Traditional compared to new systems for land management in vineyards of Catalonia (Spain)

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Abstract

In Catalonia (NE Spain), as well as in other regions of Mediterranean Europe, the lands with dry land vineyards, especially in sloping areas, have suffered great changes in the last 15-20 years. Some cropped lands have been abandoned, but in others, with vineyards dedicated to production of high quality wine and cava, the cropped area has increased, with more intensive and highly mechanized agricultural systems. This has required great changes in the planting and cropping systems, with previous mechanical land conditioning, reducing relief irregularities and decreasing slopes, through levelling operations and bench terracing. This has lead to sharp changes in soil properties, both in surface and subsurface soil, affecting the hydrological properties, the effective rooting depth and the drainage system.

This paper includes a description of the traditional and new cropping systems and techniques used in vineyards of two of the more representative regions (Alt Penedés and Priorat), where agriculture is mostly dedicated to dry land grape production for high quality wine and cava. In both regions the climate is Mediterranean semiarid, with very variable and erratic rainfalls, mainly concentrated in a few storms during autumn-winter seasons, coinciding with the vine's resting period, and the lower surface cover.There were observed and evaluated hydrological and related effects on soil water regime and erosion processes, derived of the changes introduced on the traditional cropping systems. In the Alt Penedés region, with calcareous soils derived from marls, the new technologies have led to higher runoff losses, to increased surface and mass erosion, to lower rooting depths, and to higher effects on grape production and wine quality, derived of irregularity in the amount and distribution of rainfall. In the Priorat region, with more stony soils derived of schists, the new bench terracing, although it decreases surface rainfall runoff and increases effective rooting depth compared to the traditional system without periodical surface removal of the soil (which was done in the past using animal power), recent studies are showing increase of actual and potential risks of continuous gradual and less frequent catastrophic landslides and gully formation in the terraced lands.

Keywords: Spain, Catalogna, Vineyards, Erosion, Terraces, Mediterranean area, mechanization

Comparaison des systèmes traditionnels et modernes de gestion des vignes de Catalogne (NE. Espagne).

Résumé

En Catalogne (NE de l'Espagne), les versants cultivés en vignes non irriguées ont souffert de grandes modifications ces 20 dernières années. Certains terrains cultivés ont été abandonnés, mais ailleurs, la surface cultivée en vignobles de bonne qualité a été étendue et la culture intensifiée et mécanisée. Les systèmes de plantation et de culture ont été profondément modifiés après planage méchanisé des terres et construction de terraces en gradins à pentes faibles. Ces changements ont modifié profondément les propriétés hydrologiques des sols et du sous-sol, la profondeur d'enracinement et le drainage du terrain.

Cette étude décrit les modifications des systèmes culturaux après nivellement, surtout pour les vignobles destinés à produire des vins de bonne qualité. Dans les deux sites, le climat

est semi-aride méditerranéen et les pluies erratiques tombent en automne et en hiver à une période où les sols sont dénudés et les vignes au repos. Les résultats sont basés sur des études en cours dans deux zones représentatives. On y a observé les caractéristiques hydrologiques et les effets sur l'érosion des systèmes traditionnels et modernes . Dans la région d' Alt Penedés, avec des sols calcaires issus de marnes, les nouvelles techniques ont entrainé l'augmentation des pertes d'eau par ruissellement, l'augmentation de l'érosion de surface et des mouvements de masse, une réduction de la profondeur d'enracinement et des modifications profondes des rendements de raisins et de la qualité du vin en fonction de l'importance des pluies et de leur répartition .
Dans la région du Priorat, avec des sols plus caillouteux sur schistes, le nouveau terrassement en gradins a augmenté l'enracinement sans qu'il soit nécessaire de remuer deux fois par an la terre, comme dans l'ancien système de culture. Des études récentes montrent que le terrassement en gradins augmente les risques de glissement de terrain et le ravinement.

Mots-clés : Espagne , Catalogne, Système mécanisé, vignes, Erosion ,Terrasses, Milieu semi-aride, méditerranéen.

Introduction

Vineyards for dry land grape and wine production, after being introduced by Greeks and Romans more than 2000 years ago, has become a traditional crop in the highly sloping agricultural lands of Catalonia (NE Spain). The area with vineyards decreased at the end of the XIX century due to disease problems, and in the last 50 years for economical reasons. Recently, in the last 25 years there have been abandoned more than 100.000 ha (10% of the cropped area) of marginal agricultural dry lands in Catalonia, optimizing the production potential of the rest of the lands, while increasing the area under irrigation. Nowadays, 25% of the agricultural lands in Catalonia are irrigated, and produce more than 70% of the whole agricultural production.
Vineyards remain mostly under dry land conditions (100.000 ha) for high quality wine (8 % of the whole production by volume in Spain) and cava (99% of the whole Spanish production) still in relatively small (5-20 ha) family properties. With the present scarcity and cost of handwork, and the requirement to speed all operations, the tendency is towards the full mechanization of all practices, including harvesting. This requires vine guided lines with lateral pruning, with 2,4 – 3,2 m. among lines, and 1,2 – 1,4 m among plants. This gives a much lower protection of the soil surface than the traditional free growing vines following contour lines, although in both cases the soil protection is poor in autumn-winter when most of the strong storms occur. Mechanization also requires long and straight lines, as much as possibl. In many cases this leads to the destruction of traditional small conservation structures as stone walls, and to heavy land levelling or terracing, with drastic changes in the surface drainage network and on the surface soil properties.
Organic matter content in the surface soil decreases with the new practices to values lower than 1%. It is considered very important for improving soil properties related with retention of water and nutrients, and for improving the quality of wine. In order to increase the soil organic matter content to more than 1,5%, there are required and practiced applications (mixed with the 0-20 cm surface soil) of 59-60 metric tones/ha of compost or other organic residues every 2-4 years. The effects are generally appreciated after more than ten years of continuous additions to the lands where traditional practices were changed.
Two regions representatives of Catalonia, where the vineyards for high quality wine production has increased the last 20 years, changing drastically the traditional practices, and introducing new varieties, are the Alt Penedés (30 000 ha of vineyards) (Figures 1-4) and the Priorat (5000 ha of vineyards)(Figures 5-8). In both regions the climate is Mediterranean

the climate is Mediterranean semiarid, with an average annual rainfall of about 600 mm, very irregularly distributed, with the highest rains in autumn-winter, and with high differences from one year to another (400-750 mm in Alt Penedés, and 300-900 mm in Priorat. Many storms in autumn, and sometimes in spring, are of high concentration and intensity, generally more than 20 mm/hour and sometimes higher than 100 mm/hour (Alquézar et al. 1990; Generalitat de Catalunya, 1990; Ramos and Porta, 1994)

Traditional and new cropping practices

Alt Penedés

The Alt Penedés region belongs to the Anoia-Llobregat rivers watershed, connected to the Mediterranean Sea. Grapes for high quality wine and cava production is the main crop in the area since the XIV century, with an increase in the cropped area the last twenty years. To the native varieties Xarello and Perellada there have been added introduced varieties as Chardonnay and Cavernet Sauvignon. The vineyards are mostly rainfed, due to regulations for quality control and scarcity of irrigation water. The topography of the area is highly undulated, and even hilly, with cropped fields in 4-20 % slopes, and altitudes of 250-400 m

The soils generally have low or not profile development, mainly due to the levelling operations for smoothing the land surface for mechanization. In many cases, the present cropped lands have man made soils of 40-80 cm depth, formed after breaking up, and deep ploughing with heavy machinery, the under lying soft geological parent material (usually lutites with high calcium carbonate content), that are brought to the surface after heavy earth movements associated to mechanical smoothing of the slopes. These soils are low in organic matter (< 1,5 %), with high silt fraction (40-60 %), and very rich in Ca carbonates. They have a very high susceptibility to surface sealing (Ramos, Nacci and Pla, 2000), with decreasing infiltration, resulting in high runoff and high surface erosion rates.

In this region, the traditional cropping system included free growing vines, usually planted following contour lines, in broad based terraces, supported by stone walls in steeper slopes (Ramos and Porta, 1997), with every field (5-20 ha) surrounded by drainage ditches. The soil between rows was ploughed at 10-15 cm depth, using animal power or small tractors, in order to facilitate rainfall infiltration during the resting and rainier period of autumn-winter, and to control weeds. Traditional contouring broad based terraces, together with contour cropping, usually were very effective for gathering runoff water, conveying the excess to waterways or ditches between fields, and finally to the big gullies or "barrancos" draining the area (Nacci, 2001).

In the last 20 years, due to scarcity of workers, and on order to increase cost/benefit ratios, the agricultural practices have become more mechanized, with new plantations dominated by wire-frame control of vine growth, in straight and long rows separated by 2-3 m, to facilitate mechanization of most of the operations, including harvesting. This has required the enlargement of fields, the smoothing of slopes, and the modification of the agricultural systems, with the elimination of the traditional terraces with stone walls and other conservation practices. As a consequence, generally there has been an acceleration of soil surface erosion (5-20 Mg/ha year) (Uson, 1998) and an intensification of mass movements including gully erosion (300-500 Mg/ha year) (Martínez 1998). Tillage practices include operations to induce deeper root development, to increase rainfall water infiltration, to decrease evaporation losses of soil water, and to control weeds. Periodical tillage at 15-20 cm depth, with blades removing and cutting roots close to the plants, do not allow root growth in the surface 15-20 cm soil, which is maintained loose most of the time to act as protecting mulch against evaporation losses of deeper soil water. After harvesting, in order to improve the infiltration of rainfall water, there are usually excavated deep furrows (> 20 cm depth)

across the slope and in the middle of the line between planted rows. Afterwards the surface soil is periodically (8-10 times/year) ploughed at 10-15 cm depth, particularly when the soil surface has developed seals and crusts by raindrop impact after the main storms. These periodical tillage operations contribute (together with application of small amounts of herbicides) to control weeds, to increase rainfall infiltration and to reduce losses of subsurface soil water by direct evaporation.

The repeated shallow cultivation for weed and crusting control (generally when the soil is still very wet), together with additional mechanical operations for pruning, fertilization, application of pesticides, fixing of vines to the wire frame, and harvesting, induce structural degradation of the surface soil, and compaction at 15-20 cm depth. The continuous ploughing operations are also progressively terracing the land between rows by displacement of 20-40 cm of surface soil from the upper to the lower part of the inter row spaces. Besides, every 10 to 15 rows, depending on the slope, there are built narrow (2-3 m wide) bench terraces, with reverse slope, to stop, absorb and deviate runoff water and sediments coming from the upland rows. With straight rows and enhanced runoff as a result of mechanization, these bench terraces are not so effective in conveying runoff water to the waterways, and the high concentration of runoff induces rill and gully erosion in the generally non vegetated waterways, and mass losses by retreating the heads of the gullies where the runoff from the waterways concentrate. Mass movements in the terraces, mainly in the lower parts of the fields and in active growing gullies, are also probably induced by subsurface and surface runoff of gravitational water coming from higher parts of the field, flowing on top of layers (compacted soil or consolidated lutite) with reduced saturated hydraulic conductivity (Pla and Nacci, 2001). Usually, the farmers quickly refill rills and gullies inside the field with soil. The heads of the large gullies in the lower part of the fields are generally protected with stones, pruning wastes, and cemented structures, which are only partially and temporarily effective in most of the cases.

It may be concluded that in general the new, almost full mechanized, cropping practices in dry land vineyards of the Alt Penedés region, are accelerating soil erosion processes. This is partially due to the changes in the topsoil, associated to the reshaping of the topography for facilitating mechanized practices, and to the mechanized practices themselves. Frequently, the new soil conditions also bring about limitations on the root system depth and development. All these changes usually result in drastic alterations in the soil moisture regime, with effects on surface runoff, on surface erosion and mass movements, and in the retention of rainfall water in the soil to be used by the wines (Nacci, 2001). In some cases, in order to solve the problem of water deficit for the crop in some years and periods, there are being introduced drip irrigation systems to apply small amounts of water, only to solve deficits during critical periods for the crop affecting the grape production.

Tables 1 and 2 present some general effects derived from the transformation of the traditional management system and practices.

Cropping System	Rooting depth (Interval) (cm)	Bulk Density (g / cm^3)	Rainfall Infiltration Rate (mm / hour)	Storage Capacity of Av. Water (mm)
TRADITIONAL	60 (20 – 80)	1,4 – 1,5	25 - 50	160 – 200
NEW	45 (15 – 60)	1,7 – 1,8	5 – 10	80 – 120

Table 1.- Soil physical properties as affected by the change in cropping system in vineyards of the Alt Penedés region (Catalunya, Spain). (Av.: Available)

Cropping System	Dry Year (480 mm/year)				Rainy Year (700 mm/year)			
	Runoff mm	Int. Drain. mm	ET mm	Prod. Mg/ha	Runoff mm	Int. Drain. mm	ET mm	Prod Mg/ha
TRADITIONAL	100	0	380	12	150	140	410	14
NEW	200	0	280	5	320	30	350	8

Table 2.- Distribution of the rainfall water in a dry year (Return period: 5 years) and in a rainy year (Return period: 5 years) among losses by runoff and internal drainage (Int. Drain) and water effectively used by the crop (ET), and grape production (Prod.) (Var. Chardonnay), in traditional and new cropping system of vineyards of the Alt Penedés region (Catalunya)

Priorat

The Priorat region belongs to the Montsant-Siurana-Ebro rivers watershed, also connected to the Mediterranean Sea. The climate is semiarid, with average rainfall of 600 mm, and average temperature of 12-14 °C. The topography of the area is mountainous, with cropped areas in 10-80 % slopes, at 200-650 m a.s.l.. Soils are developed on slates and schists from the Paleozoic, and are called "licorella" soils. They are not calcareous, slightly acid, very poor in organic matter and very stony (20-50 % by weight), sometimes with a gravely pavement on the soil surface. Fine soil fractions, mainly smectite clays, increase with depth. The soils are generally less than 50-60 cm depth, on top of a highly weathered and fragmented rock.

The agriculture in the Priorat region is based mainly in rain fed woody crops, like almonds, olives, hazelnuts, and specially grapes. The grape crop for wine production was established in the region since the XI century, and in one time most of the area was occupied by vineyards. From the end of the XIX century until fifteen years ago, the area of vineyards was decreasing, and the abandoned fields were progressively occupied by native vegetation including some species of Quercus and Pinus. At present, vineyards represent more than 50 % of the cropped area in the region, and has been increasing since 1990, and specially the last 5 years.To the traditional local varieties (Garnatcha negra, Carinyena) producing mostly red wines of high graduation, there have been recently added new introduced varieties as Cavernet Sauvignon (Generalitat de Catalunya, 1990). Since 15 years ago there has been a fast growth of new vineyards, in areas that had been occupied by secondary forest, and by recovering old vineyards partially abandoned. This growth is the result of the increased markets and prices for the good quality wines resulting from mixing grapes from the old plantations with the new introduced varieties.

The traditional vineyards in Priorat were planted with varieties (Carinyena, Garnatcha, etc) producing very strong wines but with very low yields (< 3 Mg/ha). The planting pattern was mainly following the approximate contour lines, in very small (1/2 to 2 ha) individual fields, with vines and lines 2-3 m apart, which were renovated after more than 50 years. There was maintained the natural relief and slopes, and the only conservation structures were non continuous stone walls located in the drainage ways and in places, where based on local experience, there was more danger of soil movement by surface or mass erosion. In many places those walls, and the cropped areas, reached almost the top of the hills, and still many walls may be seen under the forests that now cover some of those areas. In the still remaining old plantations most of those walls have not been maintained or repaired for many years, because of the economical problems associated to wine production in the area prior to 1990,

lack of hand labour to do the work. As a consequence many of the walls partially collapsed and their effectivity for controlling erosion decreased.

In the past the land between the stone walls was generally removed by ploughing the surface 10-15 cm, generally after harvest, using man or animal power. That removal helped both to control weeds, to increase rainfall infiltration and to enhance deeper rooting. This practice almost has disappeared in the last decades, except where a gentler slope allowed to use a small tractor or a motocultor. In these case the weeds were controlled by herbicides. As a result of continuous no-tillage, sometimes the vine roots concentrated on the surface soil, where the effects of dryness derived from scarcity or not well distributed rainfall are more marked. Also derived of it there has been an increasing surface and gully erosion, removing most of the fine earth from the surface soil, leaving a gravely surface pavement. These effects of no tillage contributed to a more reduced and erratic production of grapes, not completely solved with the increased use of chemical fertilizers. In spite of this, some of the old traditional vineyards are maintained, due to the high prices the wine producers pay for the grapes produced under those conditions, because they are required for producing the high quality wines when mixed with the new introduced varieties.

The new plantations are made in a way to allow mechanical operations in the vineyards. This requires as a first step clearing the forest, followed by removal of soil and underground rock using heavy machinery, to build bench terraces 2-5 m wide, depending on the slope. In those terraces there are planted one to three lines of vines of new varieties,1,2 m apart. In most of the cases the walls of the terraces are not protected, except by the regrowth of natural vegetation. In some cases the stony soil in the surface of the newly built terraces is grinded to fine earth using a special equipment attached to a tractor.

The effects of these drastic changes on the relief and soils for new plantations, on the surface and subsurface hydrology, and derived consequences, are now being studied in the field. It has been already observed that in the terraces, part product of excavation and part of refilling, the soil variability is very high. Also the water retention is higher than in natural slopes, which added to the low stability of the terrace walls leads to frequent landslides at different levels when continuous rainfall in one or several consecutive days reach values of 100 mm or higher. The higher water retention capacity, together with the introduction of more productive varieties, leads to higher grape production (8-10 Mg/ha) in the terraces than in the traditional old plantations. To reduce more the risks of water deficiency, affecting quantity and quality of production, in many of the new plantations in terraces there are installed drip irrigation systems, to be used only in critical periods of the vine not having enough water to guarantee a minimum production. In any case the sources of irrigation waters are very scarce, and consist mainly in subsurface water extracted laterally on the hill slopes ("minas").

Conclusion

It may be concluded that the lack of maintenance of some soil and water conservation structures in traditional vineyards of the Priorat, due to past economical and practical reasons, has led to more shallower rooting systems, and to more runoff losses and increased surface erosion, carrying away mostly the fine fraction. This also may lead to a lower and more irregular supply of the required water to the vines, resulting in lower and more erratic grape and wine production.

In the new built bench terraces, the retention of most of the rainfall water, may lead, depending on the soil or rock material forming the terraces, and the concentration of rainfall events, to higher and more secure grape production. On the other hand this type of terracing may lead to higher instability of the slopes and increased risks of catastrophic landslides, with all the environmental effects derived from them.

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Figure 1.- Traditional vineyard planting pattern in Alt Penedés (Catalunya, Spain).

Figure 2.- Land surface mechanical reshaping for new vineyard planting pattern in Alt Penedés (Catalunya, Spain)

Figure 3.- New vineyard planting pattern in Alt Penedés (Catalunya, Spain)

Figure 4.- New vineyard plantation with absorption bench terraces without stone walls every 12-15 rows in Alt Penedés (Catalunya)

Figure 5.- Traditional vineyards in Priorat (Catalunya, Spain)

Figure 6.- Traditional vineyard planting pattern in Priorat (Catalunya, Spain)

Figure 7.- Terracing for new vineyard planting pattern in Priorat (Catalunya, Spain)

Figure 8.- New vineyard planting pattern in Priorat (Catalunya, Spain)