Freie Universität Berlin

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Physical Geography

Landscape sensitivity analysis for soil erosion risk assessment of harvested coppice forest in the Italian Central Apennine region

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Introduction

Climate change, globalization and the growing demand for energy and raw materials have resulted in an increasing demand for forest resources at a worldwide scale. In Italy, forestland is the second most common type of land use covering about 87,592 km² (29% of the land surface), out of which 42% is currently managed as coppice forest (INFC, 2007). As a result, a vast area of the country, mostly located in mountainous areas characterized by heavy bursts of intensive and erosive rainfalls that hit the steep slopes (van der Knijff et al., 1999), is subject to operations of wood extraction. For some of these forest landscapes this practice of land resource exploitation may result in irremediable damages. The aim of this study is to contribute to research on accelerated soil erosion risks in Italian forests that are involved in the wood supply chain.

Study Area

Two first-order watersheds (Fig.2) have been selected to cary out direct observations and quantifications of the topsoil morphological evolution under two different forest management approaches.

The experimental watersheds (named EX-01 and EX-02) are located in a rather remote mountain location inside the Regional Nature Reserve of Monti Cervia and Navegna (Latium). Both watersheds are incised into middle Miocene flysch in pelitic-arenaceous facies. The predominant soil is a not very well-developed yellow-brown (7.5YR 3/2 - 10YR 4/4) Endoleptic Cambisol formed by alteration of the parent material. The average annual rainfall is 1,270 mm, while the average annual temperature is around 11.3 °C.

Between May 2008 and December 2009, the coppice vegetation (Acerus, Quercus pubescens and oak) of the study site EX-01 was harvested entirely using the shelterwood technique (about 150 trees ha⁻¹ standing after the clear-cut). Study site EX-02 in contrast remained undisturbed. Here, the tree density is approximately 2,400 trees ha⁻¹ and the tree heights range from 7 to 15 m.

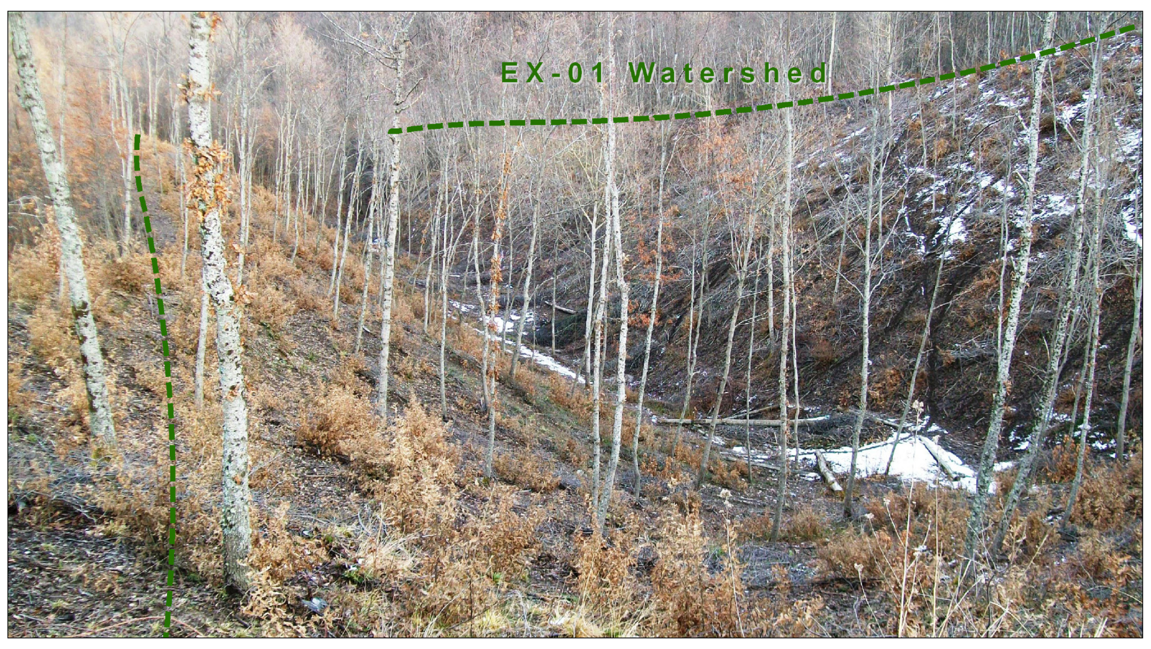

Figure 1: EX-01 watershed in January 2009.

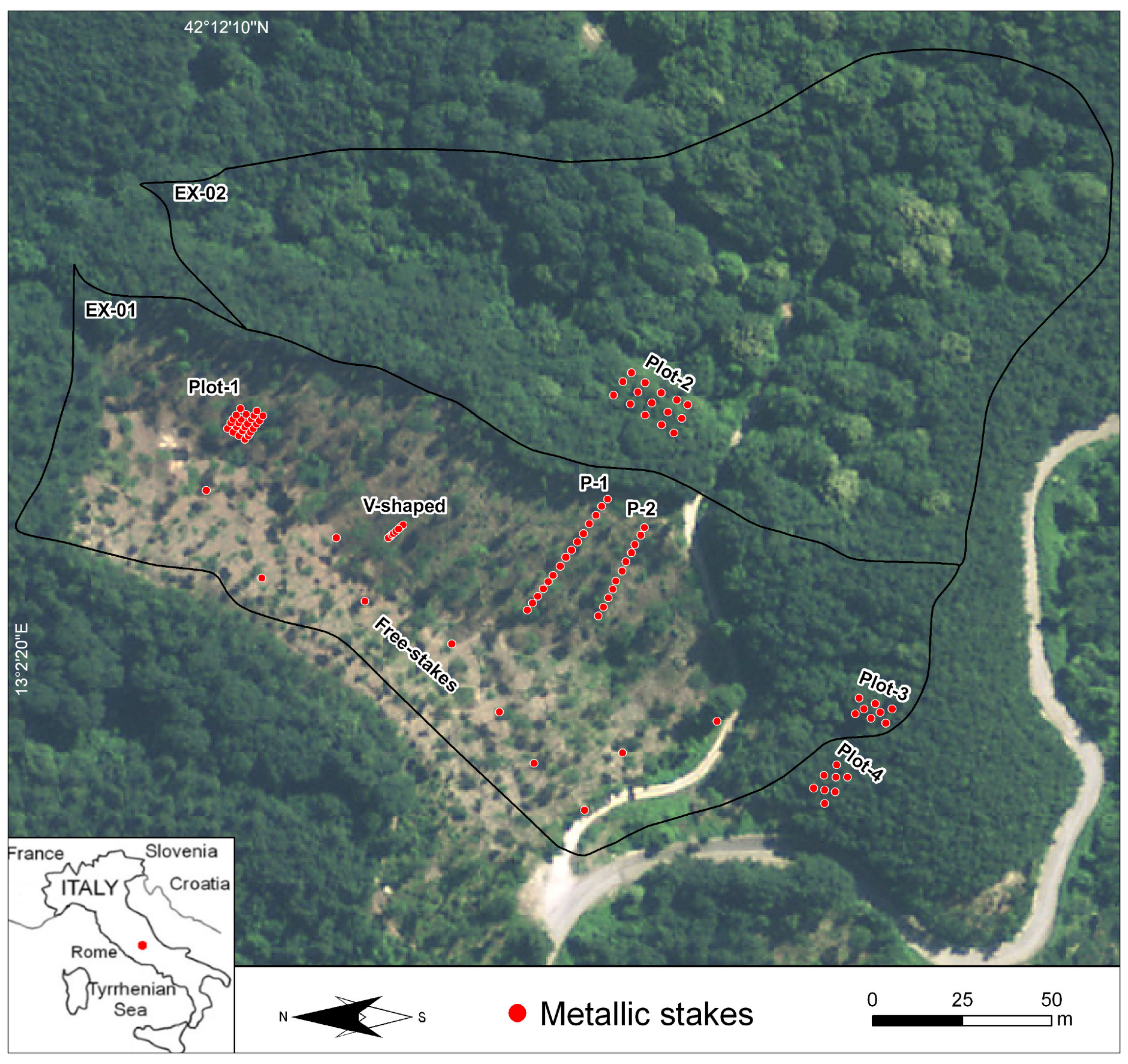

Figure 2: Study sites and metallic stakes.

Methods

The work activities followed two main lines of study: a) landscape sensitivity analysis to assess the soil erosion susceptibility and b) direct field measurements of the change in soil surface level.

For the analysis of the landscape's susceptibility to water soil erosion an analysis of the potential soil erosion risk was carried out (van der Knijff et al., 1999). For this purpose, a RUSLE mode has been run considering the RUSLE basic risk factors (i.e., K-factor, LS-factor, R-factor). All parameters were computed following the methodology reported in the USDA Handbook 703 (Renard et al., 1997). The LS-factor was computed using a 2.5 m resolution DEM while the R-factor was calculated based on 15-min interval rainfall data of the Collalto Sabino station. The soil erodibility (K-factor) calculation rest on 35 soil samples collected through DGPS-guided systematic sampling. The samples were analyzed for grain size (LDS method), total organic/inorganic carbon (Woesthoff Carmhograph) and bulk density in the Physical Geography Laboratory of the FU Berlin.

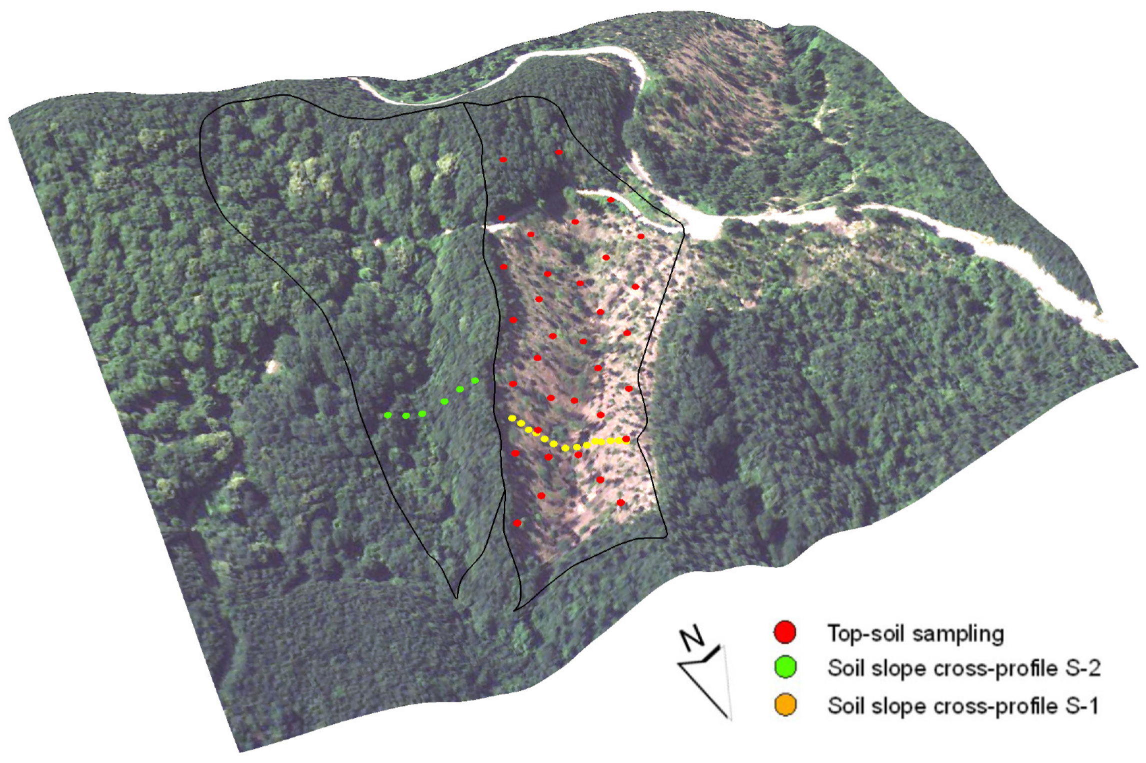

Figure 3: Soil sampling locations.

To ensure a continuous observation of the soil surface changes caused by water erosion, 85 metallic stakes were driven into the soil. In the EX-01 watershed 70 metallic stakes with a diameter of 10 mm and a length of around 500 mm were placed across the watershed surface in July 2008. Beyond this, 15 iron stakes were placed into the EX-02 watershed. For both watersheds, the stakes were distributed in different patterns across the surface and geo-referenced with a Leica tachymeter (Fig 2 and Table1). The changes of soil surface measured by the iron stakes were regularly checked every four months in accordance with the annual variations of the rainfall patterns in January, May and September. In doing so, between September 2008 and May 2010 six metallic stake records were taken.

Table 1: Monitoring stations.

Monitoring station	Nr. of stakes	Monitored period	Monitoring station	Nr. of stakes	Monitored period
P-1	15	Aug. 2008 - Apr. 2010	Plot-3	8	Aug. 2010 - Jul. 2010
P-2	11	Aug. 2008 - Apr. 2010	Plot-4	8	Aug. 2010 - Jul. 2010
Plot-1	26	Aug. 2008 - Jan. 2010	V-shaped	8	Aug. 2008 - Apr. 2010
Plot-2	15	Aug. 2008 - Apr. 2010	Free-stakes	10	Aug. 2008 - Apr. 2010

Results

Land susceptibility to soil erosion: The grain size analysis (LDS method) revealed similar distribution patterns of the soil particles in the area (σ= clay: 1.6, silt: 4.8, sand: 6.1). According to the 35 topsoil samples analyzed for their grain sizes, silt loam (60.6%), and to a lesser extent sandy loam (30.3%) texture classes dominate the EX-01 watershed. All soil samples were characterized by their low clay fraction contents (4-10%). The TOC values in the watershed range from 0.7 to 14.8%, while the averages values are 4.1, 5.6, and 4.5, for low, medium and high watershed positions, respectively. The K-factor, calculated according to the characteristics of the sampled soils data, ranges from 0.016 to 0.09 t h MJ⁻1 mm⁻1 with a mean value of 0.056 (σ= 0.0177). The LS-factor shows a moderately high average value of 5.9 (σ= 4.6) with local maximum values (from 20 to 25) on the hillslopes. The temporal variability across the year shows high values of rainfall erosivity during the autumn period and during the second half of spring (Table 2).

Based on these analyses and specifically the multiplication of the three considered parameters, a map with the assessment of the potential soil erosion risk has been created (see Fig. 4).

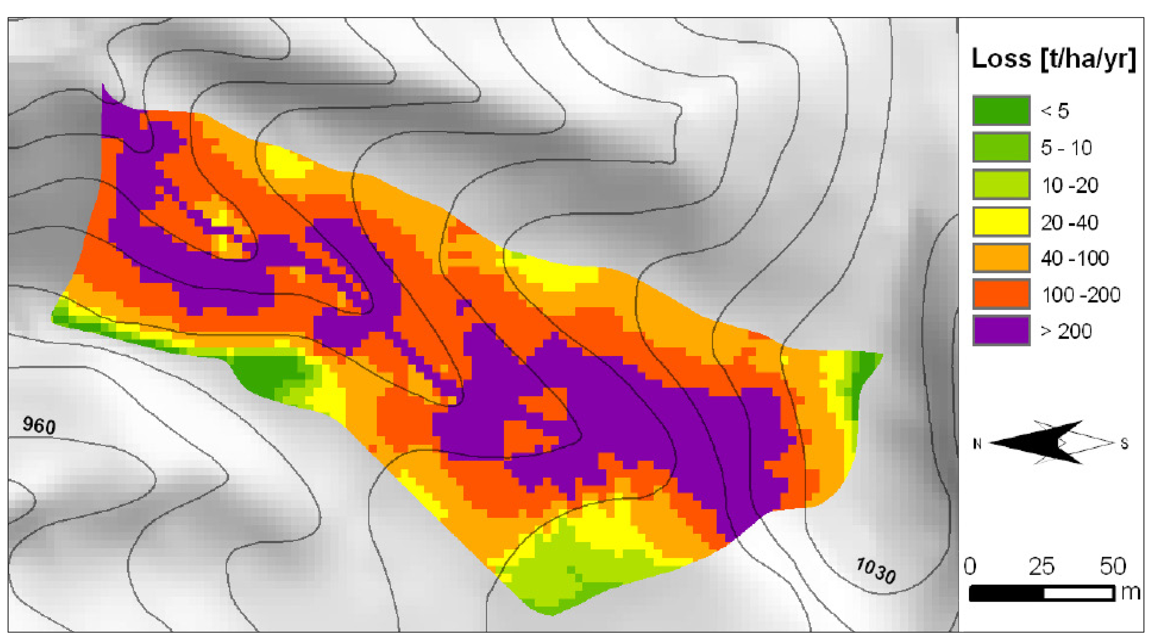

Figure 4: Potential soil erosion risk map.

Soil erosion response: The analysis of the changes in the surface level obtained from the metallic stake records revealed a dominant soil mobilization in the harvested watershed EX-01. In 18.8%, 26.1% and 55.1% of the stakes placed in the EX-01 watershed variations (erosion or accumulation of sediment) equal or greater than 0-5 mm, 5-10 mm and >10 mm, respectively, were recorded. In contrast, in EX-02 none of the stakes measured values of a soil surface change in excess of 0.5 mm. The cumulative surface level variation of the observation points in the EX-01 watershed is 98 times the one of EX-02 during the study period. There is a strong correlation between the sediment movement regime and the precipitation pattern.

Table 2: Cumulative surface change after 16 months.

Date	Day	Rainfall	Rainfall erosivity	Average change	
				EX-01	EX-02
	[-]	[mm]	MJ mm h⁻¹ ha⁻¹	[cm]	[cm]
4/1/09	116	717.4	1571	0.025	-0.52
6/5/09	238	430	158	0.02	-0.47
8/9/09	361	144.2	138	0.01	-0.42
8/1/10	480	687.8	963	-0.025	-0.57

Figure 5: Two metallic stakes which shown high erosion (left) and sedimentation (right).

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Regionalization of the experimental sites: The area under investigation is lithologically framed in the arenaceous and arenaceus-pelitic turbidatis unit of the Messinian. It stretches across a mountainous sector of about 4,494 km² with altitudes between 100 and 2,500 m a.s.l. (mean 760 m a.s.l.). This geological sector is mainly covered by Eutric Cambisol and Dystric Cambisol. According to the Corine land cover map, it comprises 1,896 km² of forestlands. Drawing on the forest cover change map created in this study, the area subject to forest harvesting or fires was 9,200 ha in the observation period from July 2010 to July 2011. This area is composed of 6,480 individual sub-areas (Fig. 6).

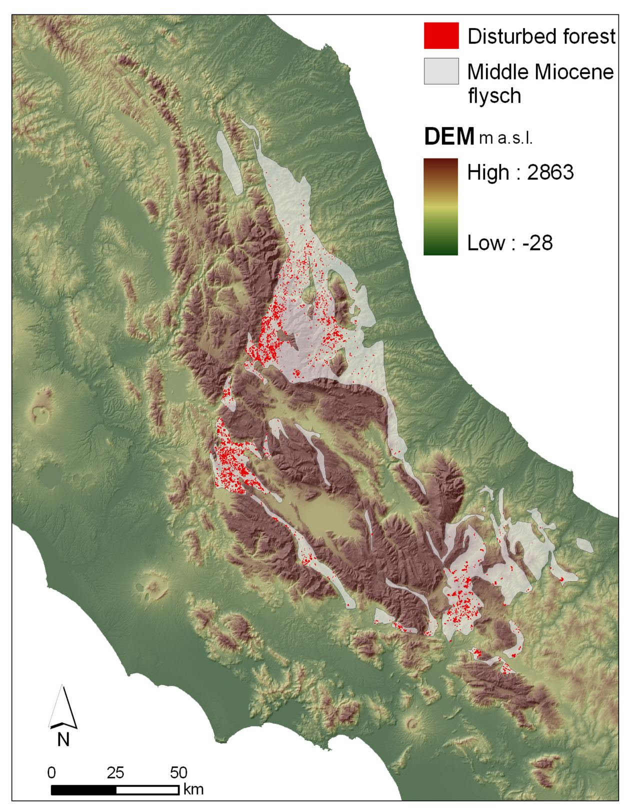

Figure 6: Disturbed forest on flysch.

Discussions and Conclusions

The high potential soil erosion risk estimated for the area was quantitatively confirmed by the field measurements of the field work. There is a prevalence of soils categorized as soils with an erodible texture. These soils have a low percentage of clay which, in turn, determines their low soil cohesion (Torri et al., 1997). This situation is only partially compensated by the quite rich content of organic matter. As a result, the soil was mainly classified as highly erodible. The removal of the vegetation left the soil covering the steep slopes under aggressive rain events. 25 out of 70 stakes (36.2%) placed in the harvested watershed indicated a negative change in the surface level greater than 1 cm. Finally, during the period from August 2008 to January 2010 rates of net soil loss of 49 t ha⁻¹ yr⁻¹ for the harvested and 2.3 t ha⁻¹ yr⁻¹ for the undisturbed forested areas were estimated.

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7th EUropean Congress on REgional GEOscientific Cartography and Information Systems
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