INFLUENCE OF TOPOCLIMATIC VARIABLES DERIVATED FROM DIGITAL TERRAIN MODELS OVER THE VEGETATION REGENERATION PROCESSES IN BURNED AREAS

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ABSTRACT

In this work, the signification of some topo-climatic variables deduced from a DEM over vegetation regeneration processes after wildfires monitored on a semi-arid region from Landsat TM images has been analysed. Ten DTMs – associated to hydrological (slope, terrain curvature, upslope catchment area) and thermal conditions of terrain (potential direct solar radiation)—has been extracted from a grid DEM (25x25m) and it has correlated with NDVI values of two dates (1987 and 1994) and its differences. The slope, curvature profile, curvature surface and mean curvature has been calculated using different and neighbourhood (3x3 and 5x5 pixels) but in all the cases the relationship with the NDVI has been very poor. The upslope catchment area also presents a very low correlation with the vegetation. Only the potential solar radiation shows a very clear relationship. It has been concluded that thermal factor present the main influence on the regeneration processes due the physical conditions of the area (semi-arid Mediterranean climate and soils little deep and very poor). Also it has been observed a clear relation of the significance of the potential solar radiation with the regeneration vegetal cover associated to the lithology. Over permeable geologic substratum (calcareous areas) the relationship is less clear that on impermeable substratum (marls, clays and gypsum).
The work presented here shows that the employment of MDE and their MDT derived from satellite images allow us to explore environmental relationships on a microscale. This could, with difficulty, be carried out with other methodologies, which could, in turn, establish deductions of great significance in the functioning of ecosystems.

1. INTRODUCTION

The increased availability to users of digital elevation models is allowing detailed analyses to be carried out which would have been difficult to imagine only a few years ago. One example is provided by the analysis of vegetation evolution in semi-arid climates, such as the case presented here. The dynamics of vegetation is complex and subject to many factors, not just endogenous characteristics (availability of seeds, competition between species,...) but also it is strongly associated with abiotic factors in the biotopo (microclimatic factors, soils, human uses) In Mediterranean semi-arid areas, characterised by long dry periods and irregular rainfall patterns, the main limiting factor in the development of vegetation is the lack of available water, for which reason the humidity distribution is a first order factor for knowing how the vegetation is distributed and with what density This limiting factor, which is evident throughout the vegetation wherever there is a dry Mediterranean climate, is even more notable when the vegetation cover is removed by forest fires. In the region of Valencia forest fires can be considered a problem of great magnitude since in the past decade as much as 25% of the forest has been damaged in this way.

Based on digital elevation models it is possible to define a series of parameters that could quantify the spatial variations that potentially influence the distribution of the humidity associated with thermal and hydrological processes. In this study the significance of these factors, both hydrological – cross-section curvature, cross-section area, accumulated basin area and slope – and thermal – potential direct solar radiation– has been analysed to see the effect that they have over the recuperation of the vegetation mass after a fire.

Previous studies had indicated that for the area in question the fundamental parameter to take into account is the potential solar radiation, but it was also expected that it would be necessary to look in more detail at the influence that hydrological parameters may have. For this, firstly, for each pixel in the model the specific basin area has been calculated and, secondly, the curvature and slope have been considered for different neighbourhoods (3x3 and 5x5). The vegetation has been characterised using the NDVI calculated from Landsat TM images corresponding to June 1987 and June 1994 which had been radiometrically corrected with respect to each other.

2. STUDY AREA

The working area is located at the valley of the Cantabán river and surrounding relieves, including the main part of the Muela de Cortes de Pallás and the Caroche platform, at the most occidental region of the province of Valencia (East of Spain). The area is limited by the following U.T.M. coordinates: 657000 and 4329000 at the southwest, and 680975 and 4354975 at the northeast. The valley comes downward from south to north to the Júcar river, fitted over the soft and non-permeable triassic materials (IGME, 1979 y 1980). The close range relieves are mainly composed of cretacic carbonated series with a tabloid geological structure, and get 1100 m of altitude at the Caroche peak. Though some sectors present a *plateau* morphology, they have steep slopes associated to cut valleys created the strong basins draining the area.
Though there is a high lithological variability in the sector, some specific zones are widely homogeneous, specially in calcareous and dolomitic areas. Several litological units were established grouping stratigraphic series with a certain degree of coherence, in order to analyze the different geological substrates (table 1).
As it is showed on table 2, the climatic characteristics are typical of a mediterranean area with some continental influence.

Table 1. Lithologies, wildfire date and affected area studied

Lithology	Code lithology	Wildfire date	code wildfire	Surface analysed Km^2
Limestones and dolomites	A	6/07/78	78	**3.21**
Limestones and dolomites	A	17/07/79	79	**44.85**
Marls and limestones intertwined	B	17/07/79	79	**6.59**
Marls, gypsum and clays (Keuper)	C	17/07/79	79	**3.44**
Limestones and dolomites	A	19/07/84	84	**5.08**
Marls and limestones intertwined	B	19/07/84	84	**1.80**
Marls, gypsum and clays (Keuper)	C	19/07/84	84	**1.31**
Limestones and dolomites	A	27/07/85	85	**57.50**
Marls and limestone intertwined s	B	27/07/85	85	**4.27**
Marls, gypsum and clays (Keuper)	C	27/07/85	85	**1.02**
Limestones and dolomites	A	05/08/90	90	**4.27**

Table 2. Mesoclimatic characteristics

Meterological station	*Geographic position*	*Climate type (Thornwaite)*	*Martonne Aridity index*	*Gaussen Hydric deficit*
Ayora, la Unde	39º05',1º03'W, 1.193 m	D B'2 d b'4	20,2	10,3
Cofrentes	39º14' N, 1º03'W, 394 m	D B'3 d b'4	17,6	9,1
Teresa de Cofrentes	39º06'N, 1º02'W, 561 m	D B'2 d b'4	15,4	7,9
Enguera, las Arenas	38º55'N, 0º54'W, 826 m	C1 B'1 d a'	21,1	10,7

From the bio-climatic point of view, and applying the methodology of Rivas-Martínez (1987), the area of study is into the type meso-mediterranean medium, with the exception of some bottom parts of the valley, classified as meso-mediterraneum low. Regarding the ombroclimate, the entire area is inside the dry dominium.

The potencial vegetation of La Muela and Caroche would be composed of oaks (*Quercus rotundifolia*), but the degradation by continuous fires since the decade of 1960, as reported on table 1, reduced them to small forests (Costa, 1986). The current vegetation, as defined by the II Inventario Forestal Nacional and corroborated by field tests, is dominated by large areas with xerophyta bush (*Quercus coccifera, Juniperus oxycedrus, Ulex parviflorus, Rosmarinus officinalis, Thymus vulgaris*). There are some local and small patches of *Pistacia lentiscus*. In deep soil and shaded areasthey show up some plants like *Arbutus unedo* and *Quercus rotundifolia*. The most common trees is *Pinus halepensis*, at some areas together with *Pinus pinaster.* Soils are not deep, in general, and only those parts located on shaded areas have a clearly defined humiferous layer. There is evidence of erosion processes in those sectors with non permeable lithologies and sparse vegetation. Over the marls and clays from the Keuper there are large *rills* and *gullys*. Fast erosion can be also appear in some limestone areas with inserted marls and sparse vegetation.

3. METHODOLOGY

3.1. Image analysis

The satellite images were preprocessed and georeferenced to UTM coordinates, using ground control points and obtaining a geometric accuracy of 0.684 pixels. Since the indicator of the evolution of the vegetation is the NDVI derived from the satellite images it is necessary to check and to radiometrically correct these images.The images ought to have been corrected for the effects that the atmosphere has on the radiation, but due to the lack of data that explains the behaviour of the atmosphere, it was decided just to compare the radiometric properties of the two images used in the study. For this a correction was carried out to adjust the average and standard deviation of one image in relation to the average and standard deviation of the other, so that the histograms of the two images were comparable.

In order to work only on areas with spontaneous natural vegetation, the rest of the areas (urban, agricultural lands, water bodies, etc.) were masked out by means of a supervised classification using a Landsat TM image. The training areas to be used by the classifier were extracted with the support of an exhaustive interpretation of the aerial photographs. After a separability analysis, five bands were used, and a trained maximum likelihood classifier considering *a priori* probabilities extracted from previous works on the area (Pardo, *et al.*, 1999). The result was evaluated using a confusion matrix, achieving a overall accuracy rate of the 97,1%.

Other two masks were created, one of them for non burned areas, and the other for non studied lithologies. After application of the three masks over the total set of data (multispectral images, NDVI images and topo-climatic variables), twelve study areas with spontaneous vegetation that had suffered several forest fires at different dates were finally obtained.

3.2. MDT analysis

The way in which vegetation is regenerated after a fire is unavoidably related to the topography of the terrain it occupies. Based on digital elevation models it is possible to deduce in a quantitative way some topographic characteristics –with very clear topo-climatic significance—such as the slope and the curvature, catchment areas, as well as other factors directly linked to the topography of the area such as the potential solar radiation.
From the digital elevation model of the Spanish Army Geographic Service (SGE), with a 25m x 25m grid size, maps of slope, orientation and catchment specific areas were calculated. This DEM was also used as the basis for calculating solar radiation.

3.2.1. Curvature and slope map. For each cell of the DEM, the variation in altitude around the point is calculated in the directions X and Y, using the following expressions. (Felicísimo,1994):

Considering the 3x3 neighbourhood:

$$p = \frac{\partial z}{\partial x} = \frac{(z_{i-1,j+1} + z_{i,j+1} + z_{i-1,j+1}) - (z_{i-1,j-1} + z_{i,j-1} + z_{i-1,j-1})}{6.h}$$

$$q = \frac{\partial z}{\partial y} = \frac{(z_{i-1,j-1} + z_{i-1,j} + z_{i-1,j+1}) - (z_{i+1,j-1} + z_{i+1,j} + z_{1+i,j+1})}{6.h}$$

Considering a 5x5 neighbourhood:

$$p = \frac{\partial z}{\partial x} = \frac{(z_{i-2,j+1} + z_{i-1,j+1} + z_{i+1,j+1} + z_{i+2,j+1}) - (z_{i-2,j-1} + z_{i-1,j-1} + z_{i+1,j-1} + z_{i+2,j-1})}{20h}$$

$$q = \frac{\partial z}{\partial y} = \frac{(z_{i-1,j-2} + z_{i-1,j-1} + z_{i-1,j+1} + z_{i-1,j+2}) - (z_{i+1,j-2} + z_{i+1,j-1} + z_{1+i,j+1} + z_{i+1,j+2})}{20h}$$

where z=f(x,y) is the elevation stored in the DEM and h is the cell size, in this case 25 metres.

By increasing the size of the neighbourhood, the values of the heights of the pixels around the central point are not considered although they are the points for which the parameters are calculated, from which it can be concluded that increasing the number of neighbours and thereby the amount of data, does not improve the calculation and it is necessary to look for other methods in which we can be sure that all the elevations are used with a significance or weight in function of their distance from the central point.

From these values it is possible to calculate the slope of the terrain **α**, creating an image with the same dimensions as the original, in which each point stores the value of the slope calculated with the following expression (Felicísimo,1994):

$$\alpha = \frac{1}{\mathrm{tg}\sqrt{p^2 + q^2}}$$

To calculate the curvature the variation in the slope is calculated around a point (or in this case grid cell). It is possible to calculate what is called the curvature profile K_v (curvature of a normal section of land surface by a plane which includes an external normal vector and a gravity acceleration vector in a given point of the land surface) and curvature surface K_h (curvature of a normal section of the land surface, this normal section is orthogonal to the section with K_v in a given point of the land surface (Florinsky and Kuryakova,1996). Each of these parameters, calculated using the expressions given below, is created in the form of an image:

$$k_h = \frac{-(q^2 r - 2pqs + p^2 t)}{\left[\left(p^2+q^2\right)\sqrt{(1+p^2+q^2)}\right]}; \qquad k_v = \frac{-(p^2 r + 2pqs + q^2 t)}{\left[\left(p^2+q^2\right)\sqrt{(1+p^2+q^2)^3}\right]}$$

where,

$$r = \frac{\partial^2 z}{\partial x^2}; \quad t = \frac{\partial^2 z}{\partial y^2}; \quad s = \frac{\partial^2 z}{\partial x \partial y}$$

Considering a tt x tt neighbourhood:

```
w=(tt-1)/2
for i=w,m-w do begin
        for j =w,n-w do begin
                for ss =-w,w do begin
                r(j,i)=(a(j-w,i+ss)+a(j+w,i+ss)-a(j-(w-1),i+ss)-a(j+(w-1),i+ss))+r(j,i)
                t(j,i)=(a(j+ss,i-w)+a(j+ss,i+w)-a(j+ss,i-(w-1))-a(j+ss,i+(w-1)))+t(j,i)
                end
```

$$s(j,i) = \frac{(a(j+w,i-w) + a(j-w,i+w) + a(j-(w-1),i-(w-1)) + a(j+(w-1),i+(w-1)) - a(j-w,i-w) - a(j+w,i+w) - a(j+(w-1),i-(w-1)) - a(j-(w-1),i+(w-1)))}{4*(tt-2)*d^2}$$

$$r(j,i) = \frac{r(j,i)}{tt*(tt-2)*(d^2)}$$

$$t(j,i) = \frac{t(j,i)}{tt*(tt-2)*(d^2)}$$

```
        end
end
```

From the curvature profile and curvature area images it is possible to obtain a third image **H**, calculated as the average of the other two (Florinsky & Kuryakova, 1996):

$$H = \frac{k_h + k_v}{2}$$

With the topographic parameters defined and stored in images of equal grid size, number of rows and columns and with the same geographic reference, a single image called the multivariable digital model (Felicísimo,1994) is created, in which each of the bands corresponds to each of the topographic characteristics calculated above. To this multivariable model can be added some more bands such as the potential solar radiation and the normalised vegetation indices.

3.2.2. Calculation of the upslope catchment area. One of the factors that, together with the slope, the orientation and the curvature, defines the terrain is a map indicating the water accumulation potential of each point. This stores for each point the number of other points on the map from which water would drain to that point. To calculate this parameter it is first necessary to produce a map of flow directions; a possibility offered by the Arcview Spatial Analysis program.

The values represented in a flow direction map are eight numbers each corresponding to the eight directions that the water could flow into adjacent cells. The direction of the water flow is determined by comparing the elevation of the pixel with its eight immediate neighbours..

The directions are:

E $\rightarrow$ 1	W $\rightarrow$ 16
SE $\rightarrow$ 2	NW $\rightarrow$ 32
S $\rightarrow$ 4	N $\rightarrow$ 64
SW $\rightarrow$ 8	NE $\rightarrow$ 128

Once the direction map has been calculated it is possible to define the accumulated areas as a function of the eight direction values. Thus the cells with the highest values are the areas which collect water draining from other cells and the areas with 0 value correspond to elevated areas which drain into the neighbouring pixels. These pixels are found on the watersheds and can be used to delineate the drainage basins.

The calculation of the catchment specific area does not consider either evapotranspiration or infiltration of the water into the ground although it is still useful for showing the places where water could accumulate, areas which due to their greater humidity, a priori, favour regenerative processes, especially in areas like the study area where the lack of water is a determining factor in the characterisation of vegetation species.

3.2.3. Potential Solar Radiation Maps. To calculate an solar radiation map it is necessary to use two types of information (Ruiz *et al.* 1999):

- data that vary in time, that is depending on the position of the sun in each instant, and
  the incident solar radiation at a specific place and a particular time depends on:
  - the solar constant (α) : the radiation received by a 1 cm^2 surface at the top of the atmosphere,
  - the position of the sun : the height of the sun above the horizon (h) and its azimuth (A),
- data that vary in space, referring to the position of the point receiving the solar radiation.
  - latitude (φ), slope (β) and orientation (θ)

The solar radiation at the top of the atmosphere (R_a) can be deduced from the solar constant and the height of the sun:

$$R_a = \alpha \cdot \sin h$$

The incident radiation on an area on the surface of the Earth (R_s), taking into account the alterations due to the effect of the atmosphere, can be calculated using the expression:

$$R_s = R_a \, [\, (0{,}29 \cos \varphi) + (0{,}54 \; n/Na) \,]$$

in which the top of the atmosphere radiation is seen to be modified by the latitude and the cloudiness (n/Na). Although this formula includes a correction to the solar radiation due to cloudiness, since the study area is not extensive, and as there were no meteorological stations that could provide reasonable cloudiness measurement, it was considered that the clouds would have affected the whole area to the same degree and that, therefore, cloud cover did not cause spatial variations. The map calculated shows the maximum direct solar radiation over the area, which is considered proportional to the real radiation taking into account the effect of clouds.

The data referring to each point where the solar radiation is incident correct the values in function of the slope and orientation of each point.

Using the formula proposed by Lambert the following expression is obtained:

$$R_i = R_s \, [(\cos h \sin \beta \cos (A - \theta)) + (\sin h \cos \beta)]$$

by which is calculated the energy received (R_i) at any time for each cell. However, this formula does not take into account the effect of shadows caused by the relief, but rather it calculates for each cell whether it receives radiation and how much. For this reason the projected shadows were deduced for each instant calculated.
In order to know the importance of the effect of the solar radiation on the distribution of the vegetation it is necessary to create an annual solar radiation map. For this it is necessary to calculate the direct radiation for every instant in the year. However this calculation would generate a huge and unmanageable volume of data, making it reasonable to determine representative moments that would explain the radiation behaviour with a smaller volume of data. From the study of the optimisation of the calculation of the annual potential solar radiation presented by Urbano (1999) it has been deduced that with 105 sun positions it could be generate a significant map of this variable.
The map of potential solar radiation calculated by a program developed by us, is created by the integration of each of the moments selected, and its geometric properties (25 metre grid step) coincide with the digital elevation model used to produce it.

4. RESULTS

Once the ten parameters of topographic origin are calculated, the values are correlated in each of the xx homogeneous units of study with the NDVI corresponding to the two analyzed dates, to include the differences between both. First, the results which demonstrate hydrological parameters are presented, then those associated with thermal parameters.

4.1. Study of the curvatures

The correlation coefficients show a very bad relationship between the curvature parameters and NDVI values. These bad correlation index are observed for each of the curvature parameters, types of material, and fires studied. All of the cases yield very low values, which shows that neither the profile nor the surface of the curvature present a significant relationship with the recovery process of the vegetation. As well, the tendencies, which should presumably always be negative, are not constant, which reaffirms the weak significance that this parameter displays.
It is interesting to observe that none have improved as a consequence of the different location considered. In fact, due to the slight significance neither an improvement nor a deterioration are noticed.

4.2. Upslope Catchment area

The parameter of the upslope catchment area (CA) does not present a significant degree of correlation –its indexes oscillate between –0.09 and 0.09—with the development of vegetation either. The values, as seen with the curvature parameters, do not only present a very low correlation coefficient, but also in some cases, contrary to prediction, show negative correlations. From the results obtained, it can be deducted that the hydrological factors show very little significance in the distribution of the vegetation, regardless of the lithology in which it is located.

4.3. Slope

The slope of the land shows little direct correlation –oscillating between –0.15 and 0.32—, with values higher than those of K_v, K_h, H and CA, but in any event always low and, more importantly, with different tendencies. In reality, the slope should not establish a direct relationship but instead its influence should only be significant in places with very steep slopes, where these inclines impose a limitation for the development of life. In any event, assuming that the values are significant in areas where the slope is indeed a limitation, that significance is underestimated, as the dimension of the pixel imposes a certain degree of generalisation of the land forms. In this way, the map of slopes does not come to recognise spaces with slopes greater than 45º when, in reality, they exist. On the other hand, the amplification of the area does not elevate the significance in any way.

4.4. Potential direct solar radiation

This, of all of the parameters analyzed, is the only one that shows well defined correlation indices and, in some cases, show a clear influence of the distribution of the vegetation, as has been shown in previous works (Pardo *et al.*, 1999, Pardo *et al.*, 2000, Urbano, 1999). From the figures obtained, ideas can be deducted that signal the importance of (i) the solar radiation values for the growth of vegetation, (ii) the lithology and (iii) the time passed since the fire.

Table 3. Correlation coefficient´s potential solar radiation vs. NDVI of the burned areas

		dif-ndvi	ndvi87	ndvi94		dif-ndvi	ndvi87	Ndvi94		dif-ndvi	ndvi87	ndvi94
FIRE-1978	*solar radiation*	-0,25	-0,12	-0,24		X	X	X		X	X	X
FIRE-1979	*solar radiation*	-0,30	-0,42	-0,50		-0,35	-0,35	-0,46		-0,23	-0,21	-0,37
FIRE-1984	*solar radiation*	-0,30	-0,18	-0,32		-0,40	-0,53	-0,64		-0,38	-0,10	-0,33
FIRE-1985	*solar radiation*	-0,11	-0,23	-0,23		-0,39	-0,34	-0,46		-0,65	-0,33	-0,66

First, we should emphasize that once sufficient time has lapsed a clear relationship is established between the solar radiation values and the values of NDVI. In all of the cases it has been observed that the areas that receive more energy are those that register lower NDVI values. In the graph xx the relationship between the mean NDVI of the studied zone and the mean solar radiation values is displayed. The regression line that shows the signaled tendency is exhibited.

In any event, significant difference according to the type of underlying material is observed: the areas in which impermeable materials are found -marl, clay - although interspersed between permeable materials, show a more clear relationship between solar radiation and NDVI than others in which only permeable materials are found (such as limestone and dolomite).

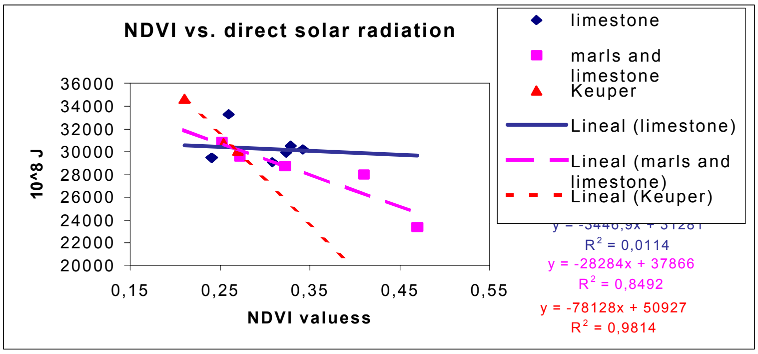

Fig. 1

To assess the significance of the solar radiation, first the regenerative process of the vegetation covering itself should be characterized. In areas close to the studied zone although somewhat more humid, as is the Garraf plot, close to Barcelona in Catalunya , it has been observed that in two or three years the coverage has reached 90%. In even more humid areas like the forests of *Pinus sylvestris* of Ripollès, in the Catalonian Pre-Pyranees it has been observed five years after the fire that the foliage index has reached its maximum level (Gracia and Sabaté, 1996). The study of the NDVI evolution in on our zone of work is separate from this, the process of regeneration is much more slow, observing a tendency to increase the NDVI even after 15 years have passed. This expansive tendency of vegetation is larger with the alternate series of marl and limestone than with the areas in which only limestone is found.

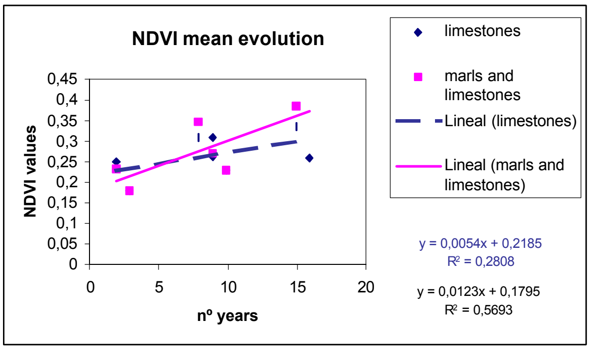

Fig. 2

It is due to this that the control of the solar radiation over the vegetation tends to grow, with the passing of years after the fire. The fig.2 shows the tendency lines over the negative correlation, in fact, if the correlation indices presented in table xx are analyzed, it can be observed that in all cases there has been improvement between 1987 and 1994. On the other hand, it deserves to be emphasized that the correlation values are larger in those areas in which we find marl with limestone interspersed as opposed to those which are composed only of limestone. The values of those two are more significant than those of sections of Keuper (formed by clay, marl and gypsum), and the worst correlation being found in the calcareous materials.

That said, that the slight adjustment of the regression line can be observed over all the lithologies, due as much to the NDVI values as to the level of correlation with the potential solar radiation, is profoundly marked by local factors.

The studies of detail - using area and field photographs - demonstrate that the places in which the solar radiation does not show an elevated significance are often associated with (i) the ground in a determined region that maintains the greatest predictable humidity for lithological changes neither reflected in the geological cartography of the zone, nor by the underground water surges and filtrations that accumulate a proportion of water in the ground greater than predicted, or (ii) the fire affecting the area in an disproportionate manner (Pardo, *et al.*, 2000).

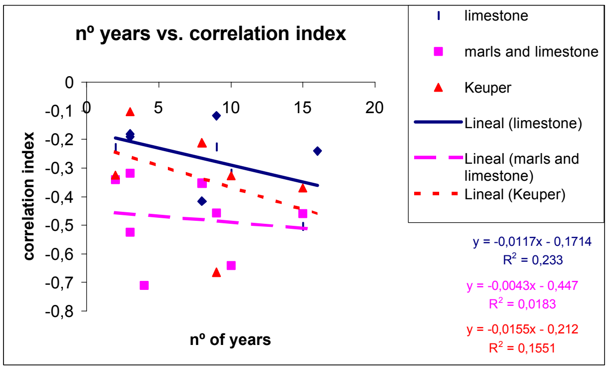

Fig. 3

5. DISCUSSION AND CONCLUSIONS

Of the results presented that, without a doubt, call for the most attention are, on one hand, the modest significance that the hydrological parameters show when considering the recovery of vegetation and, on the other, the high significance that is shown by the potential solar radiation in this same matter. There are many studies that demonstrate the importance of the different curvature parameters, and the specific valley has concentrated an accumulation of water, especially those associated with underground flows (Florinsky, 1998, Moore *et al*., 1991, Franklin, 1995). In the Florinsky and Kuryakova study (1996) in the mountainous region of Rudni Altai (East Kahazstan) correlation values were quite high (between -0.28 and -0.60) between the three curvature parameters studied here and the distribution of vegetation. It also reached significant correlations between the CA parameter and the vegetation cover. What could be the reason for the weak level of significance in our case? One possible explanation could come from the particular conditions of the ground in the area studied. The thickness in all of the cases is very small - it rarely reaches 10cm, and in many cases, in sunny areas above all, remains reduced to the superficial humiferous layer- so that the underground flows in these slopes will have little significance and the storage of water will always be scarce. The rains themselves are generally scarce and badly distributed - the mean number of days of rain annually oscillates between 30 in the drier zones and 60 in the zones with more rain - as a minimum in the summer. However, the areas where the humidity of the soil is maintained during a longer period of time is determined by those regions which have a lower evapotranspiration and, in that case, depend fundamentally upon the intensity of the solar radiation that they receive. It can be concluded, therefore, that in areas like the one studied, with a contrasting Mediterranean climate, and with the soil very little deep, the most significant exogenic factor for the recovery of the vegetation cover after a forest fire is the availability of water, which is profoundly influenced by the rate of solar radiation it receives, and the capacity to store water, which, in turn, is determined by the type of rock found there.

The work presented here shows that the employment of MDE and their MDT derived from satellite images allow us to explore environmental relationships on a microscale. This could, with difficulty, be carried out with other methodologies, which could, in turn, establish deductions of great significance in the functioning of ecosystems.

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