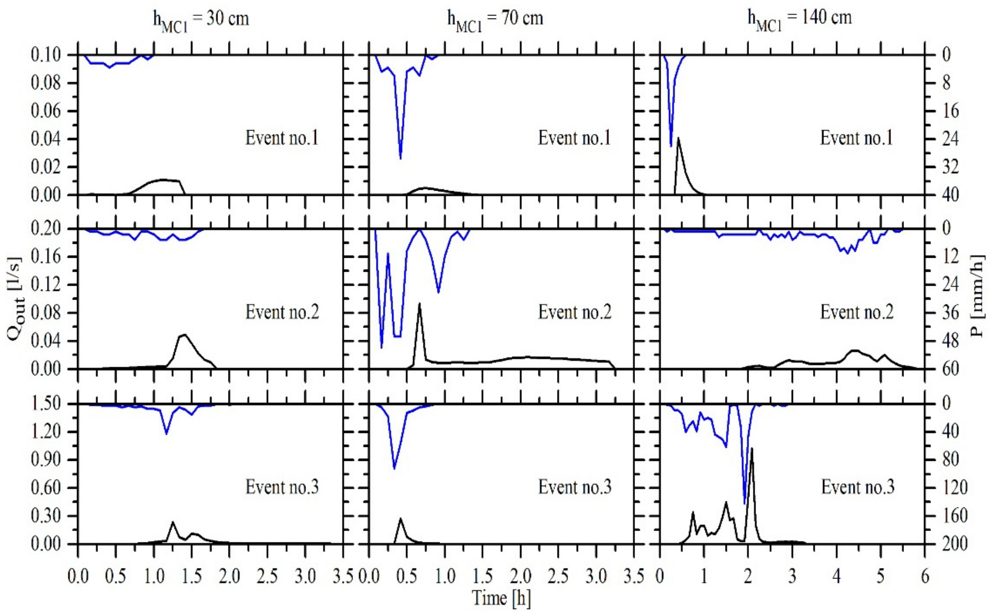

Figure 5. Isolated natural rainfall (**blue line**) and runoff (**black line**) for different MC1 vegetation heights (h_{MC1}).

A similar behavior has been detected in terms of lag time, i.e., the time difference between the rainfall start and the runoff start.

The MC1 effect on runoff coefficient has been investigated also for the artificial rainfall test, in which being approximately constant in time and similar for the four tests allows a better overview of the analyzed phenomena. The high simulated rainfall intensities (Table 1) do not allow investigating the lag time since it is too short for all the tests.

Figure 6 shows the rainfall-runoff data observed in the four tests. The local input flow rate variability, clearly visible in all the tests except for the vegetation height equal to 140 cm, depends on the experimental farm hydraulic network that could not guarantee a constant rainfall intensity and on the variable windy condition (observed in test no. 4).

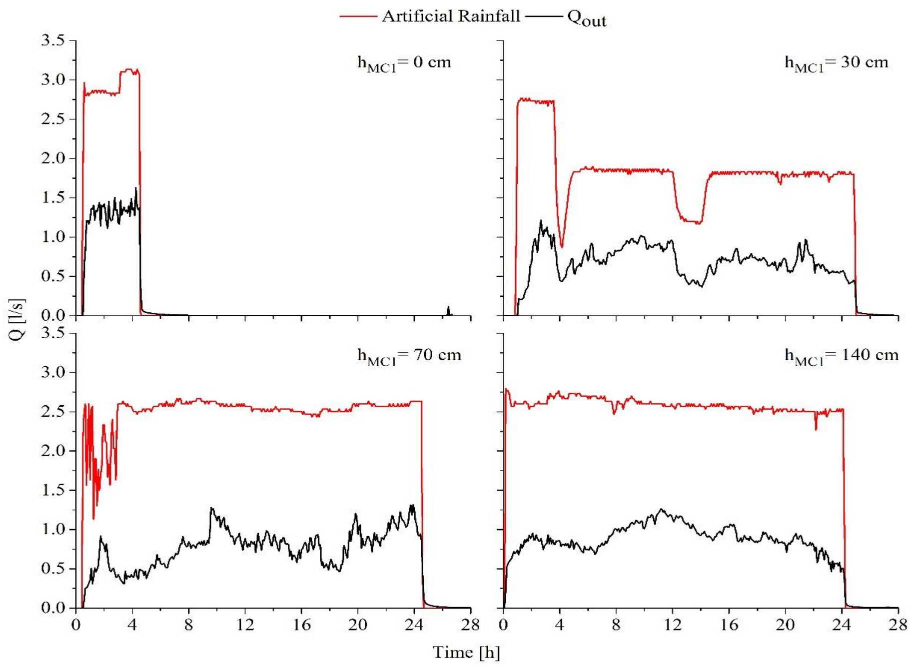

Figure 6. Artificial rainfall and output discharge for different MC1 vegetation heights (h_{MC1}).

Table 3 reports the runoff coefficient values estimated on the four tests and confirms that it decreases while increasing the MC1 height. While the reduction is negligible for configuration 2 (h = 30 cm), it is becoming relevant for h = 70 cm reaching the 30% respect to the bare soil condition.

Table 3. Runoff coefficient for artificial rainfall tests.

h_{MC1} (cm)	Test Rainfall Intensity (mm/h)	Test Duration (h)	Runoff Coefficient (-)
0	170	4	0.50
30	140	24	0.49
70	170	24	0.36
140	160	24	0.34

3.2. Soil Erosion

Figure 7 shows the ratio between the eroded soil amount and the rainfall volume observed in the four tests. It is noteworthy that, in the artificial rainfall conditions, the test in the bare soil configuration (test no. 1) was interrupted after 4 h of rainfall due to the massive soil erosion (Table 1). Figure 7 clearly shows that the eroded soil material for the configuration of bare soil is impressively higher than the corresponding values obtained using "vegetated" configurations. In particular, from test no. 1 to 3 a soil erosion reduction (normalized on rainfall height) of about 300 times has been obtained, similar to the reduction observed for test no. 4. These data confirm that the vegetation efficiency can be considered as maximum at h_{MC1} = 70 cm. Indeed, with h_{MC1} = 30 cm, we obtained a reduction in soil erosion, with respect to the bare soil, of about 35 times.

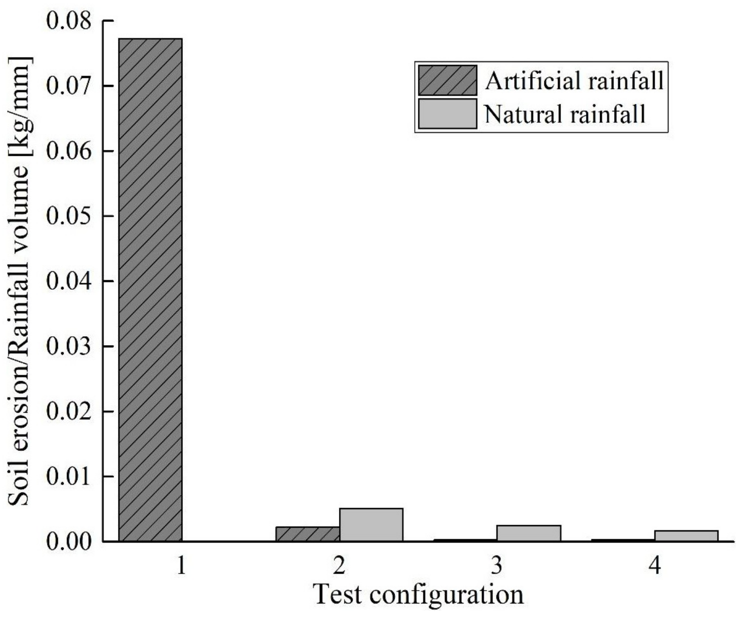

Figure 7. Ratio of eroded material (kg) to cumulative rainfall value (mm) for the four vegetation configurations, in artificial and natural rainfall conditions.

The obtained results are in line with recent studies that investigated the individual plant species effect on soil and water losses, documenting that plants control runoff generation and sediment production. For example, Chau and Chu [68] assessed the erosion-reducing potential of five native fern species of southern China (Blechnum orientale, Cyclosorus parasiticus, Dicranopteris pedata, Nephrolepis auriculata, and Pteris vittata). Each fern species reached two levels of cover (40 and 80%) in 1.0 × 0.5 m^2 soil boxes tilted to 50°, compared to the boxes with bare soil. The erosion control performance was tested using a computer-controlled pressurized rainfall simulator, which provided a rainfall intensity of 100 mm/h to reflect a heavy rainstorm event. The high cover of ferns (80%) reduced the runoff volume by 65.0% and sediment loss by 96.1% compared to the bare soil.

Significantly, the soil erosion reduction was detected by Stanchi et al. [69] across 6 years (with 12 natural events with sediment production) in a sloping vineyard located in Aosta Valley, equipped to assess the effect of different soil managements (permanent grassing, chemical weeding, and buffer strips). Moreover, the impact of mechanization on the sediment amounts and properties was assessed. Permanent grassing and buffering showed comparable effects, reducing soil erosion considerably. In fact, the average erosion rates ranged from negligible (mainly in grassed rows/buffering) to 1.1 ton/ha per event (after weeding). The tractor passage, dependent on the adopted soil management approach, visibly accelerated the erosion process. In this experiment, permanent grassing strongly reduced erosion (in most cases from 2 to 10 times, depending on the event characteristics).

The mitigation effect exerted with permanent grassing by Stanchi et al. [69] was therefore considerable and in agreement with our study and with the findings of Biddoccu [70], who reported a reduction of up to 90% of the erosion rate in rows with cover crops vs. conventional tillage in similar environments.

Moreover, Mohamadi and Kavian [71] observed a direct relationship of eroded material with rainfall kinetic energy, approximated by a non-linear equation. In order to verify such relationship, soil erosion has been related to the rainfall kinetic energy computed using the equation proposed by Wischmeier and Smith [72]:

$$E = 210.3 + 89\ I \tag{1}$$

where E is the rainfall kinetic energy in J m^{-2} cm^{-1}, and I is the intensity in cm h^{-1}.

The results obtained are listed in Table 4. As it can be seen, the kinetic energy values are almost constant for the artificial tests, and this is due to the fact that we set the same rainfall characteristics.

Table 4. Eroded material and kinetic energy for the four tests.

Test	Rainfall Type	Eroded Material (kg)	Kinetic Energy (JM^2)
No. 1	- Artificial	- 52.51	- 320
No. 2	Natural Artificial	0.615 7.48	162 312
No. 3	Natural Artificial	0.195 1.12	191 320
No. 4	Natural Artificial	0.185 1.00	192 317

The test with bare soil provides the highest value in terms of the eroded material. It is interesting to note that with the same kinetic energy, tests no. 3 and 4 substantially provide the same soil erosion values. Consequently, the relationship between the kinetic energy and eroded material does not fit a linear function, confirming the Mohamadi and Kavian [71] contribution.

The developed experimental tests suggest useful feedbacks for future analyses. Indeed, we are aware that further experiments are needed for statistically characterizing the obtained conclusions and for better trying to reproduce optimal rainfall patterns on the experimental plot. In addition, each test should be repeated several times in order to have a stable intensity rainfall and, if the stability is not reached for the full experiment duration, a minimum observation period could be considered as an optimal reference for the analyses. This will allow for a richer data set to explore the variability of the obtained results.

As previously stated, this research represents the first experimental tests on this particular anti-erosive solution. These tests respond to the need to more deeply know the behavior of these bioengineering solutions. In Italy, the growing use of these techniques is confirmed by the very recent construction of the new Genoa-San Giorgio Bridge, where the banks were stabilized with NBS similar to the one tested in this research.

This work also fills the need to increase the investments for natural risk reduction/mitigation. In fact, following the coronavirus pandemic, the European Commission launched a comprehensive and ambitious recovery plan, where particular attention is given to investments in the field of naturalistic engineering and in the use of NBS for the mitigation of hydrogeological risk.

4. Conclusions

In this paper, we studied a nature-based solution for hillslope erosion mitigation. While the results concerning the runoff coefficient variation do not allow for a general conclusion to be reached, suggesting a reduction of 30% in the case of vegetated hillslope limited to the artificial rainfall case, the soil erosion reduction results are clear and promising. Indeed, a consistent decrease of the eroded material (up to 300 times) was observed compared to the investigated vegetation cover (for 70 cm height) with respect to the bare soil condition. Moreover, as shown by the results reported in Figure 7 and Table 4, no particular difference between the vegetation height of 70 and 140 cm has been noted in terms of soil erosion, which is probably due to the 70 cm vegetation height that already represents a configuration of maximum efficiency for the reduction of the kinetic energy of rain.

Our results confirm that the use of MC1 represents an effective method against hillslope erosion. Future research work is already ongoing with the aim to compare the performance of MC1 to other vegetation covers.

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