16. Land, Land Use, and Land-Use Conflict[1]

J.R. Olarieta, R. Rodríguez-Ochoa, E. Ascaso.

Departament de Medi Ambient i Ciències del Sòl. Universitat de Lleida

1. Introduction

The objective of this paper is to provide an overview of land characteristics in the Ebro Valley, and particularly in Lleida, and of the different types of land-use that have been practised in this area through history. Finally, we propose a case study in relation to land-use alternatives in the area affected by the 1998 wild forest fire in the Solsonès region.

2. The land

The Mediterranean areas of southern Europe are characterized by their high percentage of mountain areas as much as by their climatic conditions. Whereas a gently undulated relief predominates in Central Europe, British Isles, and Scandinavia, an abrupt but low relief predominates in the Mediterranean region (Figure 1).

The Mediterranean climate involves an intense dry period between spring and autumn, and two rainfall peaks, one in spring and another one in autumn (Figure 2).

Ecosystem productivity is limited by the dry period. This is particularly intense on south-facing slopes compared to north-facing slopes, because potential evapotranspiration, estimated by the Turc method, amounts to 1050 mm around Lleida on the former and to 900-950 mm on the latter, whereas mean annual rainfall is hardly 400 mm.

As we move north towards the Pyrenees rainfall increases and potential evapotranspiration and moisture deficit decrease. Mean annual rainfall in the valleys along the Pyrenees is

[1] Published as Chapter 16 in: J. Estany (ed.), *Agriculture and Agri-food Production in Perspective. Profile of the Sector in Catalonia*. Edicions de la Universitat de Lleida, Lleida, 2006. ISBN: 84-8409-207-0.

around 900 mm while mean annual potential evapotranspiration (Thornthwaite method) is only 600 mm. This helps to explain why irrigation water in these valleys in the XVIII century was not used for winter cereal but only for grasslands in the valley bottoms in order to ensure a good first cut in July to obtain hay for winter feeding of animals (Piqué, 2000).

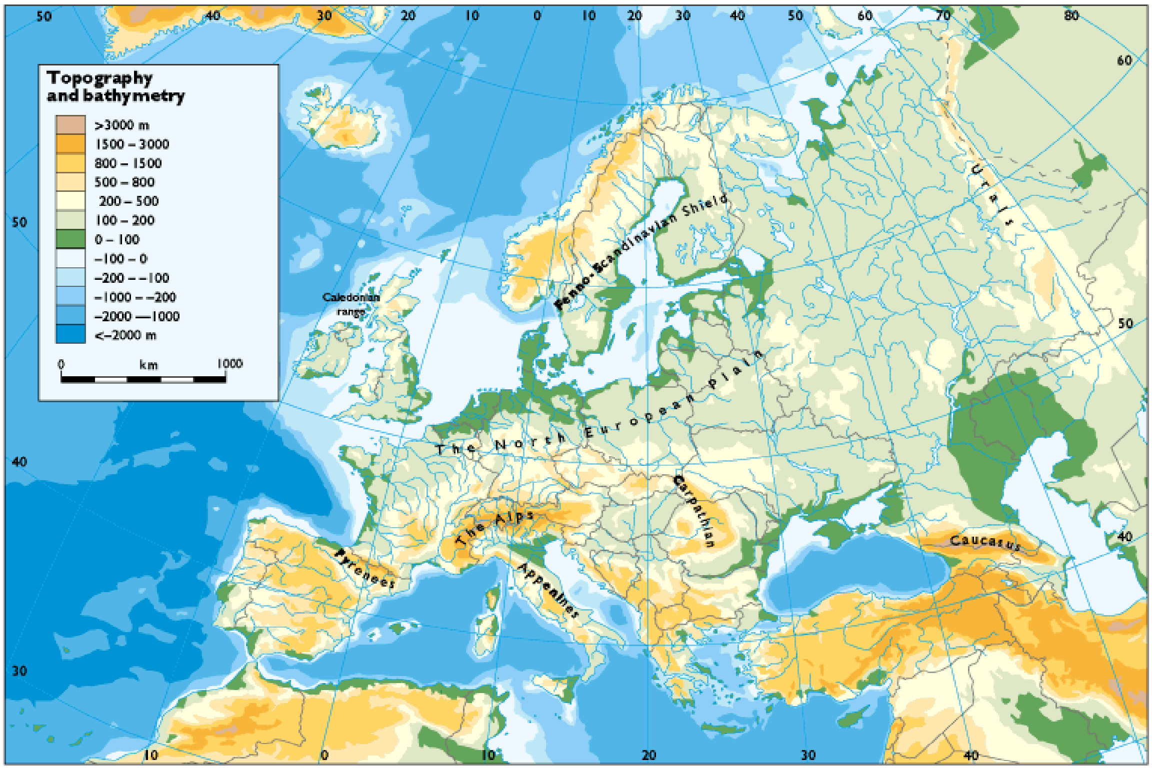


Figure 1.- Topographic map of Europe (Source: Stanners and Bourdeau, 1995).

Rainfall, particularly in autumn in coastal areas, comes in a few high-intensity events, and much of it, therefore, is not effective as it does not infiltrate into the soil and runs away as surface runoff. Floodings are also quite frequent as, in many cases, towns have expanded into flood plains and into *ramblas*, i.e. river channels that only carry water during the wet seasons.

Soils in the region around Lleida have pH values around 8.0-8.5, high calcium carbonate content, mostly over 20%, and a moderately fine texture. Their rooting depth is highly variable, very deep on valley bottoms and terraced slopes and very shallow on some slopes and old river terraces.

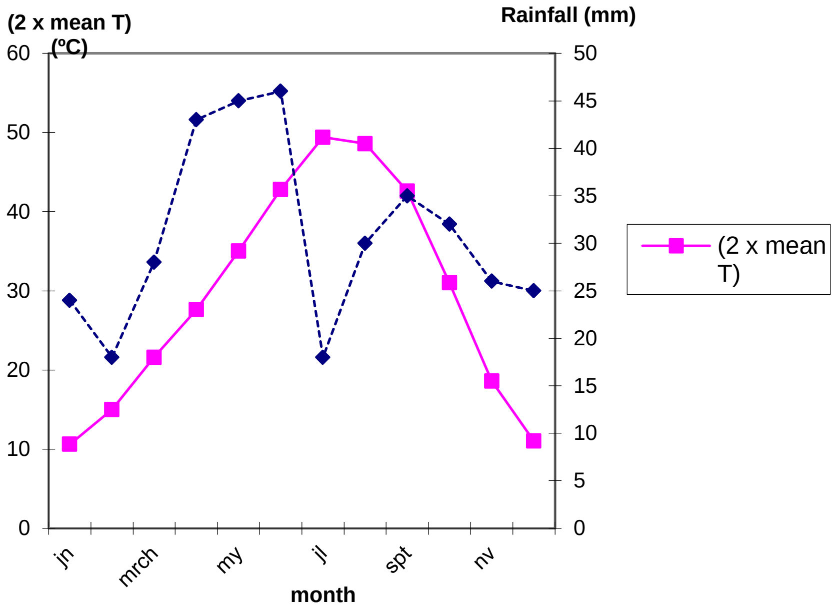


Figure 2.- Mean monthly rainfall and temperature for the Lleida weather station (1939-1980).

Saline soils are quite frequent on depressions and valley bottoms and sometimes they also have sodicity problems. The area covered by these soils increased after the development of irrigation without an adequate provision of drainage systems, and in some cases due to land levelling performed without conservation of soil surface horizons leaving saline/sodic geologic material on top of the land.

Gypsum-rich soils, which have very specific chemical, physical and biological characteristics, are also frequent in the area around Lleida, providing various management problems.

Soils developed on glacial deposits appear in the Pyrenees in valley bottoms and lower slopes. Here, and also in other mountain areas of Catalunya, soils without calcium carbonate may appear, frequently reaching pH values of 5, and of 4 in some cases.

3. A historical perspective of land use

Agricultural land-use around the Mediterranean has been historically based on the 'Mediterranean trilogy', i.e. winter cereals, mainly barley and wheat, vineyards, and olive orchards. These were the main crops in rainfed areas but also in irrigated plots.

Soil and climate conditions have had a strong influence on the location of villages and on the spatial distribution of various land uses. The traditional theory about the distribution of major types of land use (agriculture, pastures, and forestry) in concentric circles around the village constitutes, therefore, a circular reasoning as the location of the villages is influenced, among other factors, by the availability of water, sunlight (and therefore the preference for south-facing spots), and a minimum area of land with relatively good conditions for food crop production.

The central part of the Conca de Barberà region (Tarragona), for example, is an agricultural area (cereals, almond, olive and hazelnut orchards are the main crops) where small *Pinus halepensis* forests remain on 10-15% slopes which do not preclude agricultural use, but with shallow soils on hard geological strata (conglomerates and sandstone) that impair cultivation.

Information available on land-use distribution in 1865 in the valley of Ager (La Noguera, Pre-Pyrenees) shows that vineyards and olive orchards were dominant on south-facing slopes at an altitude below 700 m in order to get good solar radiation to avoid frosts and improve fruit ripening. North-facing slopes below 900 m and south-facing slopes between 900 m and 1200 m were mostly occupied by forests and winter cereals, the latter on gentle slopes concave on the contour with relatively deeper soils. Winter cereals were the dominant crops on the main valley bottom, where the only irrigated fields of the area as well as the villages were located.

Development of small-scale irrigation systems using water directly from rivers dates back in many cases around Lleida to the *andalusí* period (8th to 12th centuries) as an adaptation to the extreme drought conditions. Irrigation did not result in substantial changes in the crops grown but its fundamental purpose was to ensure yields against climatic vagaries (Vicedo *et al*., 1999). In later periods, in fact, feudal landlords promoted cereal and mainly vineyard production as these were products with good conservation and transport characteristics, and most important, they were exchangeable for money (Eritja, 2000).

Between the 16th and 18th centuries, there was an important expansion of rice and hemp cultivation in irrigated areas around Lleida (Forns, 2000). Rice probably occupied low-lying areas with saline and poorly drained soils, but it produced frequent social conflicts due to the health problems caused and to the amount of water used. Hemp was a fundamental crop within the crop rotations to the extent that some tenancy contracts explicitly asked for this crop to be grown with some specified frequency. There were two main reasons for this interest, as on the one hand, it was a basic fibre in ship-building, and on the other, in agricultural terms, it is a crop that shades competing weeds and produces lots of organic residues.

Rainfed areas, dominated at the time by common land and large holdings, remained as extensive grazing land for transhumant (seasonally nomadic) sheep flocks up to the 18th century. Then, a deep transformation of agriculture took place throughout Catalunya with a big expansion of vineyards, and in Lleida with the change from grazing lands to cereal fields. But grain production in these rainfed areas around Lleida remained at a very low intensity level right up to the first half of the 20th century due to both the extreme climatic conditions and the low quantities of manure available for fertilization. In some areas plots were left under fallow every two years, but on soils with the worst characteristics for grain production (due to little available-water capacity, salinity, and/or sodicity problems) fallow frequency would increase up to five out of six years.

Fertilization at that time was dependent on small quantities of manure from transhumant sheep flocks that would amount to less than 1 $Mg.ha^{-1}.year^{-1}$ in Lleida (Saguer and Garrabou, 1996), and on the ashes from *formiguers*, because the use of synthetic fertilizers did not become widespread until early in the 20th century. *Formiguers* were piles of vegetation, usually weeds and biomass from forests or field margins, covered with soil that were burnt and the ashes spread on the fields. Also in this case some tenants were asked in their contracts to produce a certain amount of *formiguers* in each plot.

Forests, therefore, were a source of food, energy, pasture, and various materials that were not replaced and that, especially in the case of grazing by goats, jeopardized forest regeneration. The scale of these processes of forest nutrient extraction and transport to agricultural plots was such that even today in mountain areas throughout Europe, non-agricultural plots which were planted to forestry 200 years ago still show completely different soil and vegetation characteristics (lower concentrations of available phosphorus and potassium, for example) from those of agricultural plots that were also planted at the time.

At the end of the 19th century, *filoxera*, an insect pest (*Daktulosphaira vitifoliae* (Fitch)), spread through Catalunya devastating the vineyards. At that time agricultural land-use had probably reached one of it peaks, and from then on many plots were abandoned, particularly small stone-terraced plots on slopes far away from farms and villages.

At the same time and through the first decades of the 20th century the big expansion of irrigation took place around Lleida. Reservoirs were built in the Pre-Pyrenees, and in many cases this meant the flooding of villages and the migration of their inhabitants (Figure 3). Catchments were in most cases also planted to forestry, but these plantations were based on two or three species, mainly from the *Pinus* genus, and were not successful in some cases (Figure 4).

Figure 3.- The Santa Ana reservoir in the Pre-Pyrenees.

Irrigation development in the large holdings around Lleida had huge labour requirements both for transformation works and for crop management afterwards, and thus the colonization villages were built (e.g. Raimat, Suchs, Gimenells) with their characteristic architecture and building distribution. Big landowners had to give over to the State part of their land in payment for the building of the general irrigation infrastructure, and this land was shared among new settlers. This process was loaded with conflicts that have been dragged up to this day (Bretón, 2000).

Fruit orchards (apple, pear, and peach) had been introduced at the beginning of the 20th century, but the 1936-39 Civil War in Spain delayed the process, which was not recovered until the second half of the century, when lucerne production also had a big expansion.

Figure 4.- Landscape on Tertiary gypsum. Some dead or poorly-growing 15 year-old *Pinus halepensis* specimens planted as part of an afforestation project can be seen in the foreground.

Today some big irrigation projects are still being developed (Algerri-Balaguer, Segarra-Garrigues), but these projects are facing two major issues. Production choices, even with irrigation, are restricted to crops which are already in surplus in the market. Furthermore, the EU requires the protection of parts of these rainfed areas as habitats for steppe birds (8,000 ha out of a total of 70,000 ha in the Segarra-Garriguess project), and this requirement is producing a heated response from farmers who for many decades had been promised the arrival of this water.

The transformation of agriculture during the second half of the 20th century has produced a continuous process of polarization of land use. On the one hand, we find abandoned areas where forest vegetation has recovered to dominate the landscape and agriculture remains of cases as a merely symbolic remainder (Pyrenees, Pre-Pyrenes, mountain areas, rain fed areas in southern Lleida). But in irrigated areas, agricultural systems based on the intensive use of inputs from outside the farm have developed.

Partly as a result of this process, urban areas have greatly expanded, occupying in many cases the old small irrigated areas around them, and also soils with a very good suitability for agricultural production. Although successive Land Acts in Spain have asked local governments to protect this kind of land from urban development, this principle has almost never been put into practice. The problem is particularly pressing, of course, around big cities like Barcelona, where an attempt to protect some agricultural areas, like the 'Parque Agrario del Llobregat', has had a minimal impact.

This history of agriculture is related to a parallel history of soil use and soil erosion and development. The colonization of southern areas of Sierra Nevada (Granada) with settlers from Galiza and Asturies (northern Spain) during the 16th century, for example, seems to have triggered intense processes of soil erosion in the area and the beginning of the development of the deltas of Motril and Adra (Andalucía) (Grove, 1996). Some authors stress the importance of the human factor in these processes (Hillel, 1991) but others suggest that natural factors (extreme climatic events, strong slopes, shallow soils) are equally important (Blaikie and Brookfield, 1987; Peña *et al*., 1996).

In any case this has not been a linear and continuous history either, as periods of strong erosion and soil stabilization have alternated. Such periods have not necessarily coincided with periods of expansion and abandonment of agriculture respectively. The building of stone terraces on slopes in the Mediterranean region, which started back in the Bronze Age (Hillel, 1991; Grove, 1996) (Figure 5), has been very frequent during periods of expansion of agriculture in mountain areas. Similarly, the abandonment of agriculture in those stone-terraced plots has coincided with periods of strong water erosion before the full development of forest vegetation (Figure 6).

Figure 5.- Stone-terraced slopes in Margalef (Tarragona) with olive and almond orchards.

Evidences of these processes are frequent in Catalonia, as, for example, the presence of soil subsurface horizons on the surface of the land, and the appearance in valley bottoms of soil A horizons buried under sediments of various thickness (Figure 7).

The dating of sediments in valley bottoms around Zaragoza (Peña *et al*., 1996) suggests that the process of accumulation of sediments in these valleys, and therefore the process of soil erosion in the surrounding catchments, started during the Neolithic period, some 6,000 years ago. At that time, these processes were not very intense either because vegetation disturbance was not general or because environmental conditions allowed a quick recovery of the vegetation cover. But from some 2,500 years ago until the Roman Era, soil erosion processes of high intensity became widespread. These authors relate the present state of degradation of ecosystems on gypsum rock in the Ebro Depression to this historical period. They also suggest that even though the human impact on vegetation was a significant cause of the process, the semiarid climatic conditions were responsible for its intensity, while the peculiar characteristics of soils developed on gypsiferous materials did not encourage the regeneration of vegetation (Figure 4).

Figure 6.- Collapse in the stone-wall of a terraced plot in Bellaguarda (Lleida). Previously used for agriculture, the plot was abandoned in the 1960s-70s, natural regeneration of *Pinus halepensis* developed, but a wild fire swept across the area in the summer of 2005.

4. Land-use decision making after a wild forest fire: the case of the Solsonès region

In the summer of 1998 some 18,500 ha in the Solsonès region (north-eastern part of the province of Lleida) were affected by a wild fire. About 12,500 ha of those were forests and about 6,000 ha were agricultural fields and all belonged to private landowners. The altitude of the area affected ranges from 500 m to 930 m.

Figure 7.- Soil profile (Fluventic Haploxerept) in a valley bottom in Montblanc (Tarragona). Notice buried A horizons at 50-70 cm and 120-150 cm depth.

The intensity of the fire was variable (Map 1). About 68% of the area was intensely burnt and all above-ground vegetation died, while in 3% of the area shrubs and grasses were burnt and tree needles were exposed to the heat of the fire but not to the flames so that some stayed on the trees and the rest fell down providing good soil cover. The fire spread very irregularly over 21% of the area, leaving some trees alive within patches that were otherwise completely burnt. In 7% of the area, the fire only burnt the shrubs without affecting the trees, which mostly survived. And about 1% of the area was not really affected at all.

4.1. Climate

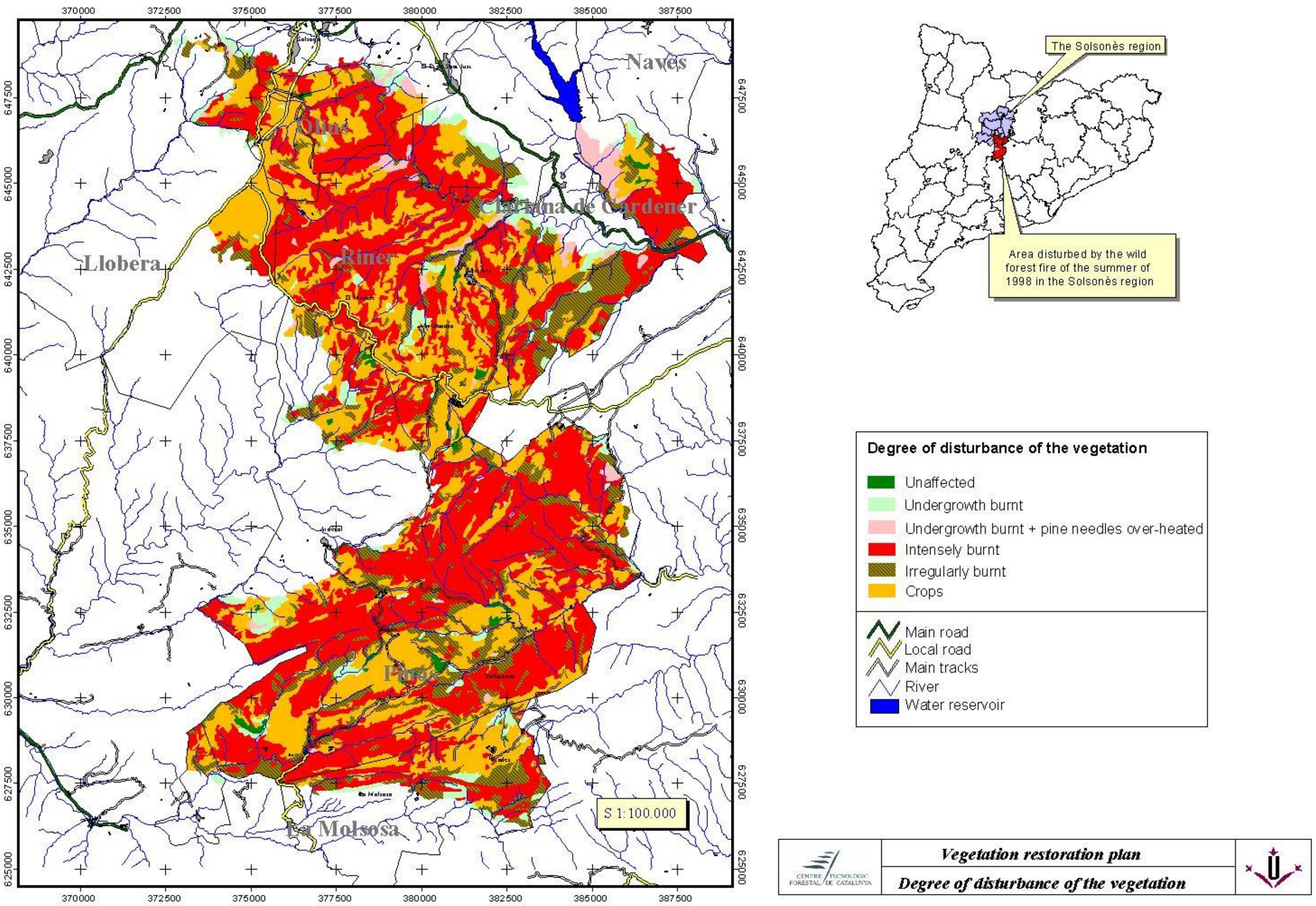
The climate in the area is Mediterranean, with a dry period between May and October, and two rainfall maxima, one in autumn and another one in spring. Mean annual temperature is 12ºC, with a mean monthly maximum of 22ºC in July and August and a minimum of 3.8ºC in January. Mean annual rainfall varies between 500 mm in the southwest and over 700 mm in the north.

4.2. Geologic materials

Geologic materials in the area affected by the fire are mainly mudstone and sandstone in almost-horizontal strata in the north, providing a typical tabular relief, while they are strongly folded in the south. Quaternary sediments occupy valley bottoms, slopes concave on the contour, and slopes protected by stone terraces.

4.3. Soils

Soils are mostly moderately-fine textured, with few stones, calcareous, and low in organic matter content (less than 4% in most mineral surface horizons). On plateaus, south-facing slopes, and upper parts of other slopes soil depth may be less than 30 cm and frequently less



Map 1.- Degree of disturbance of the vegetation in the area affected by the 1998 wild fire in the Solsonès region.

than 15 cm. On other slopes soil depth varies between 30 cm and 50 cm, while on valley bottoms and concave slopes (usually modified by stone terraces) soils are generally deeper than 75 cm.

4.4. Spatial distribution of land use types

Agricultural plots in the area affected by the 1998 fire, which were mostly used for rainfed cereal production (wheat and barley), occupied valley bottoms and slopes of less than 15º, which were protected in many cases by stone terraces providing a local slope of less than 10º.

The main tree species in the forests was *Pinus nigra*, mostly in single-species stands with some scattered trees of *Quercus sp.* Mixed stands of *P. nigra* and *P. sylvestris* appeared on valley bottoms and upper slopes over 900 m altitude, while mixed stands of *P. nigra* and *P. halepensis* appeared on south-facing slopes at any other altitude and on west and east-facing slopes below 650 m.

Forests occupied the steeper slopes of the area and also flatter areas with very shallow soils on hard geologic strata, mainly sandstone (Figure 8). They also appeared on some stone-terraced plots with slopes less than 10º where agriculture had been abandoned 50-100 years ago and which where too narrow for heavy agricultural machinery.

All these land-use types were integral to mixed farms called *masies*, which provide a disperse distribution of population. In most cases, intensive animal production (mainly hog and beef) is the main source of income. Most of the land of the *masies* is privately owned by the farm manager, even though there are some cases of tenancy. Forests were also privately owned, but quite frequently the owner is absent, living in some city, and forest management is undertaken by a third party.

Figure 8.- Pre-fire landscape of the northern part of the Solsonès region affected by the fire.

4.5. Factors affecting land-use decision-making after the fire

The framework of factors affecting land-use decision-making in the area affected by the 1998 fire is shown in Figure 9. In principle, agricultural plots would remain as such while forest plots would remain or be changed to other uses according to the equation affecting the specific plot.

European policy asks each farmer to fallow 15% of the area dedicated to cereal production. Therefore, many farmers were willing to change some of their forest plots affected by the fire to agricultural use in order to maintain the total amount of land under this kind of use (Figure 10).

Regional policy in Catalunya in relation to intensive animal production requires farmers to have a minimum of 1 ha per 33 pigs as a sink for pig slurry, and again the possibility of changing fire-affected forest plots to agriculture was an opportunity to increase the size of the animal farm.

UE scale: set-aside policy

Regional scale: legislation on intensive animal production

Local scale: land-use plans

Farm scale:

- socio-economic situation
- main produce
- land available for set-aside
- land available for slurry application
- location of plots within the farm

Plot scale:

- suitability for forest production (*P. nigra*)
- suitability for forest regeneration
- suitability for agricultural production (rainfed grain)
- risk of soil degradation after the fire

Figure 9.- Nest of factors affecting land-use decision-making in the area in central Catalunya

On the other hand, land-use regulations varied between the various local councils, so that, for example, in Cardona such regulations did not allow the conversion of forest plots to agriculture in any circumstances, while this change was possible for example in Pinòs.

Within each *masia*, the availability of agricultural plots in order to fulfil both European and regional regulations imposed a certain 'need' to convert fire-affected forest plots into agriculture. Other factors, such as the availability of labour, capital, and a new generation of farmers that might guarantee the future of the agricultural enterprise, also influenced decisions on land use.

Figure 10.- Area of intensely-burnt forest being prepared for agricultural use.

And finally, at the plot scale, various issues, such as the plot suitability for agriculture, forestry, and pasture production, and the risk of degradation by soil water erosion after the fire, also interfered with the process of decision-making.

The risk of soil water erosion after the fire was high or very high on 64% of the area affected by the fire. Nevertheless, rainfall was quite low during the year following the fire, so that by March 1999, 85% of the area showed a low degree of water erosion, and the other 15%

showed a very low degree. The former were mostly intensively burnt areas on slopes concave on the contour.

In 1999, soil water erosion measurements in intensively burnt forest areas showed rates of about 20 $Mg.ha^{-1}.year^{-1}$ on south-facing slopes over 20º, while on north-facing slopes less than 20º soil erosion rates were insignificant.

Soil erosion rates were still negligible throughout year 2000 in plots on slopes less than 20º where only shrubs had been affected by the fire. On south-facing slopes over 20º with a similar degree of fire intensity erosion during that year was 40 $Mg.ha^{-1}.year^{-1}$.

In intensively burnt plots on north-facing slopes of 5-20º, rates of erosion in year 2000 were about 60-70 $Mg.ha^{-1}.year^{-1}$, but they reached 80-90 $Mg.ha^{-1}.year^{-1}$ on intensively burnt south-facing slopes over 20º. Plantation of *P. nigra* after the fire with subsoiling on the contour did not decrease erosion rates on the former.

Forest regeneration after the fire was very poor due probably to low rainfall during the year following the fire and to the naturally-poor regeneration of *P. nigra* after a fire, as opposed to *P. halepensis*.

In the spring of 2000, nevertheless, 99% of the area that previously to the fire was covered by mixed stands of these two species had less than 1100 pine seedlings per hectare, which is the minimum density considered to ensure the future viability of the forest. Furthermore, 58% of the area had no seedling at all.

In the summer of 2000, after a rainy spring, in areas that prior to the fire were covered by single-species stands of *P. nigra*, pine seedling density was still insufficient, i.e. less than 1100 seedlings per hectare, in intensively burnt areas on all south-facing slopes and on 67% of north-facing slopes. In areas where the undergrowth had been burnt and pine needles had been over-heated, pine regeneration was insufficient on 60% of the south-facing slopes and on

30% of the north-facing slopes. Finally, regeneration was also insufficient in 10% of the areas where only shrubs had been burnt.

Forest productivity in the area is related to soil rootable depth and to slope aspect. With deep soils (Typic Xerofluvent, Typic Calcixerept, Typic Haploxerept) on valley bottoms and slopes concave on the contour with stone terraces, mean annual increment is 5.5-8.0 $m^3.ha^{-1}.year^{-1}$. On straight or convex slopes with rather shallow soils (Typic Xerorthent, Lithic Xerorthent) mean annual increment varies between 3.5 $m^3.ha^{-1}.year^{-1}$ on north-facing slopes and 1.0-2.0 $m^3.ha^{-1}.year^{-1}$ on other slopes.

Plot suitability for agricultural use depends on soil rootable depth, degree of slope, and plot size and shape. With deep soils plots would be left fallow under the EU set-aside programme in 10% of the years, and grain yields would be 2500 $kg.ha^{-1}$ in 15% of years, 6000 $kg.ha^{-1}$ in 9% of years, and 4000 $kg.ha^{-1}$ in 66% of years. With shallow soils, plots would be left fallow in 20% of years, and grain yields would be 1900 $kg.ha^{-1}$ in 13% of years, 4500 $kg.ha^{-1}$ in 8% of years, and 2300 $kg.ha^{-1}$ in 59% of years.

Crop management costs would increase by about 75% in small plots with narrow and short shapes, as is the case of many stone-terraced plots. On the other hand, application of manure or pig slurry is 30-50% higher in plots with shallow soils than in plots with higher productivity.

Soil water erosion processes are quite high on agricultural plots. With slopes steeper than 7º, simulation models show the loss of 30-40 cm of soil in less than 100 years with traditional tillage operations, while these rates would decrease to 3-5 cm of soil loss in 40-50 years with non-tillage systems, which are not frequent in the area. On slopes less than 7º soil loss would be about 10 cm in 40-50 years.

Empirical evidence somehow supports these results, as shallow soils are very frequent in agricultural plots of the area. In 90% of agricultural plots sampled in the area on slopes less than 10º, with or without stone terraces, soils are less than 50 cm deep. On the other hand, only 54% of forest plots in similar locations had soils with this depth.

These differences seem to be related to the accumulation of soil erosion processes throughout history in agricultural plots because within this group of plots differences in soil depth are not related to differences in slope angle. Only 20% of agricultural plots with slope less than 6º have soils deeper than 35 cm, while 50% of those with slopes between 6º and 10º have soils with this depth. Furthermore, agricultural plots in the area quite frequently have no soil left whatsoever, and farmers are in fact ploughing the soft geologic material, mudstone, that was previously underlying the soil.

4.6. Issues for discussion

The Solsonès forest area affected by the 1998 fire may be divided into various units according to their biophysical characteristics and to their different land-use problems and possibilities:

- define each of these units,
- discuss the land-use decision-making criteria for each one of them after the fire,
- suggest any other piece of information that may be needed in this context and that has not been presented here.

5. Bibliography

BLAIKIE, P.; BROOKFIELD, H. (eds.) (1987). *Land degradation and society*. London: Methuen.

BRETON, V. (2000). *Tierra, estado y capitalismo. La transformación agraria del occidente catalán, 1940-1990*. Lleida: Milenio.

ERITJA, X. (2000). "*Dominicum comitis*: estructuració feudal de l'horta urbana de Rufea (Lleida) durant la segona meitat del segle XII". In: E. Vicedo (ed.), *Terra, aigua, societat i conflicte a la Catalunya occidental*. Lleida: Pagès Editors. p. 25-46.

FORNS, J. (2000). "Cohesió local i conflictivitat en l'ús de l'aigua a la Catalunya de Ponent: la sèquia de Pinyana (segles XIV-XVIII)". In: E. Vicedo (ed.), *Terra, aigua, societat i conflicte a la Catalunya occidental*. Lleida: Pagès Editors. p. 137-159.

GROVE, A.T. (1996). "The historical context: before 1850". In: C.J. Brandt, J.B. Thornes (eds.), *Mediterranean desertification and land use*. Chichester: John Wiley. p. 13-28.

HILLEL, D. (1991). *Out of the earth. Civilization and the life of the soil*. Berkeley: University of California Press.

PEÑA, J.L.; CHUECA, J.; JULIAN, A.; ECHEVERRIA, M.T. (1996). "Reconstrucciones paleoambientales en el sector central de la Depresión del Ebro a partir de rellenos de valle y conos aluviales". In: A. Pérez, P. Martini, W. Chesworth, A. Martínez (eds.), *Dinámica y evolución de medios cuaternarios*. Santiago de Compostela: Xunta de Galicia p. 291-307.

PIQUE, J.R. (2000). "L'aprofitament de l'aigua a les altes valls pirinenques, com a element de diferenciació social. La vall de Barravés, segles XV-XVIII". In: E. Vicedo (ed.), *Terra, aigua, societat i conflicte a la Catalunya occidental*. Lleida: Pagès Editors. p. 117-135.

SAGUER, E.; GARRABOU, R. (1996). "Métodos de fertilización en la agricultura catalana durante la segunda mitad del siglo XIX. Una aproximación a los procesos físicos de reposición de la fertilidad agrícola". In: R. Garrabou, J.M. Naredo (eds.), *La fertilización en* *los sistemas agrarios. Una perspectiva histórica*. Madrid: Fundación Argentaria and Visor Distribuidores. p. 89-126.

STANNERS, D.; BOURDEAU, PH. (eds.) (1995). *Europe's Environment. The Dobřiš Assessment*. Copenhagen: European Environment Agency.

VICEDO, E.; BOIXADERA, J.; OLARIETA, J.R. (1999). "Sistema hidráulico, organización de los riegos y usos del agua en la huerta de Lleida (1830-1950)". In: R. Garrabou, J.M. Naredo (eds.), *El agua en los sistemas agrarios. Una perspectiva histórica*. Madrid: Fundación Argentaria and Visor Distribuidores. p. 225-253.