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INTRODUCTION

The area of the Anoia-Alt Penedés is located in the NE of Spain (Catalonia). It is connected to the Mediterranean Sea by the Anoia-Llobregat rivers watershed. Grape in vineyards for high quality wine and cava (spanish champagne) production, has been the main crop in the area since the XIV century, with an increase in cropped area the last 10-15 years. It is mostly rainfed, due to regulations for quality control and lack of irrigation water. The topography of the area is highly undulating and even hilly, with cropped areas on 4-20 % slopes.

Erosion processes in the area are partially related to lithology, geomorphology and tectonics, but there are evidences that they have become highly accelerated since the introduction of vineyards. Traditional cropping systems, included free growing vines, planted following the contour lines, generally with bench terraces supported by stone walls (Ramos and Porta, 1997), and in small fields generally surrounded by drainage ditches. In the last 10-20 years, due to the scarcity of workers, and in 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 more than two meters, 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 bench terraces 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). Even with the traditional systems of soil and water conservation in the area, like wideboard terraces, it is not possible to control erosion problems when the new mechanized practices are introduced. The acceleration of gully erosion, a permanent process in the area, is also affecting the communication network and some housing developments.

In order to control these accelerated processes of surface and mass erosion there are required field layouts and conservation technologies and practices adapted to the new mechanized agricultural systems (Ramos and Porta, 1997).

SOILS

The soils in the area generally have low or no profile development, mainly due to the surface reshaping (cuts and filling) and smoothing of the soil surface for mechanization. In many cases, the cropped lands have man-made soils of 40-80 cm depth, formed after breaking up and deep plowing with heavy machinery, the underlying soft geological parent materials (usually calcilutites) that are brought to the surface after heavy earth movements associated with mechanical smoothing of slopes. These soils, generally classified as Typic Xerorthents or Typic Calcixerepts (Soil Taxonomy system), are low in organic matter (< 1,5 %), with high silt content (40-60 %), and very rich in Ca carbonates. They have a high susceptibility to sealing by raindrop impact (Ramos and Nacci, 1997), with decreasing infiltration rates, resulting in high runoff and surface and rill erosion. Grape in vineyards, especially if planted in vine guided lines with mechanical lateral pruning, provide very poor ground cover to the soil.

RAINFALL

The climate in the area of the Anoia-Alt Penedés is Mediterranean maritime, with hot summers and mild winters. The average annual rainfall is close to 600 mm, but highly variable among years (400-750 mm) and very irregularly distributed during the year. There are two periods of maximum precipitation, one during the spring and the other in autumn. In the later period (autumn), following a very dry season, the rainfall usually occurs in storms of short duration and high intensity (Ramos and Porta, 1994), which are the main reason for high runoff, and of the surface and mass erosion. It has been found that 40 % of the rain in the area occurs at more than 10 mm/hour, and 10% at more than 40 mm/hour.

AGRICULTURAL PRACTICES

Wine and cava production in the area is mainly directed to quality. Quality is affected by climate, rootstock, variety, crop management and soil properties, but mainly by water availability (excess or deficit) and nutrient supply. The supply of nutrients may be controlled by mineral and organic fertilization. There is no control on water supply, as it isdependent on rainfall amount and distribution, and soil water holding capacity. Grape yields at full production ranges from 6-10 Mg/ha, mostly depending on water availability in critical periods which is controlled by rainfall and soil characteristics.

To avoid weed competition for water, they are eliminated mainly through shallow cultivation in combination with only small amounts of herbicides, to avoid toxicity effects on grapes. Cultivation at 15-20 cm depth is also repeated after each significant rainfall event (8-10 times a year) to break down the surface crusts that develop from surface seals formed by raindrop impact on the very weakly aggregated surface soil. The objective is to assure a better initial infiltration of the rainfall water from further storms, and to decrease evaporation losses of the previous infiltrated water. Sealing, which drastically reduces the intake rate of rainfall water in the soil, generates runoff usually only after 10-20 mm rainfall in cultivated soil, and after less than 10 mm in crusted soil. The main causes are the high intensity of rainfall together with the soil characteristics (high silt and low organic matter contents) and the poor ground cover.

The repeated shallow cultivation for weed and crusting control (generally when the soil is still wet), together with additional mechanical operations for pruning, fertilization, application of fungicides, 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 plowing 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.

Traditional contouring broad based terraces, together with contour cropping, were very effective for gathering runoff water, conveying the excess to waterways or ditches among fields, and finally to the large gullies or "barrancos" draining the area. With straight rows and enhanced runoff as a result of mechanization, the bench terraces are not so effective in conveying runoff water to the waterways, and in doing so, the high concentration of runoff induces rill and gully erosion in the usually 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, especially 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 layers or consolidated lutite) with reduced saturated hydraulic conductivity.

The use of cover crops between vine rows and in vegetated waterways to reduce sealing and runoff in the fields, and rill erosion in the waterways, is limited due to difficulties in establishing and maintaining the green cover (due to soil compaction and lack of water), and the potential competition for water with the crop (Uson, 1998). Due to the characteristics of the surface soil, it is difficult to establish quickly an effective cover crop, and if the cover is less than 50%, plowing reduces runoff and erosion more than no tillage.

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 many cases.

EROSION PROCESSES AND EFFECTS

It may be concluded that the new mechanized cropping practices in the vineyards for wine production in the Anoia-Penedès area accelerate 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 cropping 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 vines, due to:

- Decrease in infiltration of rainfall water "in situ", due to higher surface runoff which concentrates in the terraces and lower portions of the field with decreasing slopes,

and in the headwalls of the large gullies ("barrancos") in the lower part of the landscape.
- Decrease and irregularities in the effective vine rooting depth and development.

The main effects are:
- Larger losses of rainfall by runoff and soil by erosion, every year.
- Catastrophic mass movements and enlargement and retreat of large gullies, in years (return periods of 5-10 years) with high concentration of rainfall, mainly in autumn.
- Lower storage in the soil profile of available water for the vine crop, with more drastic fluctuations of soil moisture in the root zone, and more probabilities of drought in critical periods of the crop.

The practices used to solve these problems and to moderate their effects, include deep plowing to increase rooting depth, continuous shallow plowing to break seals and crusts, application of large amounts of organic and mineral amendments in the topsoil, building hillside ditches and bench terraces parallel to the straight vine rows, refilling of rills and small gullies, etc., which sometimes are not very effective to control erosion, or create some additional environmental problems. This is mostly due to the empirical application of those conservation practices, without an adequate identification and quantification of the main causes and processes involved, and of the actual and potential problems of water and soil losses, and of water deficits or excess and their effects on wine production (quantity and quality).

Many of the processes of soil and water conservation and their effects are associated with the soil water regime (Pla, 1986; 1997), and to its modification by the soil and cropping management practices. This is being studied under field and laboratory conditions (Pla, 1986; Nacci and Pla, 1991; Ramos and Nacci, 1997), through measurements and monitoring of the appropriate soil hydrology parameters and rainfall characteristics (Pla, 1990), to apply a model (SOMORE) to simulate and predict soil moisture regime and associated potential problems of soil erosion and water supply to the crop at different growth stages (Pla, 1997). The measurements under field conditions included water intake rates under flooding and under simulated rainfall, and saturated hydraulic conductivity of the different layers in the soil profile. Also soil water content at saturation and at field capacity were measured in the field. Soil moisture at a matric potential of -1.5 Mpa was measured in the laboratory using disturbed soil samples. Continuous monitoring of soil moisture at different depths in the field, using TDR equipment and sampling, was used to test the validity of results simulated by the model SOMORE. The measured rainfall characteristics were amount, distribution and intensity.

Some preliminary results, used to show the potential application of the model SOMORE to this specific case are shown in figures 1-5.

Figures 1&2 show how in a year (1996) with total rainfall larger than average, but highly concentrated in autumn (days 260-350), surface sealing affects local surface runoff, and therefore surface erosion and concentration of runoff water in terraces, waterways and lower part of the slopes, causing rill erosion and mass movements. There are also shown the effects on supply of available water to the vine, especially in the critical periods of spring and early summer (days 80-210), with moderate effective rooting depth (80 cm) of the vine.

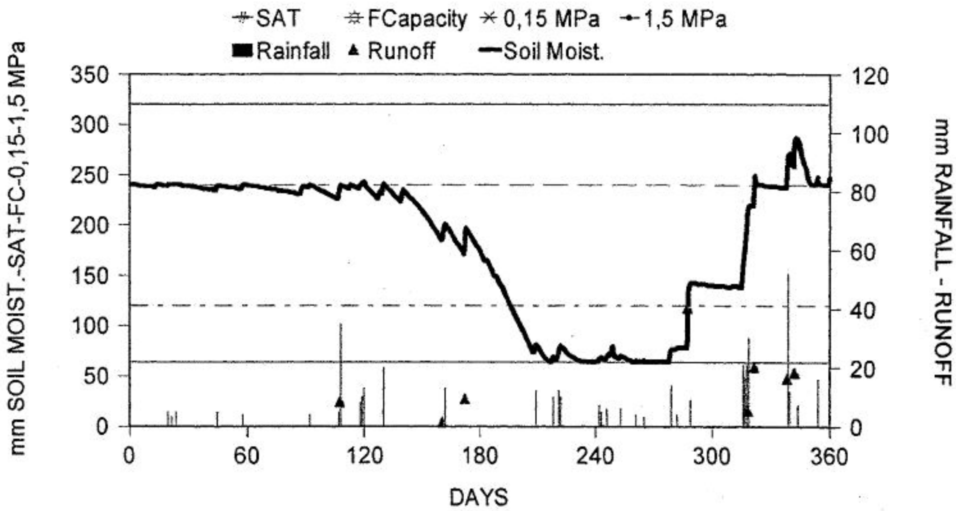

Figure 1.- Soil moisture regime in a vineyard (Anoia-Alt Penedés) during 1996 (Rain above average: 760 mm. Return Period: 5 years). Effective soil depth: 80 cm. No surface soil sealing (Minimum water intake rate: 20 mm/h). Ksat subsoil: 0,3 mm/h

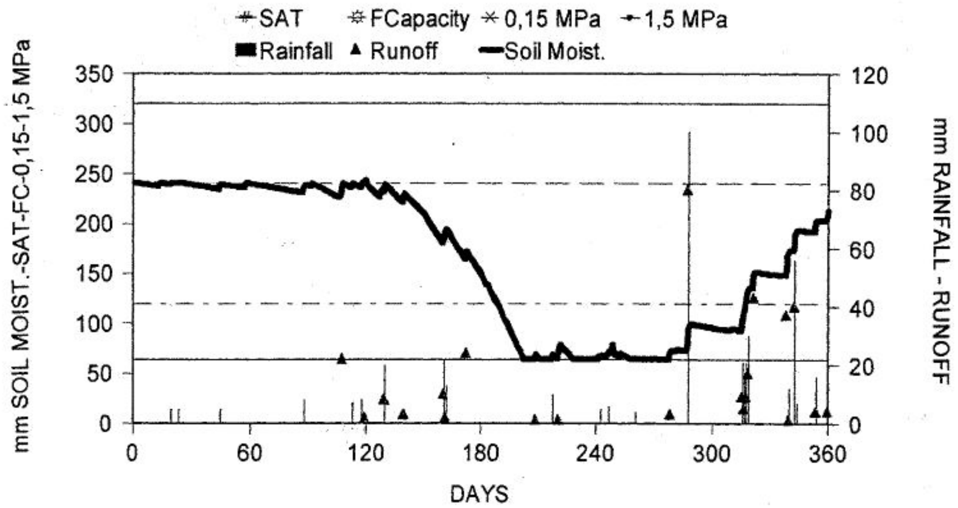

Figure 2.- Soil moisture regime in a vineyard (Anoia-Alt Penedés) during 1996 (Rain above average: 760 mm. Return Period: 5 years). Effective soil depth: 80cm. Surface soil sealing (Minimum water intake rate: 4 mm/h). Ksat. subsoil: 0,3 mm/h

Figure 3 shows how in the same year (1996), the presence of a compact layer close to the surface and terracing of the field without adequate possibilities of drainage, may lead to conditions favoring rill and mass erosion, mainly in autumn, which may be even be worse if runoff water from upper parts of the field also concentrates in the terraces, as it is frequently the case.

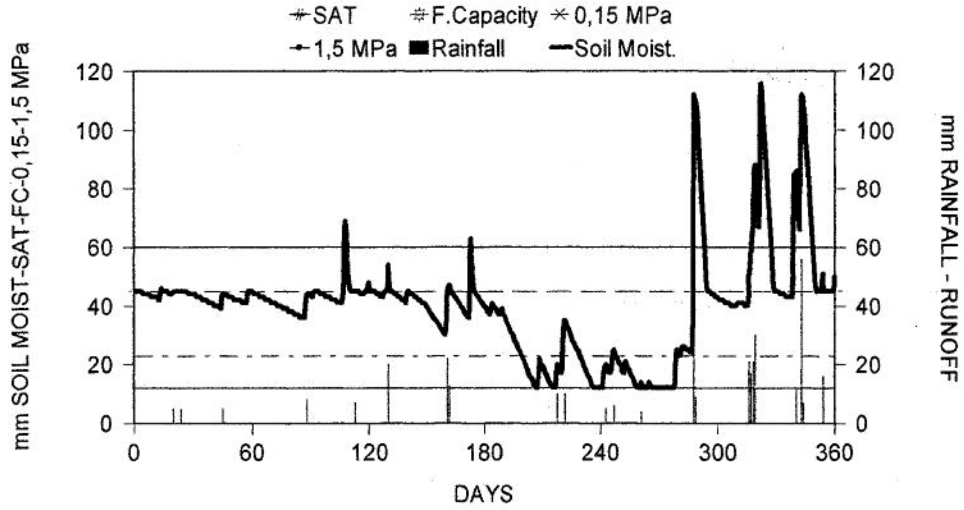

Figure 3.- Soil moisture regime in the terraces of a vineyard (Anoia-Alt Penedès) during the year 1996 (Rain above average: 760 mm. Return Period: 5 years). Compacted layer (Ksat: 0,4 mm/h) at 15 cm depth. No surface sealing (Minimum water intake rate: 20 mm/h)

Figures 4&5 show how in a relatively dry year (1997), but with a large amount of water from late 1996 rainfall stored in the soil profile at the beginning of the year, the changes in effective rooting depth (50-120 cm) and sealing effects may lead to increased surface runoff (in this case in autumn and early winter), with all the associated consequences. Among these, there are observed the increased water deficits, due to shallow roots and

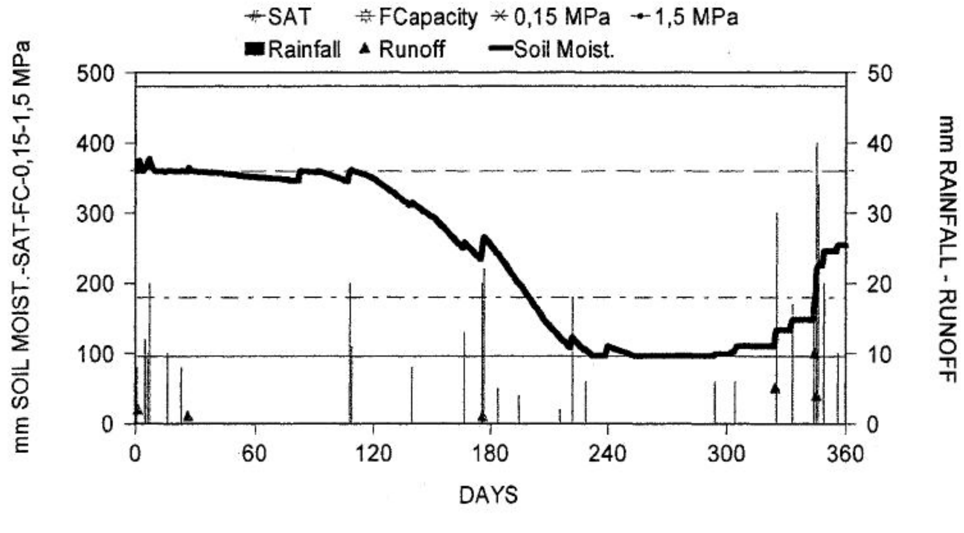

Figure 4.- Soil moisture regime in a vineyard (Anoia-Alt Penedès) during 1997 (Rain below average: 483 mm. Return Period: 5 years). Effective soil depth: 120 cm. No surface soil sealing (Minimum water intake rate: 20 mm/h). Ksat. subsoil: 0,3 mm/h

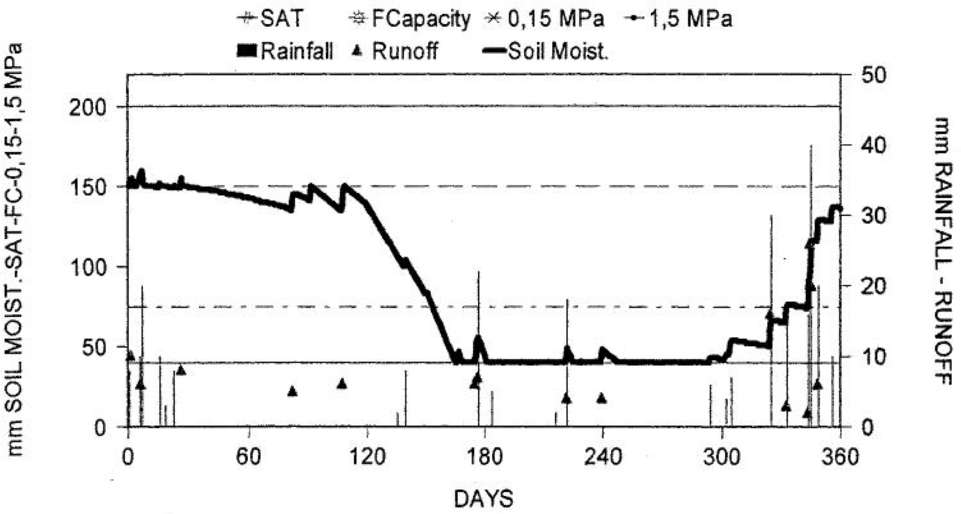

Figure 5.- Soil moisture regime in a vineyard (Anoia-Alt Penedès) during the year 1997 (Rain below average: 483 mm. Return Period: 5 years). Effective soil depth: 50 cm. Soil surface sealing (Minimum water intake rate: 4 mm/h). Ksat. subsoil: 0,3 mm/h

sealing, in the critical period of 80-210 days. Those deficits could represent a decrease to less than half (6 Mg/ha instead of 10-12 Mg/ha) in the grape production, actually measured on samples taken in different sites with those contrasting conditions in the studied area.

From the previous analysis, it may be concluded that the information provided by the simulation of the soil moisture regime with the model SOMORE, which has been successfully tested under other conditions (Pla, 1996; 1997; 1998), may also be used for a more rational selection, planning and application of the cropping systems and conservation practices, adapted to the new fully mechanized operations, in vineyard fields of NE Spain. This would contribute to control and reduce both surface runoff and erosion, mass movements, and related environmental impacts; and to improve the soil moisture conditions at the different growth stages of rainfed vineyards, resulting in higher (in quantity and quality) wine production.

SUMMARY

The soil and cropping management practices for rainfed production of grapes for high quality wine and cava production in the Anoia-Penedès area in NE Spain have been mostly mechanized in the last two decades. As a consequence of the new cropping pattern and changes in surface soil and effective rooting depth, associated to the smoothing of the lands and mechanization of the different operations, there has been an acceleration in the soil surface and mass erosion, and changes in the availability of soil water for the crop at different growth stages. Under these new conditions, the traditional soil and water conservation practices have been abandoned or have become ineffective, and the effectiveness or applicability of some newly proposed practices has proved to be limited, or is creating further environmental problems. Based on recent studies presently carried on in the area, it is shown that with the use of a simulation model based on the

integration of properly selected and measured soil and rainfall parameters, it is possible to predict soil moisture regimes for the whole year and cropping cycles for any combination of factors related with the soil, crop, management and climate in the area. Those predictions may be used for a more rational selection and application of cropping systems and of soil and water conservation practices, adapted to the new mechanized operations, in order to improve the quantity and quality of production, and to decrease environmental damages.

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