# EROSIONAL RESPONSE OF RECENTLY INSTALLED FOREST AREAS: EFFECTS OF SITE-PREPARATION TECHNIQUES

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## Introduction

Forests provide the most effective vegetation cover for erosion control and it is in forested areas that lowest soil loss rates are recorded (Hudson, 1981; Zachar, 1982). However, in cultivated forests, the stand installation and early tree growth stages are most critical, because, normally, vegetation has not yet attained a sufficiently effective cover (Dissmeyer, Foster, 1984; Lucci et al., 1994). Actually, young forest stands were identified as areas of accelerated erosion in NE Portugal (Agroconsultores e Coba, 1991). Site-preparation techniques may play, then, a major role in mitigating risks, because they are intended to improve soil conditions for plant growth and to reduce erosion (Alves, 1988).

In order to compare their effectiveness for erosion control, several customary site-preparation techniques in NE Portugal were applied prior to installing a mixed stand (*Pseudotsuga mensiezii* and *Castanea sativa*), and thereafter runoff and soil loss were monitored. This paper aims at presenting and discussing, in a preliminary approach, results of the first two years after site-preparation.

## Materials and Methods

Experimental site is located 40 km South of Bragança, NE Portugal, at 41º35'N, 6º57'W, and an altitude ranging from 701 m to 660 m. The area depicts a rolling topography. Average annual temperature and precipitation are 12ºC and 1000 mm, respectively, with typically Mediterranean seasonal distribution (Agroconsultores e Coba, 1991). Soils in the area are sandy-loam schist derived dystric Cambisols and Leptosols (FAO, 1988; Agroconsultores e Coba, 1991), with high stoniness (higher in the latter ones, which occur in steeper slopes). The soils are normally acid, moderate to poor in organic content and have low to very low P contents and low to moderate K. In a small plateau on the experimental site, soil parent material is a shallow Tertiary sedimentary deposit, resting over the schist basement. Soils developed on this material have higher silt, clay and organic matter contents, are more acid and have lower P and K, than the previously described (statistically significant differences, $p<0.05$; data from samples collected on 48 profiles before site preparation).

The area was originally a cereal field, abandoned and left for about ten years to natural vegetation recover. Prior to site preparation operations, in mid-Autumn, a heavy disk harrowing was performed all over the area, in order to reduce or eliminate original vegetation.

Experimental design comprised three blocks, where eight treatments were randomly distributed on experimental plots (**Table I**). Treatments 3 to 8 represent increasing site disturbance. Treatments 1 and 2 are references for comparing the effects of site preparation techniques either with the original condition (abandoned field) or with the potential erosion condition. The three blocks mentioned correspond to different topographic positions as follows: I - near flat plateau (6% average slope gradient); II – moderate shoulder slope (12%); III - steep mid-slope (22%). Experimental plots, 24 on total, cover an area of 375 m$^2$ each (25 m wide by 15 m long, downslope). Plantation was performed in early Spring, three months after site preparation operations, with *Pseudotsuga mensiezii* and *Castanea sativa*, in alternate

contour rows. Distances between plants and rows are 2 m and 4 m, respectively. In plots with Treatment 2, plantation was made only on half of plots' width.

**Table I –** Treatments representing site-preparation techniques tested: two controls and remainder ranked from lowest (3) to highest (8) intensity of soil disturbance.

| Treatment | Symbol | Description of site-preparation operations |
|---|---|---|
| (1) | TSMO | Control; no intervention on original abandoned field |
| (2) | TERO | Potential erosion control; ripper pass all over the area (down to around 70 cm depth), followed by ploughing against the contour |
| (3) | SMPC | No ripping or ploughing, plantation holes digged down to 80 cm depth |
| (4) | RCAV | Ripper pass all over the area (down to around 70 cm depth), ripper equipped with wings; plantation in ripper pass row |
| (5) | SRVC | No ripping; two deep plough passes for terracing [a] (down to around 100 cm depth) |
| (6) | RLVC | Ripper pass on plantation rows (down to around 70 cm depth); two deep plough passes for terracing [a] (down to around 100 cm depth) |
| (7) | RCVC | Ripper pass all over the area (down to around 70 cm depth); two deep plough passes for terracing [a] (down to around 100 cm depth) |
| (8) [b] | RCLC | Ripper pass all over the area (down to around 70 cm depth), followed by ploughing against the contour |

[a] – Meaning a furrow-hillock surface configuration; [b] – Not monitored for water and sediment losses.

For monitoring soil and water losses, microplots were installed in each one of the experimental plots, except those where Treatment 8 was applied. All fixed onto the ground, metal plates provide upper and lateral boundaries for microplots, together with a specially designed metal piece, which concentrates water and sediment on its frontal part. Losses are conveyed through a flexible hose to a 10 L plastic tank, placed downslope in a hole and covered. Tanks were painted black to avoid algae invasion. Two replicates were placed randomly on each experimental plot, except in the cases of Treatments 1 and 2, where they were four. Microplots have a fixed 1 m width, their length varying with local ground configuration, from 2.3 to 2.9 m. Extra plots for erosion monitoring, 15 m long, were installed on Treatment 2, in order to assess effects of slope length on runoff and soil loss. In Treatment 8 experimental plots, surface ground after site-preparation was such that encouraged discarding erosion monitoring on those plots, as very high surface roughness would expectedly limit sediment yield to insignificant values.

Water and sediment exported from microplots were collected after each period of precipitation. Outdoor operations comprised (i) collecting sediment trapped on microplot front edge; (ii) replacing of filled tanks by empty and clean ones. Indoor operations included (i) oven-drying and weighting sediment collected on microplot front edge; (ii) measuring tank water volume, with a graduated bucket; (iii) sampling, before and after thorough stirring water in the bucket, in each case with a 100 ml beaker, the former frozen for future chemical analysis, the latter oven-dried afterwards for sediment dry-weight determination. Runoff was calculated from measured water volume; soil loss was calculated from sediment concentration on runoff water and weight of sediment collected on microplot front edge.

An automatic weather station, placed on the experimental site, records meteorological data (precipitation, relative humidity, temperature and wind speed) at 10 min time step. As part of a research project aiming at studying the effects of site preparation techniques on forest sustainability and productivity, many variables of interest to soil and water dynamics were also measured at experimental site.

Results presented here regard quantitative data on water and sediment collected in the first twenty one events, summing 1876.2 mm precipitation in two years, beginning March 2002. Data were treated and analysed applying customary statistical techniques.

**Results and discussion**

Expressed as annual averages, runoff and soil loss in the original abandoned field were 3.5 mm and 11.6 g $m^{-2}$, respectively (**Figure 2**). In all areas treated and planted values were 2.5 to 7 times higher, for runoff, and 5 to 11.5 times higher, for soil loss. Soil loss was sharply higher on Treatment 2, TERO, with ploughing on slope (equivalent to 2.3 t $ha^{-1}$ $year^{-1}$).

Soil loss and runoff tend to increase as treatments consist in heavier machine intervention (**Figure 1**). Nevertheless, actual differences in sediment and water exported from microplot area are not substantial when comparing different site-preparation techniques. A figure to be kept in mind is that, for tested conditions, soil loss rates recorded are equivalent to around 1 t $ha^{-1}$ $year^{-1}$, and runoff to around 20 mm $year^{-1}$, meaning a 2 % runoff coefficient.

Yet, differences in sediment and water losses due to Treatment effect are statistically significant, the effect of Block and the effect of interaction (Treatment x Block) being statistically significant, too ($p<0,000$ for all effects, in two-way ANOVA, performed for both variables). The effect of Block is mainly due to slope gradient, but, seemingly, other factors add to variance such as stoniness. Furthermore, vegetation cover development, for instance, may cross the effect of Treatment with that of Block, thus leading to complex influences in results. These are to be explored in further works on the subject and highlight the relevance of local effects when research on erosion processes is conducted at this small scale.

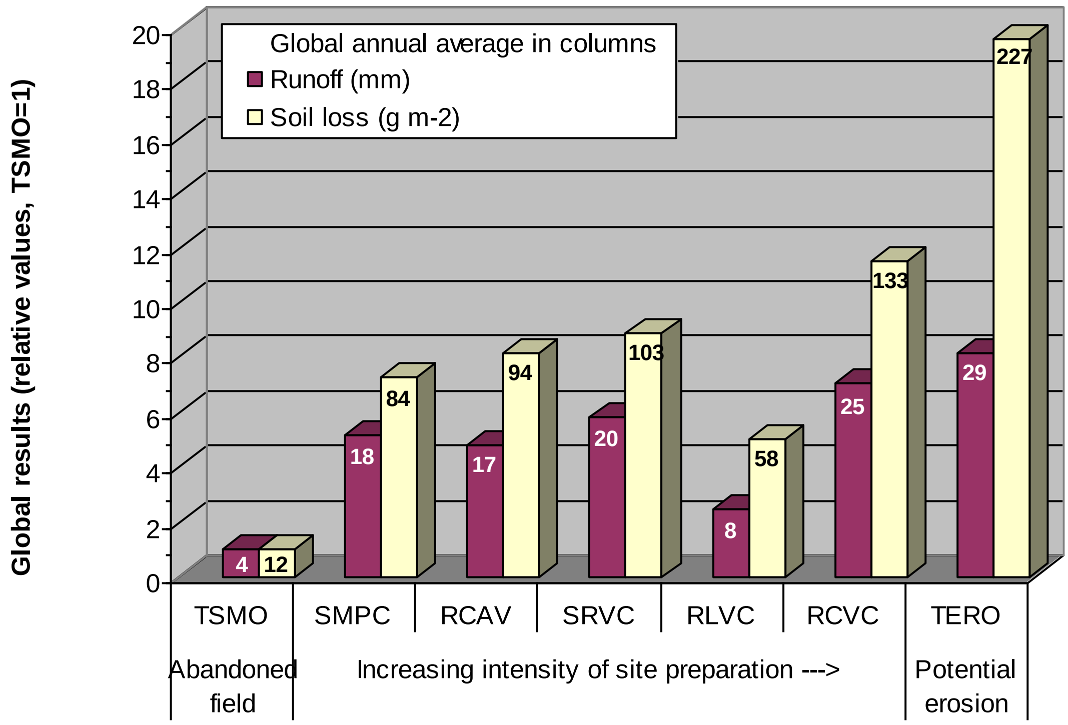


**Figure 1 –** Global annual average Runoff and Soil Loss after two years: Treatment absolute values (in columns) and values relative to original abandoned field (in ordinates).

Seasonal distribution of runoff and soil loss during the two years monitoring period is depicted in **Figure 2**. In the first year precipitation was clearly higher than in the second one. Despite the rainy Spring 2002, as expected for this climatic regime, Autumn and Winter

contributed with more precipitation to the year total than did Spring and Summer. Microplots responded to these precipitations yielding a similar pattern of seasonal distribution in what concerns runoff; yet, this was not the case of soil loss. In fact, the first rains received on microplots (Spring/Summer 2002) induced between 75 and 95 % of total recorded in two years (except in Treatment 2, TERO, where it merely exceeded 60 %). In all Treatments, the first year accounted for more than 90 % of soil loss recorded.

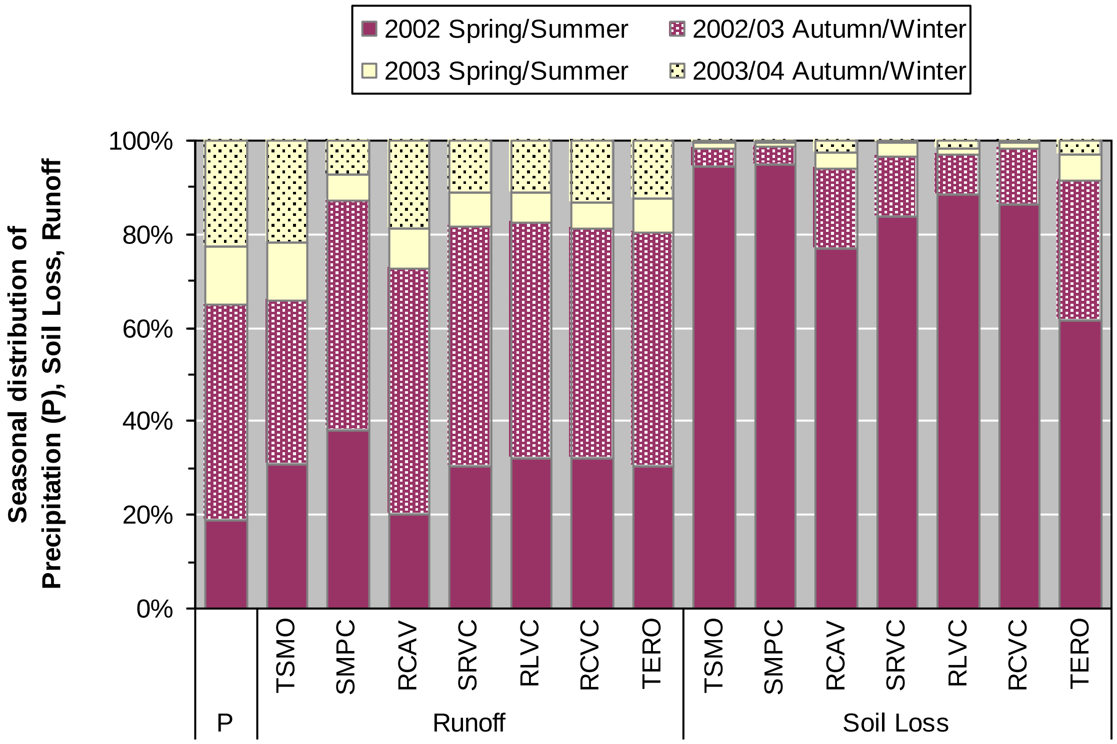


**Figure 2** – Seasonal distribution of Precipitation (P) and, for Treatments tested, Runoff and Soil Loss during the two-year experimental period.

Rainfall erosivity certainly contributed to differences in microplots erosional response observed in two years. As well, temporal changes in vegetation cover may help explaining these findings. However, the pattern of soil loss seasonal distribution, described above, is also found under Treatment 1, TSMO (original abandoned field, with high vegetation cover since the beginning of experiment). As so, the evolution of surface conditions, due to the effect of cumulative rainfall in roughness, in cohesion and in hydraulic conductivity, must be explored in order to adequately interpret results. This is clearly suggested on **Figure 3**, where a sharp decline in soil loss rates is observed after 350 mm cumulative rainfall.

## Conclusions

As a first approach to treatment of data collected, this paper only yields preliminary interpretations of results obtained.

All results considered, soil loss rates on areas submitted to the site-preparation techniques tested are equivalent to around 1 t $ha^{-1}$ $year^{-1}$, and runoff to around 20 mm $year^{-1}$ (2% runoff coefficient). These fall in the range of tolerable values and mean an apparent low impact of the techniques tested on soil and water losses.

However, soil loss and runoff tend to increase as treatments consist in heavier machine intervention, therefore suggesting the recommendation of lighter site preparation techniques in order to limit erosion hazard.

As indicated by results, major impacts of site-preparation on erosion occur in the first year of stand installation, as the rates of soil and water losses sharply decline afterwards. Vegetation cover and surface evolution may contribute to explain this finding.

Results highlight the relevance of local effects when research on erosion processes is conducted at this small scale and the need of further works on the subject.

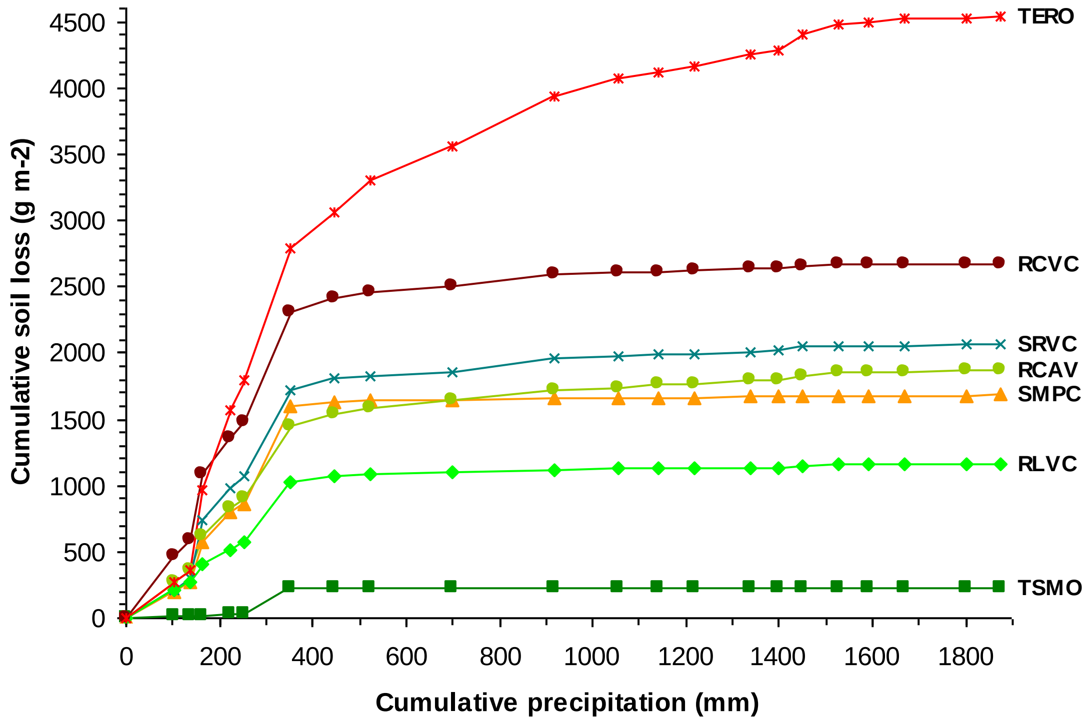


**Figure 3** – Temporal evolution of Soil Loss during the two-year experimental period for Treatments tested.

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