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Preserving and destroying soils, transforming landscapes: Soils and land-use changes in the Vallès County (Catalunya, Spain) 1853–2004

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Abstract

In this paper we analyse the relations between land characteristics and land use, and their evolution in the Vallès county (Catalunya) since 1850. We reconstructed in digital format the 1850s cadastral maps of three villages (Caldes, Castellar, and Polinyà) and those made in 1950 of five villages (the previous three plus Sentmenat and Palau-Solità). For 1999 we used the available cadastral and land-use maps and conducted field surveys. We evaluated the suitability of land for the various agricultural uses (winter cereal, alfalfa, vineyard, olive, and almond orchards) considering the different land-use systems of 1850 and 1999. Forty to sixty percent of the land was more or less suitable for each of the land uses. Whilst in 1850 land used for agriculture was 46% of the total area and 29% was used for forest, these figures turned to 28% and 53%, respectively, by 1999. Urban and industrial areas now occupy 13% of the total land area and 47% of the best agricultural land. In 1850, 34% of the vineyards and 23% of the area with cereal crops were located on non-suitable or poorly suitable land for these uses. This shows a much more strict criterion for the location of cereal fields. But it also shows how the land-owning class tried to prevent further social conflicts by leasing their least suitable land for agriculture to the landless classes. In 1850 in the village of Caldes, 85% of the cereal fields were on slopes less than 20%, but 30% of the vineyards were on slopes of more than 30%, and sometimes up to 60–70%. Slopes protected with stone terraces occupied 700 ha, 43% of the land in agriculture in 1850, and 80% of that area was used for vineyards. Building of these terraces, which were generally small, required some 120,000 work days, and was undertaken on relatively soft geological materials while they disappear on the transition to competent geological materials. These results show that land characteristics influence land-use decision making and historical landscape changes. However, the extension of agriculture to non-suitable land in 1850 reflects deeper social conflicts, and required a vast labour investment in soil conservation by the poorest rural classes. The importance of terraces within this landscape and the land-use alternatives are also discussed.

Keywords: Agrarian conflicts; Agrarian labour; GIS; Land characteristics; Land evaluation; Soil conservation; Stone terraces; Urban development

Introduction

What role has soil played in the transformation of the agrarian landscapes? What impacts has the transformation of the agrarian land uses had on soils? Since no evaluation can be independent of the uses of the land, both questions have to be dealt with together. Hence, the answers should include not only technical and environmental factors but socio-economic dimensions seen from a historical perspective as well (Olarieta, 2000; Olarieta and Rodríguez-Ochoa, 2004; McNeill and Winiwarter, 2004, 2006).

The analysis of the relationship between soils and societies has largely concentrated on the influence of the latter over the former throughout history, particularly emphasizing the soil degradation processes that have occurred as a result of inappropriate land management practices (Davidson, 1982; Blaikie and Brookfield, 1987; Hillel, 1991). The socio-economic conditions that have led to the use of such practices within a specific time-space context are hardly analysed. A symmetrical critique is being made within the Social Sciences regarding the lack of

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analysis of the nature-society relationships in the studies of historical socio-economic transformations (Chew, 1997).

This relationship becomes an important issue when studying land degradation from a long-term historical perspective. The intensive agrarian systems developed in the most populated and commercially advanced economies of Europe from the mid-17th to the mid-19th centuries exerted strong pressures on the land (Wrigley, 2004). In these advanced European organic economies, human appropriation of above-ground biological net primary production attained higher levels than the ones prevailing in the fossil-fuel era (Haberl et al., 2001; Krausmann, 2001). Claims already made during the 19th century by authors such as James Anderson, Justus von Liebig, Karl Marx, and Lucas de Olazábal, warned against soil exhaustion and the breaking of the nutrient cycles through urban growth and widening commercial networks (Garrabou and Naredo, 1996; Foster, 2000).

However, it remains unclear whether such a high human pressure led to actual land degradation before the end of the 19th century. If it did take place, it is still being debated how widespread and serious it became, and if it interacted with other ecological changes in a way that could have led to a true unsustainable situation until a new socio-methabolic regime developed.

Several researchers have stressed the importance of the measures undertaken by peasants and communal and Estate regulations to prevent those ecological changes from leading to dangerous land degradation. Among them, the integrated management of arable land, pastures, and woodlands to provide enough manure; crop rotations to avoid weeds, pests, and the spread of bioinvasions; and terracing of sloping lands to check soil erosion (Rackham and Grove, 2001; Warde, 2006). Peasants and rural communities took care of land because they depended on it to earn their living and kept doing it for as long as that dependence on land lasted (Tello et al., 2006a, b).

Sharing this co-evolutionary approach, in previous studies we have analysed various aspects of the historical evolution of the Mediterranean agrarian systems and landscapes of the Vallès county (Catalunya, north-eastern Spain), reconstructing the energy balances of the mid-19th century and end of the 20th century (Cussó et al., 2006b), and the main land-use changes (Tello et al., 2006b) and their impact on landscape structure (Marull et al., 2006). In this paper we intend to establish the role of land characteristics in the human transformation of land, i.e. to what extent socio-economic actors with decision-making capacity allocated the various land uses in each historical period taking into account the suitability of each type of land.

Materials and methods

The study area includes 13,488 ha of the municipalities of Caldes de Montbui, Castellar del Vallès, Palau-solità i Plegamans, Polinyà, and Sentmenat in the Vallès county (Catalunya, northeast Spain), 25 km North of the city of Barcelona (Fig. 1). This area has a low relief on its southern half, with altitude ranging from 130 to 250 m, but is mountainous on the northern half, with altitudes between 250 and 815 m. The lower-lying areas have a mean annual rainfall of 600–650 mm and a mean annual evapotranspiration (Thornthwaite) of 770–800 mm, while on the higher mountains rainfall reaches 800 mm and evapotranspiration 700 mm.

Soils of the southern part of the study area have developed on relatively soft materials (Quaternary sediments, mudstones, arkoses) and are, generally, moderately deep, loamy, well drained, and have a high available-water holding capacity (AWHC). On the other hand, soil of the northern half have developed on hard parent materials (limestone, dolomite, conglomerate) on steep slopes, and they are relatively shallow, loamy, frequently stony, and have a low AWHC. Fig. 2 shows the slope map of the study area.

For this region, and with the aid of a GIS, we reconstructed the historical land use pattern from the mid-19th century cadastral maps of three of the above-mentioned municipalities (Caldes de Montbui (1853), Castellar (1854), and Polinyà (1856)) produced at a 1:3000–1:5000 scale (Fig. 3). These patterns were compared to those of the 1950 (before the industrialization of agriculture) (Fig. 4) and 1999 (latest available data) (Fig. 5) cadastral maps of all five municipalities. The choice of these dates was related to the availability of data. This historical information was refined with data gathered from cadastral records of both periods, together with agricultural information contained in various statistical surveys, and in an agricultural study of the region conducted in 1874 (Garrabou and Planas, 1998). Some errors in the 1950 cadastral maps were corrected with the information obtained from the 1956 aerial photographs.

Land suitability was evaluated for both the mid 19th and late 20th centuries following the FAO Framework (FAO, 1976) by comparing the requirements of the main land use types in these two periods with the characteristics of the various land units (areas homogenous in terms of soil, climate, and slope) in which the study region was divided (Rodríguez-Valle, 2003). Slope was one of the most influential land characteristics, its importance increasing for the highly mechanized 20th century land use types, and for cereal crops compared to vineyards and olive and almond orchards. Moisture availability, as a function of rainfall, evapotraspiration, and soil rootable depth, texture, and content of stone fragments, was the other most important land quality considered. The influence of moisture availability was estimated to be most important for cereal and forage production and less so for vineyards and olive and almond orchards.

An Index Value (Boixadera and Porta, 1991) was calculated for each land unit as an indicator of their flexibility for agricultural land use. This value is estimated as the mean score of the suitability of each land unit for

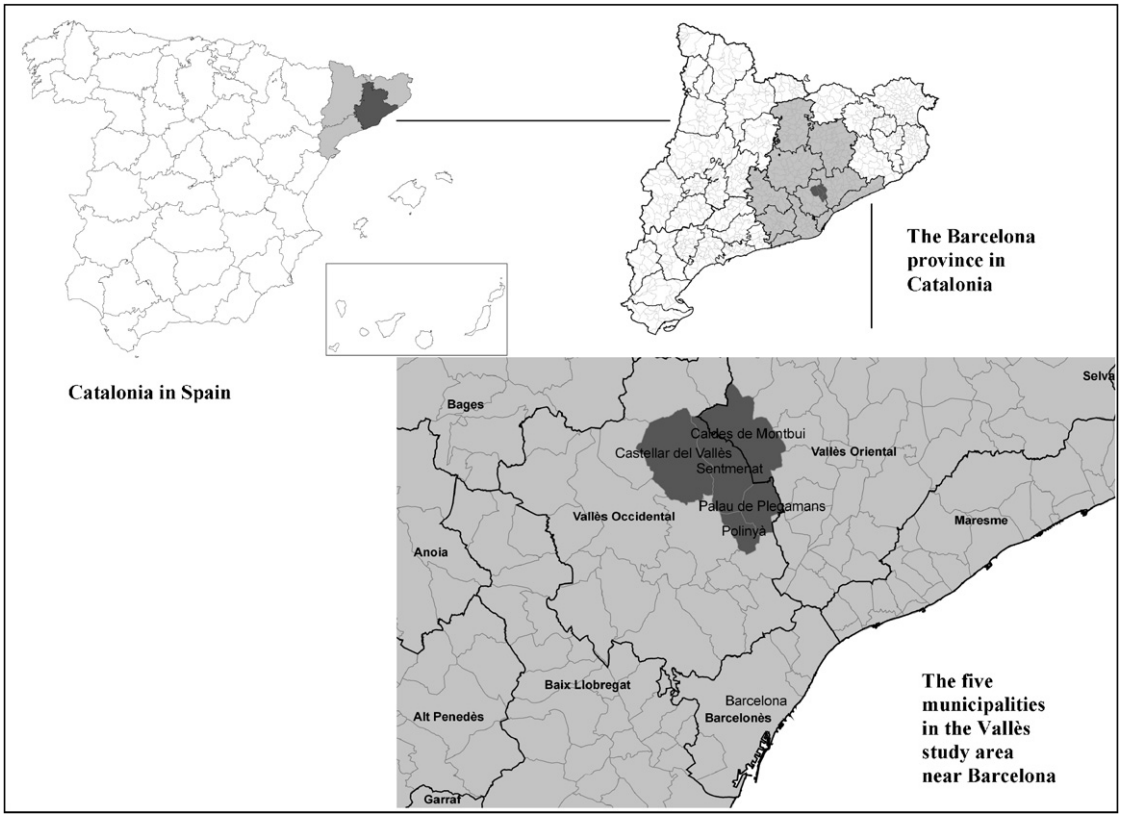

Fig. 1. Location of the study area.

each land use type, the scores assigned being 100 for very suitable, 75 for moderately suitable, 50 for marginally suitable, and 0 for not suitable categories.

The results of this evaluation exercise were compared to the historical and present land-use maps to analyse the degree of correspondence between land use and land suitability. The interpretation of these results should be made in broad terms due to the problems produced by the varying scales of the original maps and by the topographic deviations of the hand-made maps from the 19th century.

We made a more specific study of the relations between land use and land characteristics in Caldes de Montbui, particularly in its northwestern part, where stone terraces are very frequent. We studied the relation between land use and slope, and surveyed the presence of stone terraces through fieldwork and use of the 1956 aerial photos.

Results

Land use through the study period

The distribution of the main land use types has changed profoundly between the mid-19th century and the end of the 20th century. In 1860 cultivated land occupied 46% of the total land area while forests only represented 29%. As a result of the socio-economic and environmental crisis of the 'filoxera' (Daktulosphaira vitifoliae, an insect pest of vines) (1870–1890), which destroyed the old vineyards, and of the expansion of the Green Revolution after 1950, the share of cultivated land has decreased to 28%, while that of forests has increased up to 53%, following a common trend for southern Europe (Bartolome et al., 2005; Roura-Pascual et al., 2005). The area occupied by urban settlements and infrastrucutures represents 13% of the total land area in 1999 (Table 1).

In 1950, and in spite of the increase in population density (from 71 inhab km^{-2} in 1900 to 92 inhab km^{-2} in 1930) and the self-sufficient economic model imposed by Franco's dictatorship, the same trends were already showing up on a smaller scale, but the ecological functionality of the landscape was still high (Marull et al., 2006). From 1860 to 1950, there was a 69% increase in the area of forest and bush, most of this land coming from abandoned vineyards and, to a lower extent, from cereal plots. The amount of urbanized land was still relatively small in 1950 but had increased by 300% since 1860.

Land suitability

The results in Table 2 show that the study area had a high proportion of land moderately or highly suitable for the most common crops. For crops with a high demand for water, such as alfalfa, the suitable area was still 40% of the total area. Some 67% of the total area was more or less suitable for vineyard while 57% was suitable for rainfed wheat and rye. Rainfed tree crops, such as olive and

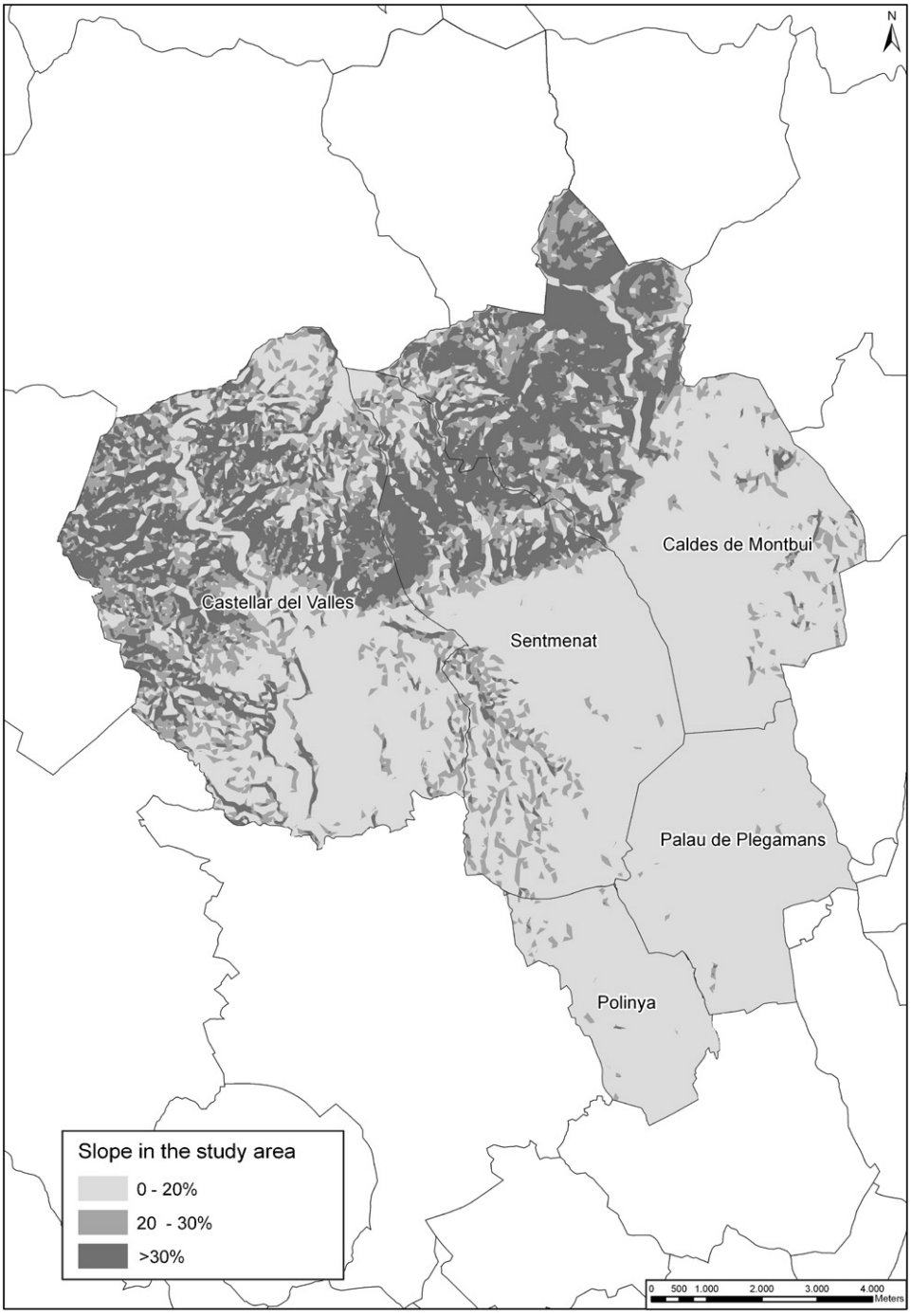

Fig. 2. Slope map of the study area.

almond, are suitable in an area larger than that for cereals but smaller than that for vineyards.

The aggregated Index Value of suitability shows that land with a high or very high flexibility for agricultural land use represents 57% (7738 ha) of the total study area and is mostly located in the southern part, where the flat land and deep soils are more frequent (see Fig. 2). On the other hand, land with a very low suitability occupies 3726 ha (28% of the area).

Did land uses fit land suitability?

Land uses fit reasonably well with the land units where they take place both at present and in the mid 19th century (Table 3). The high level of unsuitability of forage production needs to be interpreted with caution because we evaluated as rainfed alfalfa what in fact was a group of various cereals used for fodder in rotations of the 19th century.

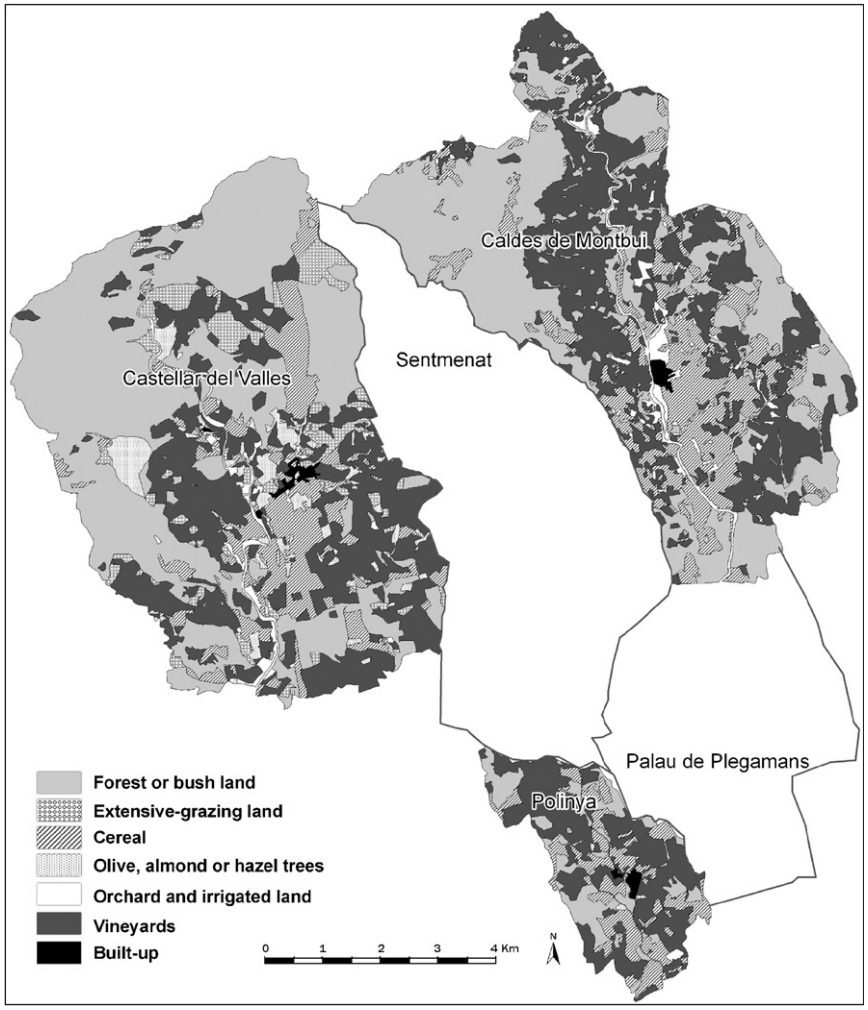

Fig. 3. Land use in the study area in the 1850s.

Most crops were grown then, and also now, in land units with a moderate or high suitability, indicating a clear empirical knowledge of land characteristics and crop requirements by the land-use decision-making agents.

The proportion of vineyards grown on land marginally suitable or not suitable (34%) was higher in 1860 than the proportion of cereals grown on such suitability classes (23%). This suggests a more selective criterion in terms of guaranteeing the harvest of grain, which is supported by the fact that vineyards received no fertilization except at plantation, because the scarce manure was kept for cereal and homestead vegetable production.

Intercrops of vines and cereals, present in 1860 but absent in 1999, were located on land more suitable for vines than for cereals, with 60% of these plots being moderately or highly suitable for vines but only 39% entering in these suitability classes for cereals (Table 3). Such intercrops were performed on plots held on 'rabasa morta' contracts (tenancy contract linked to the life-cycle of the vine plants), and the low yields of cereal obtained helped cover the basic needs of peasants.

Data from the mid-19th century also show a smaller degree of agreement between land use and land suitability compared to present time, which is reasonable considering the difference in human pressure on land. During the late-20th century agriculture occupies just 3745 ha, while in 1860 it spread over 5727 ha. The difference is not related to population density, 278 inhab km^{-2} in 1999 compared to 66 inhab km^{-2} in 1860, but to a radical transformation of social metabolism.

The concentration of agricultural activity within a smaller amount of land, with a large investment of inputs, could have allowed a better matching of land use types to land characteristics. And it is true that cultivation in only 28% of the land, compared to 46% in 1860, is coupled with such improved matching. But two important socio-environmental malfunctions hide behind this apparent improvement. The land-use mosaic of the mid-19th century, which was still dominant around 1950, has been transformed into an intensive cereal monocrop within a drastically simplified landscape.

The contrast between these two landscape structures also reveals that the growth of villages and the proliferation of

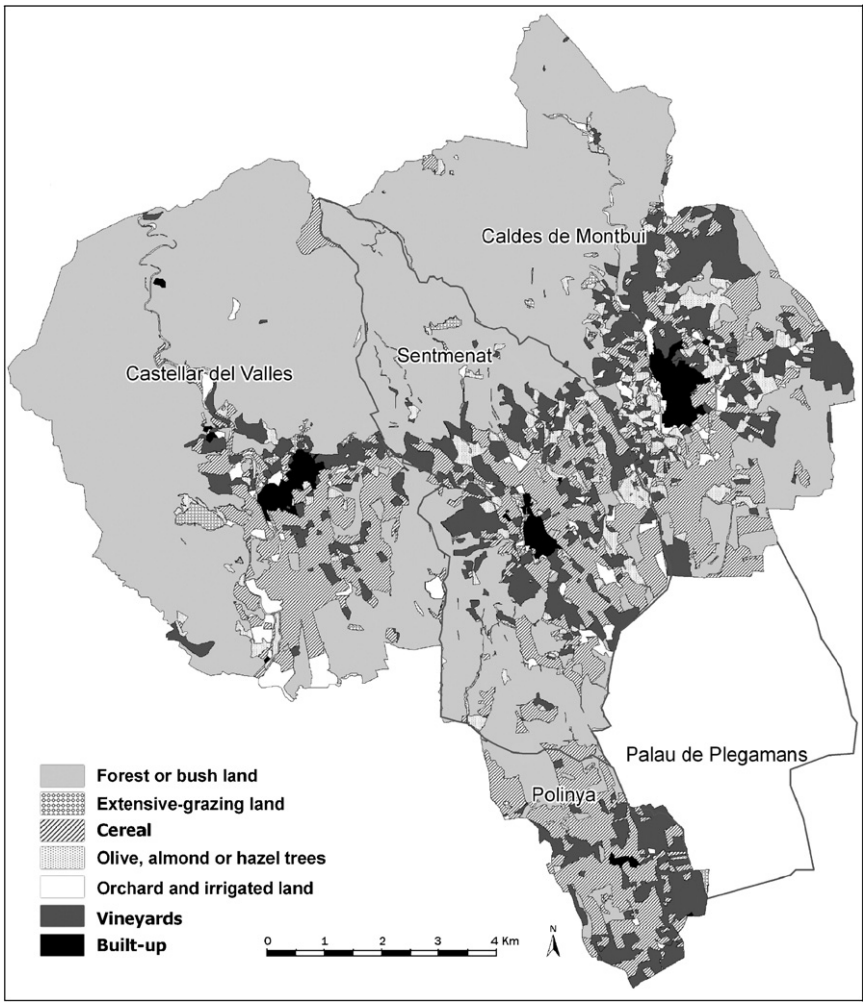

Fig. 4. Land use in the study area in 1950.

scattered urbanizations and industrial estates that destroy the biologically productive functions of soils has taken place without taking into account the characteristics and capabilities of soils. Urban planning has neglected the agricultural potential by occupying with these developments up to 47% of the land with a high or very high index value (Table 4).

Building terraces

The overlay of the land suitability and land use maps shows a degree of mismatch that cannot be overlooked (Table 3). But in 1860, some 23% of the 1666 ha used for cereal crops, 34% of the 3148 ha with vineyards, and up to 61% of the 433 ha with olive trees, were marginally or apparently non-suitable, and this just cannot be attributed to mapping errors. This mismatch involved a total of 1200 ha in 1860, which was equivalent to 20% of the total cultivated area at that time, or 30% of that presently cultivated. A different kind of mismatch occurred on land moderately or highly suitable for cereal production that the owners of farms on the best lands of the plains used for forests to obtain timber and firewood.

In terms of amount of land, the biggest mismatch occurred in the vineyards of 'rabassers', wherer the steep slopes frequently required the building of terraces. Only 64% of the land of those five municipalities had a slope of less than 20%, and 22% of the land had a slope over 40%. Otherwise, much labour had to be invested in 'landesque capital' (Blaikie and Brookfield, 1997), building terraces and access tracks even to obtain small yields.

The slope factor

To study in more detail the landscape produced by those terraced vineyards we chose the municipality of Caldes de Montbui, where only 57% of the land has a slope of less than 20%, while the remaining 1610 ha require some soil conservation measures in order to be used for agriculture (Table 5).

The overlay of the 1853 land-use map and the slope map shows that the slope factor was not irrelevant for the land-use pattern (Table 5). Cereals were mostly produced on

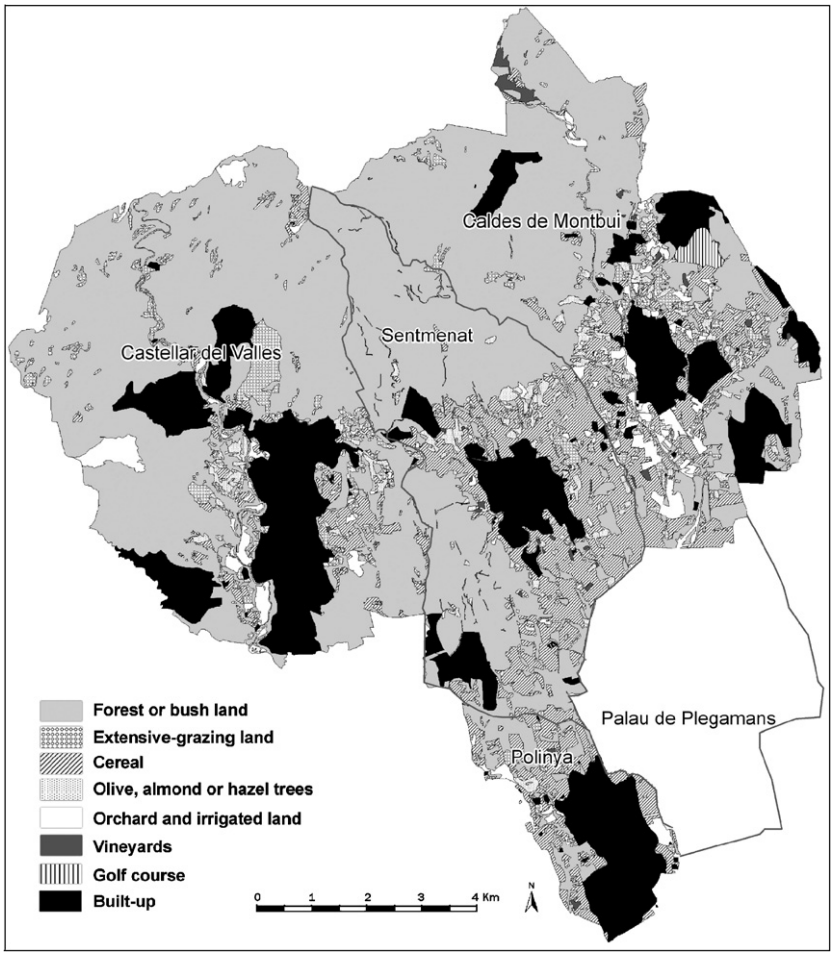

Fig. 5. Land use in the study area in 1999.

slopes of less than 20%, but also in a few terraced plots on segments of slope concave on the contour in the farms of the mountainous northwestern corner of Caldes. Nevertheless, cereals were not completely dominant on slopes of less than 20%, and this diversification may indicate a high degree of commercial exchange.

As slopes became steeper, the presence of vineyards increased and that of cereals quickly decreased. But the proportion of forest did not vary significantly, being surprisingly high on slopes of even less than 10%. These areas, mostly located south and west of Caldes, do not show any characteristic, in terms of slope, soils, or rock outcrops, that may justify not being cultivated in 1853. We therefore hypothesize that these forests were kept to provide timber and firewood for the farms in the plains. The presence of these forests may have been another factor in the scarcity of plainland available for immigrants and in the push to build terraces in the mountain areas.

Vineyards and forests were the predominant land uses on slopes over 30%, occupying 80–90% of this land (Table 6). During our fieldwork, stone terraces were described on slopes of up to 60–70% that in the 1853 land-use map are recorded as vineyards. Although the percentage of land on slope over 30% occupied by cereals is significant, the absolute amount, less than 10 ha, was so small that it was not possible to recognize them during the fieldwork, and we therefore suggest that this is mostly the result of problems with the overlaying of both maps.

Whereas 85% of the area used for cereals was on slopes of less than 20%, 49% of the area with vineyards was on slopes over that value, and 30% still on slopes of more than 30%. If we set 20% as the slope over which it was necessary to build some kind of terrace for agricultural production, then some 586 ha of land with vineyards would have needed this soil conservation measure. A further 100 ha were used for cereal production in the mountain farms on steeply sloping land. All in all, stone terraces were built on 43% of the land cultivated in the mid-19th century, or about 20% of the total surface area of the municipality of Caldes de Montbui.

A field study

The northwestern part of the municipality of Caldes is characterized by steep slopes that in 1853 were almost completely covered with vineyards. During our fieldwork we confirmed that the slopes in this area were protected with stone terraces, but that these terraces disappeared on

Table 1
Main land uses (ha) in the study area around 1860 and in 1999

	Caldes	Castellar	Palau	Polinyà	Sentmenat	Total	%
Uses in 1860							
Irrigated	55	40	155	4	47	301	2
Rainfed herbaceous	516	253	260	271	365	1666	13
Vineyard	782	665	283	352	1066	3148	25
Olive orchard	179	140	0	0	113	433	3
Other cultivated	97	37	13	6	26	179	1
Forest	974	1478	289	184	698	3624	29
Bush	614	1394	283	4	341	2636	21
Non-productive	254	125	0	0	92	471	4
Total	3473	4131	1283	821	2750	12,458	100
Uses in 1999							
Irrigated	18	18	61	18	8	123	1
Rainfed herbaceous	672	553	610	427	867	3130	23
Vineyard	47	4	0	0	11	62	1
Olive orchard	81	31	1	4	107	224	2
Other cultivated	126	11	6	24	39	206	1
Forest	2163	2973	303	190	1468	7097	53
Bush	229	304	120	44	130	827	6
Non-productive	401	577	440	199	177	1794	13
Total	3737	4471	1541	906	2807	13,463	100

Sources: various historical surveys for 1860, and http://www.idescat.es for 1999.

Table 2
Land suitability of the study area for the main crops in 1860 and in 1999

	Very suitable		Moderately suitable		Marginally suitable		Not suitable	
	ha	%	ha	%	ha	%	ha	%
Wheat								
1860	522	4	7204	53	1123	8	4639	34
1999	522	4	7204	53	1102	8	4659	34
Alfalfa								
1860	510	4	4795	36	411	3	7770	58
1999	522	4	4879	36	317	2	7770	58
Vine								
1860	7349	54	1694	13	1614	12	2831	21
1999	4423	33	4436	33	1327	10	3302	24
Olive tree								
1860	3011	22	5584	41	1221	9	3671	27
1999	2927	22	5505	41	1391	10	3664	27

Source: Rodríguez-Valle (2003).

Table 3
Proportion of each actual land use performed on each suitability class in the study area in 1860 and in 1999 (Intercrops of vine and cereal in 1860 were not evaluated as such but as both cereal monocrop and as vine monocrop for comparison purposes)

	Very suitable (%)	Moderately suitable (%)	Marginally suitable (%)	Not suitable (%)
Use in 1860				
Cereals	34	43	4	19
Forages	5	34	1	60
Vineyard	51	15	14	20
Vine-cereal intercrop (evaluated as cereal)	0	39	12	49
Vine-cereal intercrop (evaluated as vine)	28	32	12	28
Olive and almond trees	0	43	6	51
Use in 1999				
Cereals	9	82	1	8
Forages	9	62	1	28
Vineyard	62	30	5	3
Olive and almond trees	12	77	7	4

Table 4
Distribution of urban land or land occupied by infrastructures in 1999 in relation to the index value of land

Index value classes	*A*: land occupied by urban and infrastructure uses in the class (ha)	*B*: total land in the class (ha)	*A*/*B* (%)
Very high	11,101	4328	26
High	740	3410	22
Low	254	2024	13
Very low	238	3726	0
Total	2343	13,488	17

Index value classes: very high (index value of 75–100), high (index value of 50–75), low (index value of 25–50), very low (index value of 0–25). The index value is calculated as the mean score of the suitability of each land unit of the study area for the various land use types considered, the single scores assigned being 100 for very suitable, 75 for moderately suitable, 50 for marginally suitable, and 0 for not suitable.

slopes on hard geological materials (i.e., limestone and dolomite), so that the vineyard-forest border of 1853 fits very well with the transition from relatively soft rocks, such as mudstone and sandstone, to those hard rocks. Within the predominantly forested sector in this area, the small patches with crops were also established on soils developed on soft parent materials. The amount of land with soils developed on hard rocks but with slopes of less than 50%, or even 20%, that were covered with forest in 1853 was significant. The reasons for them not being used for agriculture may be that soils were very shallow (less than 30 cm), rock outcrops quite frequent, and the hard rock underlying the soils did not allow digging of the typical deep holes needed for planting vines.

The 1853 land-use map shows that these terraces had already been built and planted with vines before the short but intense 'vine fever' that developed after the French vineyards were destroyed by the 'filoxera' pest in 1867–1870 and before this pest arrived at the Vallès county in 1883–1890. Some other areas, defined as forest land in the 1853 map, were recorded, through air-photo interpretation, to have stone terraces, which was confirmed during our fieldwork, and which we suggest were the result of land-use changes to vineyards occurring during the 'vine fever' of 1870–1890. Once the insect devoured the vines,

Table 5
Land uses on the various slope classes in Caldes de Montbui in 1853

Slope (%)	Occupied by each land use (%)						Total (ha)
	Forest	Bush	Vine	Cereal	Irrigat.	Other	
0–9	27	3	29	36	2	3	1423
10–19	32	4	44	17	2	1	712
20–29	51	3	37	7	1	1	562
30–39	54	4	34	7	0	1	487
40–49	55	4	31	9	0	1	375
50–59	42	7	44	6	0	1	150
>60	35	8	53	3	1	0	37
Total	38	4	35	20	1	2	3745

"Vine" includes vine-cereal intercrops. "Others" includes urban areas, but also errors from the overlaying of maps. Total areas and percentages do not coincide with those shown in Table 2 for Caldes because they come from different sources. For Table 2 the source is the 1861 land-use survey, while data in Table 6 are the result of the GIS analysis of the 1853 land-use map.

Table 6
Distribution of each land use according to slope classes in Caldes de Montbui in 1853

Land use	Total		% of the land use in each slope class		
	ha	%	<20%	20–30%	>30%
Forest	1444	38	42	19	39
Bush	136	4	51	14	35
Vineyard	1301	35	55	15	30
Cereal	751	20	85	5	10
Others	114	3	n.d.	n.d.	n.d.
Total	3746	100	57	15	28

"Vine" includes vine-cereal intercrops. "Others" includes irrigated and urban areas, but also errors from the overlaying of maps. Total areas and percentages do not coincide with those shown in Table 2 for Caldes because they come from differents sources. For Table 2 the source is the 1861 land-use survey, while data in Table 6 are the result of the GIS analysis of the 1853 land-use map.
n.d.: not determined.

those terraces must have been abandoned, instead of being planted again with American stock, because the stone terraces could still be seen, covered by a young forest, on the 1956 aerial photographs.

The geomorphological instability of some slopes, which can be recognized now by the presence of boulders and pines falling over the slope, may have also been a limiting factor for building terraces, as they were covered by forest in 1853.

The stone walls of the terraces of the mountainous area in Caldes de Montbui are generally discontinuous and small-sized, with a height of 30–50 cm. Bigger terraces of 1–2 m only appear on a few slope segments concave on the contour that were mostly used for cereal production due to the deeper soils (more than 100 cm). Proportionately to their small height, the width of most terraces is only 1–2 m on the steepest slopes and 3–4 m on 20–40% slopes, and, therefore, only one or two rows of vines could be planted.

The soils of these terraces are mostly shallow, 30–50 cm deep, with very frequent stones, moderately fine texture, and carbonate content over 20%. On the other hand, the terraces built on granite areas have deeper soils (40–60 cm deep), coarser texture (even sandy in places), and are free of carbonates. The latter soils have little available-water holding capacity, and are marginally suitable for cereal production, which only occupied 22% of these soils, and, therefore, were mostly used for vineyards, which occupied 41% of their surface area.

Discussion

The combination of fieldwork with written and mapped historical sources of the study area, analysed through GIS and statistical methods, suggests that land suitability matters for the land-use decision-making process of the various agents involved. They are also relevant, therefore, for the historical path of landscape tranformation. Certainly this matching between land-use and suitability is not complete. In some cases, the deviation is related to processes of human reconstruction of soils, but in others, it is due to processes of soil consumption. Therefore, the issues underlying those deviations unmask significant features of the socio-economic systems involved.

The role on the economic development of Catalunya of the increasing specialization in wine-production from the 17th century to the late 19th century has been frequently emphasized (Vilar, 1966), although this process did not happen in other areas of the Mediterranean, for example in some regions in Greece (Marathianou et al., 2000). But less attention has been paid to the fact that such specialization was frequently started on very poor soils by the poorest peasant classes, with very little capital but much labour and a very rudimentary technique.

Vilar (1966) described how, during the expansion of vineyards in the 18th century, big farm owners around Barcelona preferred to produce grain by themselves on their best lands and maintained a mosaic of crops on their farms, while they leased the worst land for poor peasants to plant vines on the long-term 'rabassa morta' contracts.

Underlying that poor viticulture an increasing polarization of society was taking place. In his travel book of 1786–1789, De Zamora (1973) describes the xenophobic distrust of the landowners of Caldes de Montbui towards the landless labourers and immigrants from the Pyrenees who used to gather firewood and fruits from the forests. It should be reminded that forests were common land in the home regions of these immigrants and firewood was freely collected from these commons by local people (Busqueta and Vicedo, 1996; Tello, 1997). On the other hand, farm owners had privatized most of the forest and bushland around Caldes in early times (Congost et al., 2003).

The proliferation of 'rabassa morta' contracts since the mid-17th century could have been the result of a social

process of trial and error (Serra, 1988). The farm owners may have finally decided to allow the establishment of a population that was perceived as a growing and dangerous class on the basis of those contracts while the immigrants and landless labourers were somehow satisfied on their claims. The agreement between the two classes through these contracts obviously did not put an end to the conflicts inherent to the polarization of the rural society in Catalunya, but helped to guide them to more productive ends.

The expansion of vineyards outside the theoretical suitability limits was supported through a huge investment of labour in soil conservation structures by the poorest rural classes. Estimates of this investment range from 200 to 500 work-days per hectare, depending on soil type, tools available, and type of terrace (Blanchemanche, 1990; Critchley and Brommer, 2004). Therefore, the construction of terraces in 600 ha would have involved a minimum of 120,000 work-days, which represents the annual work of 1000 adults, considering 120 work-days per year per adult (Cussó et al., 2006a). The total population of Caldes de Montbui had increased from 1391 in 1718 to 1694 in 1787 and 3256 in 1860, and therefore the construction of those terraces would have taken more than 100 years, which is longer than the period that suggested by Blanchemanche (1990) for the construction of terraces in southern Europe (50–100 years).

Such investment challenges two widespread assumptions. On the one hand, it supports the literature that shows the lack of empirical base of the cause-effect theory of poverty and environmental degradation (for a discussion see, for example, Prakash, 1997). And on the other hand, it shows how the poorest classes can have a long-term planning horizon in contrast with the assumption about their short-term behaviour used in the literature on the economic analysis of soil conservation.

Nevertheless, an important soil and architectural heritage made up of thousands of stone terraces remains under a dense forest cover vulnerable to fire. If agricultural abandonment persists for a long time, the growing forest will finally destroy it. The old terraces of Mediterranean viticulture will disappear without ever having been mapped and catalogued.

A systematic study of the 1950 land-use maps and the 1956 aerial photographs would allow such inventory, and, therefore, the specific consideration of those terraced slopes in the regional and local land-use plans and in economic and forest policies. A conservation policy should not be restricted to merely preserving them on paper. The maintenance of these old stone terraces requires a deep change in the economic and land-use model, by supporting new extensive agricultural, forest, and animal production systems together with the use for energy production of the presently disregarded biomass.

The social cost of this neglect is soaring as a result of more extensive forest fires nourished by the accumulated biomass, and increased nitrate pollution of aquifers by intensive landless animal production. Rather than preserving the terraces, it is a question of making a profitable use of those slopes, which, certainly, require some influx of capital and labour. Who would consider using them as extensive pastures or as sources of renewable bioenergy? A very recent agreement between the forest authority and a shepherd association of Catalunya to encourage extensive grazing in order to decrease the fuel load of forests is a good step in that direction.

The cultivated area in the study region dramatically decreased after the crisis at the end of the 19th century, which was related to the spread of the vine insect pest 'filoxera', and even more after the 'industrialization' of agriculture during the 1950s. Only two thirds of the area used in 1860 remain cultivated, while the other third, plus most of the bush land, has been taken over by forest. This simplification of the landscape can have important effects for the habitats of various species (Preiss et al., 1997; Atauri and de Lucio, 2001).

Urban and infrastructure development since 1860 has destroyed 47% of the land most suitable for agricultural use, a scarce resource even at a world-wide scale. The protection from urban development of the most suitable agricultural land is considered one of the main priorities of the World Conservation Strategy (IUCN et al., 1980), but urban and infrastructural development has been one of the cornerstones of economic growth in Spain since the 1950s. While the legal tools to enact the preservation of this land have been developed, the political will to implement them has been lacking at all levels of the administration (Olarieta, 1994, 2002). And particularly so at the local level, ultimately responsible for land-use planning in Spain, which depends heavily on taxes on new urban developments as one of its main sources of income.

Land use change in the study area since 1850 shows the pattern of evolution from a 'cultural landscape' to a 'technological landscape' (Farina, 2000). In the organically based agriculture of 1850 the population lived from the land they inhabited creating a complex landscape at various spatial scales that reflected a deep knowledge of land characteristics and processes. In the global economy of the present, only about 36% of the local net photosynthetic production is now economically useful, due to the process of abandonment of the forest and bush area (Cussó et al., 2006b), and fluxes of matter and energy mostly come from the outside and just pass through the region, producing a simplified landscape with enlarged and specialized land-use areas.

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References

Atauri, J.A., de Lucio, J.V., 2001. The role of landscape structure in species richness distribution of birds, amphibians, reptiles and lepidopterans in Mediterranean landscapes. Landscape Ecology 16, 147–159.

Bartolome, J., Plaixats, J., Fanlo, R., Boada, M., 2005. Conservation of isolated Atlantic Heathlands in the Mediterranean region: effects of land-use changes in the Montseny biosphere reserve (Spain). Biological Conservation 122 (1), 81–88.

Blaikie, P., Brookfield, H., 1997. Questions from history in the Mediterranean and western Europe. In: Blaikie, P., Brookfield, H. (Eds.), Land Degradation and Society. Methuen, London, pp. 122–142.

Blanchemanche, Ph., 1990. Bâtisseurs de Paysages. Terrassement, Épierrement et Petite Hydraulique Agricoles en Europe, XVII^{e}–XIX^{e} Siècles. Éditions de la Maison des Sciences de l'Homme, Paris.

Boixadera, J., Porta, J., 1991. Información de Suelos y Evaluación Catastral. Método del Valor Indice. Centro de Gestión Catastral y Cooperación Tributaria. Ministerio de Economía y Hacienda, Madrid.

Busqueta, J.J., Vicedo, E. (Eds.), 1996. Bens Comunals als Països Catalans i a l'Europa Contemporània. Sistemes Agraris, Organització Social i Poder Local als Països Catalans. Institut d'Estudis Ilerdencs, Lleida.

Chew, S.C., 1997. Accumulation, deforestation, and world ecological degradation, 2500 B.C. to A.D. 1990. Advances in Human Ecology 6, 221–255.

Congost, R., Jover, G., Biagioli, G. (Eds.), 2003. L'Organització de l'Espai Rural a l'Europa Mediterrània. Masos, Possessions, Poderi. CCG Edicions, Girona.

Critchley, W., Brommer, M., 2004. Comprendiendo las terrazas tradicionales. LEISA Magazine 19 (4), 21–23.

Cussó, X., Garrabou, R., Tello, E., 2006a. Social metabolism in an agrarian region of Catalonia (Spain) in 1860–1870: flows, energy balance and land use. Ecological Economics 58, 49–65.

Cussó, X., Garrabou, R., Olarieta, J.R., Tello, E., 2006b. Balances energéticos y usos del suelo en la agricultura catalana: una comparación entre mediados del siglo XIX y finales del siglo XX. Historia Agraria 40, 471–500.

Davidson, D.A., 1982. Soils and man in the past. In: Bridges, E.M., Davidson, D.A. (Eds.), Principles and Applications of Soil Geography. Longman, London, pp. 1–27.

De Zamora, F., 1973. Diario de los Viajes Hechos en Cataluña. Curial, Barcelona.

FAO, 1976. Esquema para la Evaluación de Tierras. Boletín de Suelos de la FAO 32. FAO, Rome.

Farina, A., 2000. The cultural landscape as a model for the integration of ecology and economics. BioScience 50 (4), 313–320.

Foster, J.B., 2000. Marx's Ecology. Materialism and Nature. Monthly Review Press, New York.

Garrabou, R., Naredo, J.M. (Eds.), 1996. La Fertilización en los Sistemas Agrarios. Una Perspectiva Histórica. Fundación Argentaria, Visor, Madrid.

Garrabou, R., Planas, J. (Eds.), 1998. Estudio Agrícola del Vallés (1874). Museu de Granollers, Granollers.

Haberl, H., Erb, K.H., Krausmann, F., Loibl, W., Schultz, N., Weisz, H., 2001. Changes in ecosystem processes induced by land use: human appropriation of aboveground NPP and its influence on standing crop in Austria. Global Biogeochemical Cycles 15, 929–942.

Hillel, D., 1991. Out of the Earth: Civilization and the Life of the Soil. University of California Press, Berkeley.

IUCN, UNEP, WWF, 1980. World Conservation Strategy: Living Resource Conservation for Sustainable Development. IUCN, UNEP, WWF, Gland.

Krausmann, F., 2001. Land use and industrial modernization: an empirical analysis of human influence on the functioning of ecosystems in Austria 1830–1995. Land Use Policy 18, 17–26.

Marathianou, M., Kosmas, C., Gerontidis, St., Detsis, V., 2000. Land-use evolution and degradation in Lesvos (Greece): a historical approach. Land Degradation and Development 11, 63–73.

Marull, J., Pino, J., Tello, E., Mallarach, J.M., 2006. Análisis estructural y funcional de la transformación del paisaje agrario en el Vallès durante los últimos 150 años (1853–2004): relaciones con el uso sostenible del territorio. Areas 25, 106–126.

McNeill, J.R., Winiwarter, V., 2004. Breaking the sod: humankind, history and soil. Science 304, 1627–1629.

McNeill, J.R., Winiwarter, V. (Eds.), 2006. Soils and Societies. Perspectives from Environmental History. White Horse Press, Cambridge.

Olarieta, J.R., 1994. La protecció del sól agrari en l'ordenació del territori. Cas del Projecte de Pla Territorial General de Catalunya. In: Agricultura i Qualitat Ambiental a Catalunya. Institució Catalana d'Estudis Agraris, Barcelona, pp. 314–317.

Olarieta, J.R., 2000. On the use value of land in agricultural production. Ecological Economics 32, 169–173.

Olarieta, J.R., 2002. La negación de los conflictos: ordenación del territorio en la C.A.P.V. In: XV Congreso de Estudios Vascos. Eusko Ikaskuntza, Donostia, pp. 583–592.

Olarieta, J.R., Rodríguez-Ochoa, R., 2004. L'aportació de la ciència del sòl a l'anàlisi dels canvis territorials en el món rural català contemporani. In: Vicedo, E. (Ed.), Medi, Territori i Història. Les Transformacions en el Món Rural Català Occidental, Pagès, Lleida, pp. 97–120.

Prakash, S., 1997. Poverty and environment linkages in mountains and uplands: reflections on the 'Poverty Trap' thesis. CREED Working Paper No. 12. International Institute for Environment and Development, London, Vrije Universiteit, Amsterdam.

Preiss, E., Martin, J.L., Debussche, M., 1997. Rural depopulation and recent landscape changes in a Mediterranean region: consequences to the breeding avifauna. Landscape Ecology 12 (1), 51–61.

Rackham, O., Grove, A.T., 2001. The Nature of Mediterranean Europe: An Ecological History. Yale University Press, New Haven.

Rodríguez-Valle, F.L., 2003. Evaluación Agrícola de Cinco Municipios del Vallès en la Situación Actual e Històrica de Finales del Siglo XIX. PFC, ETSEA, Universitat de Lleida, Lleida.

Roura-Pascual, N., Pons, P., Etienne, M., Lambert, B., 2005. Transformation of a rural landscape in the Eastern Pyrenees between 1953 and 2000. Mountain Research and Development 25 (3), 252–261.

Serra, E., 1988. Pagesos y Senyors a la Catalunya del Segle XVII. Baronia de Sentmenat, 1590–1729. Crítica, Barcelona.

Tello, E., 1997. La conflictividad social en el mundo rural catalán, del Antiguo Régimen a la Revolución liberal, 1720–1833. Noticiario de Historia Agraria 13, 89–104.

Tello, E., Garrabou, R., Cussó, X., 2006a. Energy balance and land use: the making of an agrarian landscape from the vantage point of social metabolism (the Catalan Vallès county in 1860/1870). In: Agnoletti, M. (Ed.), The Conservation of Cultural Landscapes. CABI Publishing, Wallingford, pp. 42–56.

Tello, E., Garrabou, R., Olarieta, J.R., Cussó, X., 2006b. From integration to abandonment. Forest management in the Mediterranean agro-ecosystems before and after the 'green revolution' (The Vallès County, Catalonia, Spain, 1860–1999). In: Parrotta, J., Agnoletti, M., Johann, E. (Eds.), Cultural Heritage and Sustainable Forest Management: the Role of Traditional Knowledge, vol. 2. Ministerial Conference on the Protection of Forests in Europe, Warsaw, pp. 339–346.

Vilar, P., 1966, Catalunya dins l'Espanya Moderna. III. Les Transformacions Agràries del segle XVIII Català. Edicions 62, Barcelona.

Warde, P., 2006. Ecology, Economy and State Formation in Early Modern Germany. Cambridge University Press, Cambridge.

Wrigley, E.A., 2004. Poverty, Progress and Population. Cambridge, UP, Cambridge.