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Land terracing for new vineyard plantations in the north-eastern Spanish Mediterranean region: Landscape effects of the EU Council Regulation policy for vineyards' restructuring

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Abstract

The landscape of Mediterranean mountain areas in north-eastern Spain, in particular lands traditionally devoted to vineyard cropping, is rapidly changing. This is due to new terrace construction, being built without any environmental impact considerations utilizing heavy machinery. The European Union regulation policy for vineyards' restructuring, which subsidize up to 50% of the land terracing costs, encourages this activity. A clear example of this situation occurs in the Priorat region (Catalonia, NE Spain), where vineyards were first cultivated in the XII century on hillslopes with terracing systems utilizing small stone walls. However, since the 1980s–1990s, the viticulture boom is based on a new terracing system, relying on mechanization and resulting in high negative environmental and landscape impacts. This paper tackles several aspects that this modern land terracing/vineyard system has initiated in the Priorat: (a) the land use changes and rates of changes during the last two decades, in order to determine the magnitude of the environmental and landscape dynamics problem, (b) the assessment of the terrain morphology changes due to land terracing (volumes of soil displaced, slope morphology and slope degree changes) and (c) an analysis of the cost of the restructuring operations, mainly land terracing, subsidized by the EU policy for vineyards' restructuring. In this respect, the effects of this policy are discussed. The results show that modern land terracing methods produce huge material displacements (about 9460 ± 900 Mg ha^{-1}). These figures approximate the range of catastrophic natural mass movements and confirm land terracing as an antrophic geomorphic processes which is rapidly reshaping the terrain morphology. Land terracing costs, which represent 34% of the total costs for a new terraced vineyard, is the operation which receives the maximum EU subsidy. This has encouraged vine growers in the Priorat region to create new plantations, increasing significantly the transformation rate from 7.5 ha year^{-1} between 1986 and 1998 to 36.1 ha year^{-1} in the 1998–2003 period.

Keywords: Land terracing; Land use change; Vineyards' restructuring; Landscape effects; EU policy

1. Introduction

One of the most distinctive components of the landscape of Mediterranean mountain environments is agricultural terraces (Douglas et al., 1994, 1996; Gallart et al., 1994; Dunjó et al., 2003). They are mostly cropped in almond, hazelnut and olive trees as well as vineyards. Most of the historical terraces are of bench type with stone walls. They needed a large amount of labour since they were built and maintained by hand. Their main function is soil conservation, accomplished by reducing slope on the cultivated land and allowing run-off from the upper side of the terrace to spread out and infiltrate on the bench portion. While conserving soil and water and facilitating a more intensive cropping in steep lands (Landi, 1989), land terracing has introduced specific human induced geomorphic processes, that often are the most effective soil erosion and landscape changing processes acting at the field and hill-slope scales (Borselli et al., 2006).

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Although, during the last 50 years, land levelling and terracing have gained an important role in European agriculture, whenever and wherever the profit (market trends and subsidies) was threatened by local morphology (Zalidis et al., 2002; Borselli et al., 2006), problems or impacts associated with their implementation have not been widely studied. One of the best examples of extensive land levelling, promoted by agricultural policies, is Norway (Lundekvam et al., 2003). It was extensively introduced during the 1970s when subsidies encouraged the alteration of ravine landscapes into arable land. In other countries such as Hungary, Italy, Portugal or Spain, land levelling and terracing operations have concentrated on mechanized vineyard cultivation (Borselli et al., 2006). In Italy, particularly in Tuscany, vineyard plantations increased by 90,000 ha from 1968 to1975. Here soil movement due to land levelling was estimated at 300 Mg ha^{-1} $year^{-1}$ (Borselli et al., 2002).

In Spain, the admission to the European Union after 1986 has been one of the main driving forces for agriculture development. The acreage of rainfed tree crops such as almonds and olives has expanded rapidly in the south east (Faulkner et al., 2003; Van Wesemael et al., 2004). Vineyards have also increased areally, even into marginal areas, encouraged by policies that subsidize the conversion of old to new plantations to favour qualified productions. This expansion into marginal areas is stimulated by the EU Common Agricultural Policy which directly subsidizes modernisation of extensive plantations as well as supports rural development and the agro-industry (Beaufoy, 2003). In vineyard areas of NE Spain, such as the Penedès (Catalonia), this has led to increases in land levelling to reduce slope gradient and increase field size, removing old terraces and reshaping the land for the creation of modern mechanized plantations (Jiménez-Delgado et al., 2004). These authors reported that slope lowering by levelling without the implementation of broadbase terraces increased average annual soil loss by 26.5%.

Operations for land transformation as levelling or terracing are poorly regulated. Design and implementation usually rely on the field owner or on the person in charge of the machinery. No technical guidance is available (Borselli et al., 2006). In addition, land transformation operations are usually not or scarcely regulated by environmental impact laws. To a large extent, levelling or terracing escapes any environmental or legal controls.

A clear example of this situation is the Priorat region (Catalonia, NE Spain) (Fig. 1). This wine producing area traditionally had vineyards with terracing systems limited to small stone walls (Fig. 2). The maximum zenith of vineyards was in the late 18th and 19th centuries, when vineyards occupied 74% of the land (Morera, 1915). This traditional terracing system did not produce a significant topographic transformation of the landscape, since it did not build level or nearly level platforms, which would have required large cutting and filling. During the first half of the 20th century, a crisis in the agricultural sector resulted in the depopulation of rural area and concomitantly deintensification and abandonment of agricultural land (Douglas et al., 1994, 1996; Lasanta et al., 2001). This situation was only partially overcome in the Priorat in the 1990s, when a small group of producers introduced new vinification and marketing techniques, which pushed the wines towards the top of the international market.

The expansion of vineyards was stimulated by the EU Common Agricultural Policy through the restructuring and conversion plans (Commission Regulation EC No. 1227/2000 of 31 May 2000, which specifies detailed rules for the application of Council Regulation EC (1493/1999) as regards production potential). The main objective of these plans is to adapt production to market demand. The policy considers both compensation for the loss of earnings during

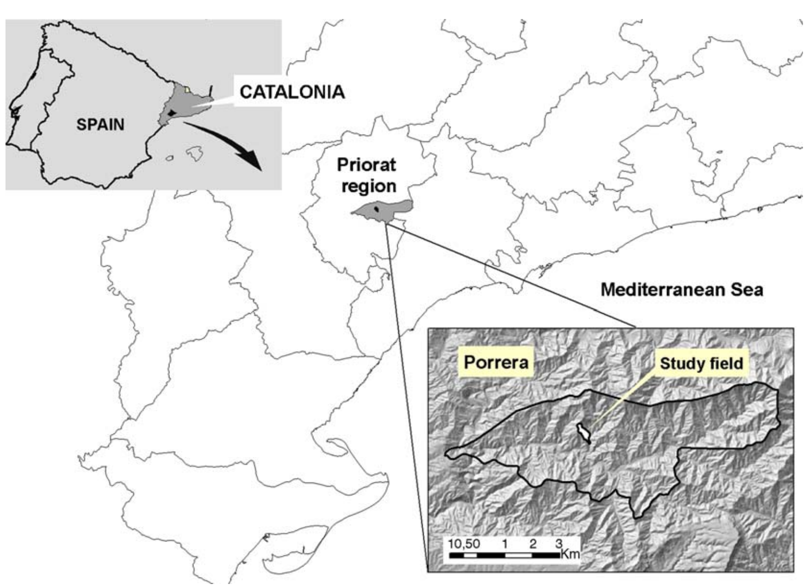

Fig. 1. Location of the study area.

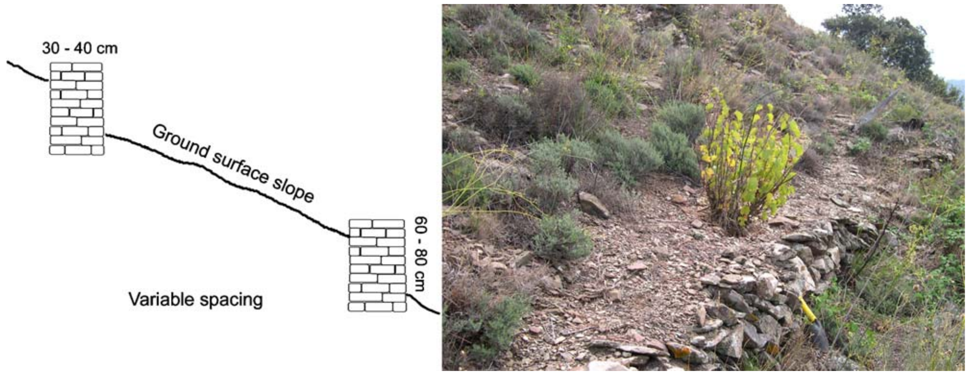

Fig. 2. Example of stone walls that composed the terracing system in the Priorat region in the past.

the period of conversion and for conversion measures itself. The subsidized measures (up to 50% of the cost or 75% in regions classified as Objective 1) include varietal conversions, relocation of vineyards or improvements of vineyard management techniques. Among those measures, the ones with the greatest impacts on the landscape are actions included in the relocation of vineyards package, and in particular new mechanized terrace construction.

In this paper, we tackle several aspects of the changes that this modern land terracing system is introducing in the Priorat region: (a) the land use changes and rates of changes during the last two decades, to assess the magnitude of the problem, (b) the assessment of the terrain morphology changes due to land terracing (volumes of soil displaced, slope morphology changes and slope degree changes), based on a sample field, and (c) an analysis of the cost of the restructuring operations, mainly land terracing, that are subsidized by the EU policy for vineyards' restructuring; in this respect, the effects of this policy are also discussed.

2. Material and methods

2.1. Study area characteristics

The analysis of land use changes and the impacts of the modern land terracing system for new vineyard plantations were carried out in the Municipality of Porrera (Priorat, NE Spain), located between UTM 31n T coordinates: East 313375–325906, North 4560119–4565062. The municipality is a representative sample area of the changes going on in the region. Its area, 2896 ha, represents 16.5% of the QDO Priorat. The main land uses are: scrubland (47.8%), forest (28.5%), vineyard (7.1%) and rainfed fruit trees (14.4%). These are similar to those found throughout the QDO Priorat: scrubland (55.6%), forest (18%), vineyard (9.2%) and rainfed fruit trees (10.9%). Porrea's climate is Mediterranean temperate with a continental influence, having an average annual temperature of 15 °C (ranging from 6 to 23 °C). Average rainfall ranges from 450 to 650 mm, concentrated in spring and autumn.

A sample field of 14.3 ha (Fig. 1) was selected to study the impacts of the new land terracing system. This field's elevation ranges from 290 to 478 m, with an average slope of 49.6%. Average slopes in the municipality are $46 \pm 17\%$. The main land use on the sample field is terraced vineyard (12.3 ha). There are other minor uses: traditional vineyard 0.6 ha, forest 0.8 ha, scrubland 0.4 ha and rainfed trees 0.2 ha. Mechanized terracing was carried out between 2000 and 2003 using retroexcavators and bulldozers, following the usual criteria and methodology for new land transformations in the Priorat region. That is: the terraces are of the linked bench type (Landi, 1989) developed in the field without plans. Their construction is based on the expertise of the retroexcavator driver, the number of terraces, the spacing between terraces and the slope of the riser depend on the slope of the original ground surface and the target width of the bench, about 2.5 m, which allows two vine rows per bench. All these characteristics make the selected field a typical location allowing us to extrapolate the results to the sample municipality.

2.2. Land use change analysis

The analysis estimates the magnitude of changes occurring during the last two decades in the Municipality of Porrera (Priorat) resulting from new vineyard construction using the new land terracing system. Data were collected for 1986, 1998 and 2003. Detailed land use maps were derived from aerial photographs from 1986 flights (approximate scale of 1:18,000, Cartographic Institute of Catalonia) and a 2003 flight flown specifically for this research (approximate scale of 1:10,000). For 1998, an orthophoto (1:5000) produced by the Cartographic Institute of Catalonia was used.

Land use maps of 1986, 1998 and 2003 were created by delineation of the corresponding cartographic units on 1:5000 orthophotos, which were generated from the ortorectification of aerial photos from the 1986 and 2003 flights. The ortorectification process used MiraMon v 4.0 (CREAF) software and 1 m digital elevation models derived as described in Section 2.3. For the 2003 map, the delineations were field checked in the sample areas to validate the class interpreted from the aerial photos with the reality. This process also served to establish the photo-interpretation elements that were used to produce the 1986 and 1998 maps. The following land use classes were considered: dense forest, open forest, scrubland, rainfed fruit trees, abandoned fruit rainfed trees, traditional vineyard, new terraced vineyard, urban area, river bed and other minor uses. ArcGIS 9.0 was used to delineate the land use maps and to analyze the changes.

2.3. Terrain modelling and assessment of morphology changes

The landscape change morphology assessment resulting from the mechanized land terracing was based on relief reconstruction previous to the construction of the terraces (1986) and after (2003). This analysis was undertaken in the sample field (Section 3.1). Since terrace construction is not based on a planned design, no land survey for building the relief model was available. For this reason, relief modelling was based on restitution of aerial photographs and later calculation of digital elevation models (DEMs).

Both DEMs (1986 and 2003) were derived from spatial interpolation of height data (2 m spaced contours and spot heights) extracted from the previous mentioned stereo pairs. Altitude data were produced by a digital photogrametric restitution process using Digital Image Analytical Plotter (DIAP) software.

From these data and additional break lines to shape the form of the terraces, two Triangulated Irregular Networks (TINs) were created using the capabilities of the 3D Analyst extension of ArcGIS 9.0. The TINs were used to interpolate height for the center-cell position of all cells in both regular output grids. The horizontal resolution given to the grids was 1 m and the vertical resolution was 0.1 m.

Systematic errors in the generation of elevation data were assessed by comparison of the two DEMs in areas without changes between the two dates. For that, nine control areas representing 1% of the study area were selected. For each one the mean of the elevation differences between the two DEMs (2003–1986) was computed (x_i). From these local elevation difference means, the mean of all control areas was computed (X). This value (0.27 m) was subtracted from the value of each 1986 DEM cell to correct the systematic errors with respect to the 2003 DEM. The deviation in the elevation differences between the two DEMs (95% confidence interval) was assumed as twice the square root of the sum of the variances of X with respect to each x_i. The resulting value (0.0868 m) was used to compute the deviation of the elevation difference estimations.

The quantification and location of terrain morphology changes due to land terracing was based on the calculation of land movements involved in the construction of the terraces (Eq. (1)) and the calculation of slope differences (Eq. (2)).

$$V = ([\mathrm{DEM2003}] - [\mathrm{DEM1986}]) \cdot \mathrm{GR}^2 \qquad (1)$$

where V: volumetric difference (m^3), [DEM2003]: Digital Elevation Model of the year 2003 (m), [DEM1986]: Digital Elevation Model of the year 1986 (m) and GR: Horizontal grid resolution (m) (1 m).

The application of Eq. (1) in raster or grid based GIS results in a new raster with the volumetric changes between the two dates per cell. A negative value in the cells in the volumetric difference map is interpreted as a cut or surface lowering, a positive value as a fill and a very low or zero value as no change.

For the calculation of slope degree differences, terrain slopes were previously derived from the DEMs by applying the slope function of Spatial Analyst ArcGIS 9.0. Then, slope differences were evaluated according to Eq. (2).

$$\mathrm{SlD} = [\mathrm{SLOPE2003}] - [\mathrm{SLOPE1986}] \qquad (2)$$

where SlD: slope differences (%), [SLOPE2003]: slope degree grid of the year 2003 (%) and [SLOPE1986]: slope degree grid of the year 1986 (m).

3. Results and discussion

3.1. Land use change analysis

Table 1 shows land use for the analyzed periods in the study area.

Table 1 reveals that during the study period the main land use was natural vegetation (forest or scrubland). During the

Table 1
Land uses in the municipality of Porrera (Priorat) for 1986, 1998 and 2003

Land use class	1986 (ha)	1986 (%)	1998 (ha)	1998 (%)	2003 (ha)	2003 (%)
Dense forest (>40% vegetation cover)	692.8	23.9	824.6	28.5	875.7	30.2
Open forest (5–40% vegetation cover)	643.9	22.2	924.0	31.9	854.2	29.5
Scrubland	691.1	23.9	459.5	15.9	378.5	13.1
Rainfed fruit trees	386.4	13.3	232.9	8.0	150.6	5.2
Abandoned fruit rainfed trees	144.3	5.0	185.9	6.4	174.0	6.0
Traditional vineyard	255.9	8.8	95.0	3.3	106.8	3.7
Terraced vineyard	20.5	0.7	111.0	3.8	291.3	10.1
Urban area	20.7	0.7	24.0	0.8	24.9	0.9
River bed	37.1	1.3	35.6	1.2	36.9	1.3

17 year study period this ground cover only varied slightly (70% in 1986 versus 72.8% in 2003). Since 74% of the land was covered by vineyards at the end of the 19th century (1894) (Morera, 1915), this illustrates clearly the degree of the vineyard abandonment during the 20th century. This pattern is similar to other Mediterranean mountain environments which were intensively used in the past for agriculture (Gallart et al., 1994; MacDonal et al., 2000; Dunjó et al., 2003).

Regarding vineyard land changes, Table 1 shows that during the first period (1986–1998), although there was an increase in the terraced class (+441.7% compared to the 1986 area), with a transformation rate of 7.5 ha $year^{-1}$, abandonment of the old traditional plantations continued. Land cover of traditional plantations decreased, by 62.9% from 1986 to 1998. During the second period (1998–2003) a reversal in vineyard abandonment occurred. In only 5 years, terraced vineyards (mechanized construction) increased by 162.4%, at a rate of 36.1 ha $year^{-1}$ (or 0.012 ha ha^{-1} $year^{-1}$). This represents 10.1% of the area and 73% of vineyards in 2003. The same trend is observed in the whole QDO Priorat region. Vineyards have increased from 876 ha in 2000 to 1591 ha in 2003, a terracing rate of 0.013 ha ha^{-1} $year^{-1}$ which is similar to that obtained for Porrera. As vineyards increase, other agricultural uses (e.g. rainfed tree plantations and olive trees) decreased at a rate of 12.8 ha $year^{-1}$ during the first period and 16.5 ha $year^{-1}$ during the second. The result is an increasing concentration in a single crop (grapes) and hence, decreasing agricultural diversification.

Using the transformation rate, the extrapolated area in vineyards in 2008 for Porrera will be 472 ha. Even with the recent growth, this figure remains far less than the area occupied by vineyards in 1900 (66.4%) (Iglèsies, 1975). However, unlike the vineyards of 1900, contemporary vineyard growth results in significant morphological alterations in the land producing huge displacements of earth and alterations in soil properties. These environmental alterations are of such a magnitude that they will remain evident for years into the future.

Some new vineyard plantations, however, are of the type ‘‘traditional vineyards’’, since wine producers believe these produce better quality wines. Table 1 shows a slight increase from 3.3 to 3.7% for the area for this class in the second period.

3.2. Terrain morphology changes

Land terracing for new vineyard plantations utilizes heavy machinery for earth moving. The new terracing system consists of large amounts of cutting and filling per unit area (Fig. 3). This is the usual practice in other regions too (Andresen et al., 2004). This type of bench terracing produces important topographical land transformations that reduces run-off and increases water infiltration. But, problems also result such as burial of original soils, changes in soil physical and biological properties (Querejeta et al., 2000), deep gully formation (Brierley and Stankoviansky, 2003), changes in the hydrological regime, erosion of risers, mass movements increases due to the inconsistency of the new slopes (Shrestha et al., 2004) and a significant visual impact in contrast with the surrounding natural vegetation and traditional vineyard plantations.

The results of the multitemporal DEM analysis between 1986 (before terracing) and 2003 (after terracing) are detailed in Fig. 4 and summarized in Table 2.

According to Table 2, 77,746 ± 7400 m^3 (5437 ± 517 m^3 ha^{-1}) of earth materials were moved for terrace construction. Overall, a net negative balance −42,990 ± 11,200 m^3 (3006 ± 783 m^3 ha^{-1}) between cut (negative) and fill (positive) operations exists. This is attributed to a higher compression of earth materials by the heavy machinery during terrace construction. In this respect, the bulk density of the top horizon before land transformation was 1.74 Mg m^{-3}; after transformation values of 2.05 Mg m^{-3} were found (Cots-Folch et al., 2004; Abreu, 2005). This compression is favoured by surface rock crushing, which is performed before the plantation to facilitate construction and to increase water retention, although this last point is not confirmed (Cots-Folch et al., 2004; Abreu, 2005). Volumetric differences due to erosion processes are ruled out because of the short period between the study dates (17 years), the high soil infiltration rates due to high surface stoniness (between 62 and 100 mm h^{-1}, with

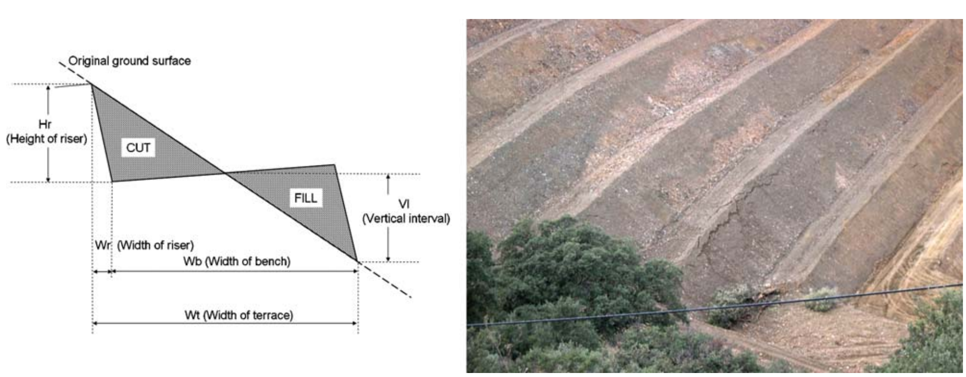

Fig. 3. Example of bench terraces constructed at present with heavy machinery in the Priorat region.

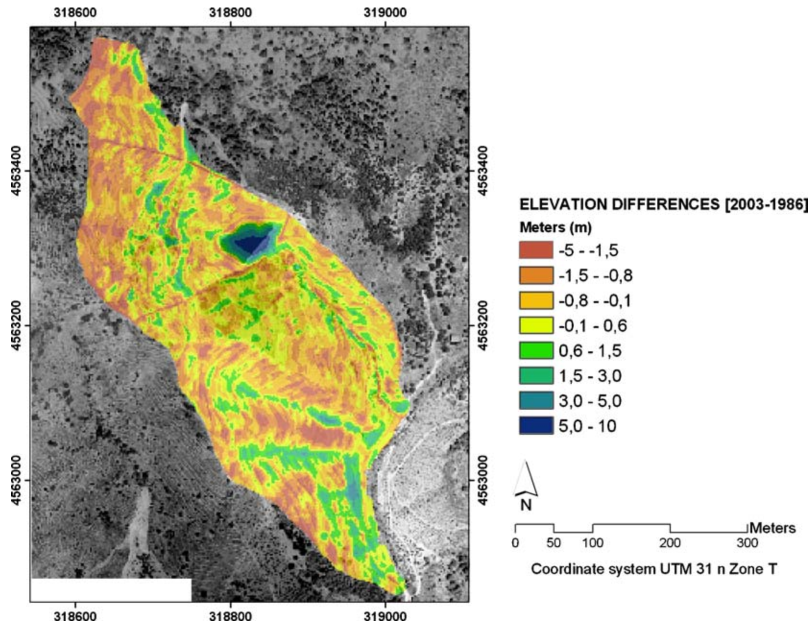

Fig. 4. Map of the elevation differences between 1986 and 2003 in the sample field study area.

simulated rainfall; Pla et al., 2004) and little field erosion observed.

The study area's earth movements associated with terrace construction are similar to those found in other Mediterranean regions. For example, Jiménez-Delgado et al. (2004) measured land movement rates of 5622 m^3 ha^{-1} in land levelling works to reduce slope gradient and facilitate machinery operations in new vineyards in the Penedès region (NE Spain). These levelling works had maximum cut and fill depths of 5–8 m. Thus, annual earth movement associated with terrace construction exceeds erosion and deposition rates, even those measured in large gullies in a yearly scale. If we consider an original bulk density of 1.74 Mg $^{-3}$, land movements in the Priorat study area account for 9460 ± 900 Mg ha^{-1} and 7027.5 Mg ha^{-1} in the Penedès area (original bulk density of 1.25 Mg $^{-3}$) (Jiménez-Delgado et al., 2004) versus 1550–2480 Mg ha^{-1} $year^{-1}$ (DeRose et al., 1998), 1322 Mg ha^{-1} $year^{-1}$ (Martínez-Casasnovas, 2003) measured in large gullies, or 302–455 Mg ha^{-1} $year^{-1}$ measured in badlands located within the Barasona Reservoir Basin in NE Spain (Martínez-Casasnovas and Poch, 1998), or 190 Mg ha^{-1} $year^{-1}$ in densely gullied badlands on black marls in SE France (Bufalo and Nahon, 1992). However, land movement rates (land terracing or levelling) are within the range of natural mass movements, which account for several tens of cubic metres to 10^5–10^9 m^3 (Shroder, 1998; Pallàs et al., 2004). This confirms land terracing and levelling as important human geomorphic processes which are able to reshape terrain morphology in a very short time scale.

A detailed analysis of the elevation difference map (Fig. 4) shows that the zones with the highest lowering or cutting values (negative elevation differences) are close to the field water divide. These areas are where land terracing works start, moving the materials to lower zones to form the bench surfaces and risers. Other areas with important cutting correspond to convex planform slopes, which were removed to build terraces as straight as possible to facilitate mechanization. The zones with higher filling (positive elevation differences) correspond to gullies, valleys and local convexities (Fig. 4), which were filled for the same reason just mentioned. In those places, filling supposes positive elevation differences between 2 and 4 m. In addition, an important positive elevation difference (up to 9 m) is observed where a pond existed. This is also a usual practice in the area to support irrigation, which is mainly used during the first 3–4 years after the plantation is established.

Regarding slope degree differences (Fig. 5 and Table 3), the average field slope changed from 49.6% in 1986 to 48.7% in 2003. However, a slope class analysis (Table 3)

Table 2
Summary of the multitemporal DEM analysis [2003–1986]

Land movement type	Affected area (ha)	Mean elevation difference (m)	Elevation difference range (m)	Volume (m^3)[a]
Extraction (cutting)	8.5	−0.91	−5.01 to −0.1	-77746 ± 7400
Addition (filling)	4.3	0.80	0.1–9.62	34778 ± 3760
Without significant changes	1.2	−0.002	−0.1 to 0.1	-19.7 ± 1000

[a] The figure after the symbol '±' indicates the deviation at 95% confidence interval.

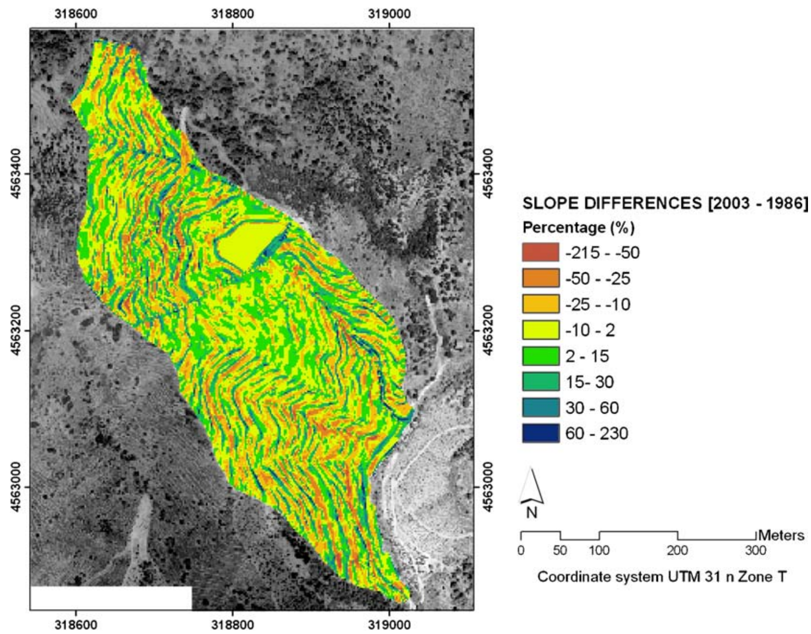

Fig. 5. Map of the slope degree differences between 1986 and 2003 in the sample field study area.

Table 3
Slope class changes between 1986 and 2003 in the sample field

Slope class (%)	Area in 1986 (ha)	Area in 2003 (ha)	Change rate with respect to 1986 (%)
0–10	0.13	0.42	+223
10–20	0.27	0.43	+59
20–40	3.09	4.53	+47
40–100	10.7	8.61	−20
>100	0.13	3.3	+2438

shows that, although the area represented by slopes 0–10% (benches) increases about 223% since 1986, the area covered in 2003 by the class >100% increases by 2438%. This reflects the steep slopes of the terrace risers (mean $39.4 \pm 9.4^\circ$, with a range between 24° and 56°). Other measures taken to evaluate the size of the terraces (20 terraces along and across the field) confirm high variability due to lack of terrace design. The terraces usually have an excessive height (Hr) (5.0 ± 3.0 m, with a range between 2.5 and 12.9 m), with a horizontal base of 2.7 ± 0.3 m. This makes terraces unbalanced when the rate between height and horizontal base is greater than 1 (Sheng, 1989) (the average is 0.8, but with a range between 0.4 and 1.5). In those cases, terrace collapse has been observed. These mass movements usually affect down slope plantation infrastructures such as terraces, paths, irrigation tubes, training sticks and wires and the own vines, which are buried (Fig. 6).

3.3. Cost of land terracing operations and possible evolution

To know the cost of the restructuring operations, mainly land terracing subsidized by the EU policy for vineyards' restructuring, and discuss the effects of this policy, cost data for starting new vineyard plantations were collected from the Regulating Council of the QDO Priorat. These costs, together with the compensation given by the EU Common Agricultural Policy for vineyard conversion measures, are summarized in Table 4. This table shows the restructuring

Fig. 6. Mass movement produced by the collapse of a riser in an area with excessive filling of materials and high slope degree.

Table 4
Cost of the creation of a vineyard plantation in the QDO Priorat

Action	Cost (€ ha^{-1})[a]	Maximum subsidy (€ ha^{-1})[b]
Uprooting	421	421
Plantation		
Soil preparation	962	962
Plant (4500 plants ha^{-1})	7437	9315
Other plantation costs	2133	240
Cost of cultivation	1052	1052
Training	3306	2705
Change from non-trained vines to trained vines	–	2849
Fence	–	4958
Horizontal lifted training	–	1772
Canary conduction system	–	8564
Soil disinfection	–	2104
Stone clearing	391	391
Land levelling	–	601
Land terracing	10818	18752
Soil reposition	–	4207
Wind walls	–	8414
Protection against rabbits	–	1202
Regrafting		
Graft (unit)	–	0.60
Other regrafting costs	–	1202
Fertilization	600	–
Pesticides	360	–
Irrigation	4508	–

[a] Prices from 2003.
[b] Maximum subsidy applied in Catalonia for vineyard restructuring actions (Order of the Catalonian Department of Agriculture 42/2003, 30/01/2003).

actions and maximum subsidy applied in Catalonia (Order of the Catalonian Department of Agriculture 42/2003, 30/01/2003). These data are used to discuss the results on landscape effects due to land terracing for new vineyard plantations.

The average cost of land terracing is about €10,818 ha^{-1} (Table 4). This represents 34% of the total costs for starting a new terraced vineyard. It is similar to the total and other plantation costs (soil preparation, plants and cost of cultivation). For 1998–2003 (Table 1), it accounts for a total investment of €1.95 million, 50% of this cost is subsidized by the EU (€0.975 million). As seen in Table 2, terracing receives the maximum EU subsidy. In this respect, the EU Common Agricultural Policy through the vineyard restructuring and conversion plans (Commission Regulation EC No. 1227/2000 of 31 May 2000) is a major determinant for development of new vineyard plantations, which is manifested in the rate of terrace construction (see Section 3.1): 7.5 ha year^{-1} between 1986 and 1998 versus 36.1 ha year^{-1} between 1998 and 2003. If this latter rate is maintained until 2008, when this subsidy policy ends, the terraced vineyard area could reach 472 ha (16.3% of the area). Based on field observations this figure is likely conservative and the final surface transformed will be higher.

This scenario of new vineyard planting euphoria likely will change when EU subsidies end in 2008 or after production begins in the new plantations. Already increased production from the new plantations has caused a decrease in prices for wine grapes. Thus, the recent EU driven planting euphoria could result in initiating a new land abandonment process in the region. Based on other documented cases, an increase in soil erosion due to a progressive degradation of the terraces and related infrastructures is a likely future scenario (Gallart et al., 1994).

4. Conclusions

In some mountain areas of the Mediterranean region, increasing vineyard terracing is being observed. These new terraces are not constructed in the traditional manner using human labour and stone walls. Their construction relies on heavy earth moving machinery. This latter method displaces huge amounts of earth materials (5437 ± 517 m^3 ha^{-1} or 9460 ± 900 Mg ha^{-1}) and results in a high landscape transformation. The figures associated with mechanized terrace construction fall within the range of catastrophic natural mass movements, from several tens of cubic metres to 10^5–10^9 m^3. This confirms terracing as an important antrophic geomorphic processes which is rapidly reshaping the terrain in many areas throughout the Mediterranean. In addition, it implies the detachment and displacement of a huge amount of soil particles, parent materials and rocks that result in the loss of the original soil profiles.

Land terracing accelerated after the introduction of the EU Council Regulation policy for vineyards' restructuring, in 2000, which subsidizes up to 50% of the construction cost. This particularly affects some mountain environments of the Mediterranean region. The cost of land terracing, representing 34% of the total costs for starting a new terraced vineyard, is the operation receiving the maximum EU subsidy (up to €18,752). This has encouraged growers in the Priorat region to create new plantations, increasing significantly the transformation rate from 7.5 ha year^{-1} between 1986 and 1998 to 36.1 ha year^{-1} in the period 1998–2003. This fast land transformation using heavy earth movement machinery is undertaken with minimal landscape planning. Primarily 'seat of paints knowledge' is used by the machinery operators in the terrace construction. Soil conservation practices are largely ignored in the construction phase. This results in situations of high geomorphologic instability, especially the collapse of unbalance risers, which can bury lower slopes while destroying terraces and associated infrastructures. This geomorphic instability could be minimized if engineering projects for correct terrace construction were demanded and monitored by the corresponding administration in charge of the subsidy proceeding control. However, it is probably too late for this to occur. Future environmental problems likely will arise in the study area due to both poor construction of the terraces and the over expansion of vineyards due to the EU subsidy.

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