Evaluating material loss and accumulation rates on high slope plots. Case study at Moussouron municipality (Crete, South Greece)

Vona M.¹, Vaiopoulos D.², Evelpidou N.², Giotitsas I.², Stathis, L.³, Deligiannakis, G.²

1. Szent István University, Institute of Environment and Landscape Management, Dept. of Landscape Ecology, 2100-Gödöllő, Páter K. u. 1., Hungary, Tel: 06-28-522-000/1833, e-mail: Vona.Marton@mkk.szie.hu
2. Remote Sensing Laboratory, Faculty of Geology and Geoenvironment, National and Kapodistrian University of Athens, 157-84, Panepistimiopolis Zografou Tel: +30 210 7274297, fax: +30 210 7274927, e-mails: vaiopoulos@geol.uoa.gr, vassilopoulos@geol.uoa.gr, giotitsas@gcparks.com, deligiannakis@gcparks.com
3. Technical Engineer, Moussouron Municipality, Crete, South Greece, e-mail: stathisloukas@in.gr

Abstract

During the last years the major threat for the deforested areas of the Crete island, especially the area of Moussouron, is the quick wash out of soil material. The wash out of soil material, due to logging activities or fire events, obstructs efforts for reforestation and natural reconstruction of the site.

For the needs of our research, the field experiments were applied at a high slope area situated at Moussouron municipality (Crete island - South Greece), where major fire events recently took place and caused serious damages at the vegetation. In specific, neighboring areas of approximately 2.6km² and 3.2km² have been burnt in 2003 and 2004, respectively.

This case study area is mainly characterized by the Mediterranean climate, having extended dry periods during summer (5% of total rainfall) and periods with intensive rainfall during winter (95% of total rainfall). The area presents high relief alterations with intense slopes (~65% of the area has slopes over 20°) and lithologically is mainly characterized by two basic formations; carbonate rocks at higher and phyllites at the lower altitudes. The aforementioned characteristics have caused the soil to intensively wash out just after the fires occurred.

The main purpose of this research is to evaluate the correspondence between the amount of eroded material and the rain intensity, at conditions of recently burnt areas. In order to approach the problem, tree trunks in a parallel to the contour lines arrangement, were installed. This way the study area was split in numerous plots with predefined dimensions and precisely measured slopes.

Just after each intense rainfall, thickness measurements of accumulated material were performed at the tree trunks, while the runoff material was also estimated at the lowest parts of each plot. At the same time, using a rain gauge, rain intensity was also measured, in order to correlate this factor to the overall soil washout.
1. Introduction

The study area is located at the western part of Crete island, at the Prefecture of Chania and is delimited by the settlements of Lakki, Kares to the south and Skines at the north (Fig. 1). The total region is 5,820 km$^2$ and it is generally characterized by high slopes, up to 53°. This is easily explained by the relief which is higher at the southern part with altitudes that reach up to 600m and lower at the northern part (139m is the lowest point). The northern part is crossed by the valley of one of the most important branches of Keritis river, the main river of the municipality of Moussouron.

![Fig. 1: The case study area in Moussouron municipality, west Crete, south Greece.](image)

The geology of the wider area is characterized by the presence of Triassic phyllites, limestones and dolomites, and Quaternary marl, sandstones and conglomerates. The case study is mostly covered by phyllites and a small part is covered by carbonate rocks. Besides the drainage network which is the prior erosion factor, the most important factors that cause erosion at the area are sheet erosion and rill erosion. In some cases even small gullies appear (Fig.2). Sheet erosion is caused by the force of raindrops impacting on bare soil (Ellison, 1944) and dislodging particles. The force is stronger under the crowns of tall trees than on cultivated plots because the drops come together on the leaf sheathes, forming larger drops (Valentin, 1981). The flow characteristics are controlled by microtopographic features, and produce either rills or sheet erosion (Emmett, 1978). The role of splash erosion, by raindrop impact, seems to be more important for the detachment. According to Horton’s theory (1945) runoff starts when rainfall intensity exceeds soil absorption capacity. In the more mountainous areas or steep drainage slopes like in typical Mediterranean landscapes, the erosive energy of runoff is more significant than that of rain. Soil loss from cultivated fields may be small (0.1 to 15 t/ha/yr – Heusch, 1970, Arabi & Roose 1989), while sediment transport may be more significant. In this case, the larger the catchment area, the more abundant and fast-moving is the concentrated runoff, causing gullying and landslips on low terraces. The rate of the soil erosion may be calculated by the distance of the divide, or the surface water flow discharge, multiplied by a power of slope gradient (Kirkby, 1978).
The main aim of this study is to identify the intensity of the erosion processes in plots of different slopes within the entire case study. Furthermore the use of GIS has enabled the creation of a map depicting the transfer of soil material at the area. The comparison between the output of the map and the results of the experiment is also an important matter to deal with. Finally, the experiment that is held is planning to create a stimulus for discussion and comparison between the plots that are under experiment and the neighboring non-protected plots.

2. Methodology

The carry-out of the experiment was held parallely with the session of GIS analysis of the area. The GIS part was based in empirical procedures that stemmed from the combination of physical, geomorphological and morphological parameters of the area (Sabot et al, 2002a&b, Gournelos et al, 2003, Gournelos et al., 2004). The final goal was the creation of a map that could depict the way that the eroded material is manipulated within the area. The analysis that took place in the GIS started with the creation of a Digital Elevation Model (DEM) using the 20m contours of the area. The DEM provided a very good resolution depiction of the relief of the area, with a detail of 10m cell size. The relief anaglyph was further analyzed to provide new DEMs for the slope and aspect of the area.

The second step was to divide the catchments of the area in three different parts, according to their slope. Their division was made in an upslope part, where slope is really low and where no erosion takes place, in a footslope part around the rivers of the catchment where the deposition prevails over erosion and in a midslope part where the main part of erosion takes place (Vassilopoulos, et al. 2005). It was found that drainage density increases according to basin’s average slope (Gregory & Wallig, 1973). Furthermore, drainage density of rills is highly related to slope gradient (Schumm, 1977). It was thus considered necessary to separate the mid slope part of the catchments in 3 more parts according to the slopes of the case study.
The third step was the creation of a grid 60x60 of a total of 3,300 cells. The geographical centre of each cell was updated with information concerning the slope value, the aspect, its location within the catchment, the altitude etc. With a proper combination of thematic maps, the final outcome was the transfer material map of the case study (Fig. 3).

The experiment was deployed into several plots within the entire case study. Characteristic regions for each one of the above slope categories were selected, and trunks were installed in a parallel direction to the contour lines to act as sediment traps. Some representative locations within each plot were chosen for the installation of sediment gaugers, and the sediment was also estimated at the bottom of each plot. The plots retain specific dimensions and the slope of each plot is steady within the entire plot. The measurements for the rain intensity were made at the central meteorological station of Alikianos. The plots have been set both on the phyllites and the carbonate rock complex formations.
3. Case Study – Discussion

As it has already been mentioned, phyllites are the dominant formation (precisely 82% of the area) and the second most prevalent formation is the carbonate rock complex (limestones, marbles and dolomites) appearing at the western part (16.9% of the area) (Fig. 4). Within the limestones an important amount of limonite deposits is included and makes its appearance in several locations. The phyllites are also characterized by the appearance of basic volcanic rocks within their body, mostly diabases.

The climate of the wider area appears alterations as we move from lower to higher altitudes. At the northern plains of the wider area, where our case study is included, the climate is warm-Mediterranean with mild rainy winters and hot dry summers. Snow, hail and fog appear to be very rare phenomena. According to datasets from the meteorological station of Alikianos, the closest station to the case study, the mean annual number of sunshine is 2,485 hours, the mean minimum and maximum temperatures are 5.3°C and 29.8°C correspondingly, and the annual rainfall height is 850mm. Half of the rainfall occurs during winter and more specifically in January, December and February, sorted by rain intensity.

As far as land use is concerned, the region has mostly private tree cultivations and in some areas mostly at higher altitudes or at more intense slopes, appears low or even no vegetation. The prevalent land use at the area is the growth of olive trees. The olive trees are the most common cultivation for the wider area as well, for altitudes up to 800m. Except for olive trees the area has also orange tree and vineyard cultivation. The low vegetation in this area is of a specific ecosystem mostly with bushes up to 2m high, with hard leaves for higher endurance in the hot and dry summer. The ecosystem is met at the area by various species (Erica manipuliflora, Arbutus unedo, Quercus coccifera, Pistacia lentiscus etc.). The cultivations mostly take place at the areas where the phyllites formation appears, whereas the part that is covered from carbonate rocks has mostly low vegetation or no vegetation at the highest slopes.

Fig 4. Geology of the study area, after the geological map of IGME.
The case study area has recently experienced two major fire events, the first one in October 2003 affecting the south part of the case study and the second one at January 2004 affecting the north part. The fires have wasted all cultivation at the area and brought permanent damage to the aforementioned ecosystem. The private cultivations have been re-established after the fires and even some areas of low vegetation had a change to their land use and are now being cultivated. A big area of the case study though has no vegetation today. Since the fires, the material transfer rates have been aggravated, mostly in the non covered areas.

The map that was created within the GIS, has the intension to provide a first idea of the expected material movement at the area and it is based on empirical procedures depicting the areas where more intense sheet or rill erosion is expected and the areas where the material is deposited. The study of the map may identify the places where the thicker soil layers are expected and where prevention measures are necessary to avoid denudation phenomena. The results of this map have shown that the more intense erosion occurs at the slopes between Pirgos and Karianos Regions on the west part of the map, while the slopes with an aspect towards the west (e.g. the hillslope of Kaprokefali region) also appear to have significant problems. The deposition areas are mostly near the river network of the area, where the water speed is lower and its transfer capability diminishes.

One of the aims of the experiment is to compare the material loss rates between the areas of the experiment and their neighboring areas, where no prevention measures are taken. The experiment was set up during February 2006, and the only serious rainfall event which occurred since then, was in May 2006. The comparison is not to be achieved yet, since there is no obvious change between the hill slopes of the experiment and the neighbouring areas. This rainfall event though has given the chance to compare the results of the map that was created within the GIS, with the natural processes. The recorded material transfer as it was recorded through the experiment, generally coincides to the empirical calculation within the GIS. The carbonate rocks, lacking soil, have appeared no transfer material, despite the different slopes. As far as phyllites are concerned, this first measurement seems to verify the results that were given by the map. Some small errors have been noticed on the areas where the boundaries between the different parts of the catchments (upper, medium, etc.) have been preset for the construction of the map.

4. Conclusion

Two of the main goals of this study have been the identification of the intensity of the erosion processes in different slopes as well as the comparison between the output of the GIS material transfer map and the results of the experiment.

The transfer material map was developed with the use of GIS and was the output of a combination of different morphological, geological and physical parameters. The result shows the areas with the different capabilities of sediment transfer, as well as the deposition areas.

The experiment was set on February 2006 and established with the help of the technical department of the Moussouron Municipality. The location of the area was chosen on the basis of the most recent fire occurrences and the areas for the plot deployment were selected and expropriated exclusively for the experiment. The tree trunks that were used were remains of the burned tree cultivations of the area. The results came from an intense rainfall event during May 2006 were used mainly for the verification of the estimation results of the GIS model. The differences between the transfer rates of each plot according to their slopes
have actually coincided with the estimation from the GIS map, with insignificant errors on the preset boundaries of the three catchment parts (footslope, midslope, upslope.)

References


