Land Use, Hydrological Behaviour and Desertification in Mediterranean Environment: Case Studies of NE Spain

Ildefons Pla Sentís
Universitat de Lleida
Lleida, Spain
ipla@macs.udl.es

Summary
The interaction of land use, land management, climate, and land degradation processes associated with unfavourable changes in hydrological processes has been studied during the last ten years in two different areas with dry land vineyards in Catalonia (NE Spain). With the use of simulation modelling based on hydrological processes and integrating the different factors involved, the hydrological behaviour and related land degradation and desertification effects were predicted under changing climate, soils, topography and land use and management in the two studied areas. It is proposed that the approach used in this study may be extended to other Mediterranean semiarid environments, to predict and prevent desertification processes.

Introduction
The main direct cause of desertification is land degradation, which affects the conservation of soil and water resources. Desertification is generally viewed as an advanced stage of land degradation, when vegetation cover falls below some level (about 35%). For many people desertification is the diminution or destruction of the biological potential of the land that can ultimately lead to desert-like conditions, usually in dry lands, but sometimes even in humid ones. It is related to soil and climate characteristics, but inappropriate land use and management may accelerate the processes of desertification. Those processes are strongly linked to unfavourable changes in the hydrological behaviour affecting soil water balance and soil moisture regime.
In the past decades, the degradation of previously naturally vegetated or productive agricultural lands, leading in many cases to barren, desertified, landscapes, has dramatically extended in many regions of the World. The reasons are mainly unfavourable biophysical conditions and negative human impacts. The areas prone to degradation and desertification are often characterized by marginal soils, and low and highly variable rainfall. The negative human impacts are mainly through inadequate land use, including deforestation, overgrazing, and deficient agricultural practices, leading to soil erosion, salinization and vegetation degradation, as a consequence of drastic changes in the water balance. This might be further aggravated by the ongoing threat of climate change.
Desertification in the more vulnerable areas with arid and semiarid climate in the Mediterranean region goes back over millennia (Dupre, 1990). The most important human actions that have triggered or intensified the processes of land degradation have been overgrazing, deforestation and forest fires, and in recent decades new land management practices, associated to agricultural intensification, mechanization, inadequate maintenance or abandonment of vast areas of terraced agriculture, over-drafting of surface and groundwater for irrigated agriculture, tourism, etc. (EC, 2003). These new land use and management practices are a consequence of changes in social economic conditions, market prices and public policy-led subsidies, consumption

patterns, etc, associated to technological progress and changing production systems. Desertification has affected more hilly sloping lands, but in valley bottoms where irrigationsalinization and sodification have become a widespread form of soil degradation and desertification. There evidence that land degradation processes leading to desertification in the Mediterranean region are getting worse, bvary from one place to the other (EC, 2003). The climate in arid and semiarid Mediterranean environments, with highly variable and erratic rainfall, increases the risk of desertification may have increased in the last decades, mainly due to drastic changes in land use and management, potential negative effect of climate change. In the medium or long term, it is prethat global climate change may accelerate the processes of desertification in the Mediterranean region (Imeson and Emmer, 1992), but at short term, land use practices leading to soil degradation There uncertaint in predictions of regional climatic change, but probably the Mediterranean region will warm significantly, with more precipitation in winter and less in summer, and declining annual precipitation in the southern part (N Africa and SE Spain)frequency and severity of droughts, the occurrence of extreme eventsaffect the land hydrology (Palutikof and Wigley, 1996).

Increasing frequency of droughts, based upon reduction in annual rainfall, leads to land desertification, but widespread incidence of drought could be a result of changing land use, without a necessary change in climate, through a reduction in the effectiveness of rainfall by land degradation processes. Climate variability changes in the frequency and magnitude of extreme events could have a greater impact than changes in mean climate alone. In mountainous areas of the Mediterranean region, with already degraded lands, heavy seasonal rainfall and extreme events may result in concentrated runoff, rushing down in great volumes as flash floods, causing extreme damage downstream. Landslides may also be initiated by those intense rainstorms in mountain areas.

The formulation of a sound soils policy, and the prevention and choice of solutions for the problems of land degradation leading to desertification must depend on the right identification of the processes involved and in the precise analysis, diagnosis and understanding of the causes and potential effects at specific places. Not doing so may lead to catastrophic effects. Despite the modernization of observation facilities by the use of satellite imagery and computer programs to analyse the data, there are still many uncertainties at the regional and national levels in the Mediterranean region, on the causes, the extent and the seriousness of land desertification. These uncertainties prevent those who manage land resources from planning properly, and introduce constraints in operation of early warning systems with regard to agricultural production and disasters such as flooding and landslides (Pla, 2005).

Water, that is often the main limiting factor of plant growth, is also the main factor directly or indirectly responsible for soil and land degradation processes. These processes, leading to desertification, are strongly linked to unfavourable changes in the hydrological processes responsible for the soil water balance and for the soil moisture regime, which are affected by the climate conditions and variations, and by the changes in the use and management of soil and water resources (Pla, 2002). Dry land crops, like grapevines, with great survival capacity under drought conditions, may help to decrease the processes and consequences of land desertification in the semiarid regions of the Mediterranean region.

Materials and methods

The interaction of changes in land use and management, and in climate, with land degradation processes associated to unfavourable changes in hydrological processes has

been studied during the last ten years in two different areas with dry land vineyards in Catalonia (NE Spain). There were evaluated problems of soil water supply to the plants through the different growing periods in the year, of surface and mass erosion, of runoff, of flooding, and related, derived of changes in hydrological behaviour under the new levelling, terracing, planting and management practices.

The study areas were located in commercial fields representative of two of the regions (Alt Penedés and Priorat) of Catalonia (NE Spain), where the area under vineyards for high quality wine and cava production has increased over the last 20 years. Accompanying this large increase in vine area has been a drastic change from traditional practices, including the introduction of new varieties. In both regions the climate is Mediterranean semiarid, with an average annual rainfall of approximately 600 mm, very irregularly distributed, with the greatest rains in autumn-winter, a very dry summer, and with large variability in totals from one year to another (400-750 mm in Alt Penedés and 300-900 mm in Priorat). Rainfall is typified by many storms in autumn, and occasionally in spring of high concentration and intensity. Climate change may increase the irregularity of this rainfall, the frequency of dry years and the probability of extreme events; phenomena that have been observed in both regions in the last 25 years.

The water use of grapevines through the growing season is characterized by lessened requirements in the periods before bloom and after harvest until fall (autumn), and a maximum consumption in the mid part of the growing season. If the reserve water capacity of the soil in the rooting zone is not enough, reduced amounts of rainfall during the main growing season of grapevines (June-August) may lead to a long term soil water deficit, which can affect growth, production and maturation, in spite of the natural survival capacity of grapevines under drought conditions.

In order to decrease costs of the scarcely available manual labour, to increase production and to speed all operations, the current trend is towards full mechanization of all practices, including harvesting. To proceed to a fully mechanised system there is a need for heavy land levelling or terracing operations, with drastic changes in the surface drainage network and on the effective soil rooting depth and surface soil properties (Pla & Nacci 2003).

The effects of these drastic changes on the relief and soils for new plantations, and of the changes in land management in the traditional plantations are being studied under different field and laboratory conditions. Measurements and continuous monitoring of appropriate soil hydrological parameters and rainfall characteristics have been conducted at field sites, complemented with laboratory measurements. These have been used as a basis for the application and validation of a model (SOMORE) which allows the simulation and prediction of the soil moisture regimes and of the associated potential problems of soil erosion and of water supply to the grapevines at different growth stages (Pla 1997; Pla, 2002; Pla and Nacci 2001). In many cases adaptations and changes in the methodologies were required to make adequate measurements, particularly under field conditions.

Results and conclusions

It was found that most of the problems of soil and water conservation were associated with the effects of climate change and of soil and cropping management practices on the soil water regime. The new fully mechanized, land management and cropping practices in the dry land vineyards of the Alt Penedés and Priorat regions of Catalonia (Spain) result in drastic changes in the soil moisture regime. The major effects are on surface

runoff, surface erosion and mass movements, and in the retention of rainfall water in the soil for utilisation by the grapevines. Analysis, based on appropriate *in situ* evaluations of climate characteristics and of soil hydrological properties and proœsses, complemented with the use of simple simulation water balance models based on those processes, may be very useful, and even indispensable, for an adequate planning of more sustainable land use and management for grape wine production, or other alternative uses. The study reported here investigated different previewed scenarios of changing climate and agricultural policies with strong potential to cause changes in land use and management in the Mediterranean region.

In general, it may be concluded that hydrological approaches would be essential to identify and assess the causes and processes of desertification. The evaluation of the hydrological processes, under different scenarios of changing climate, soil properties, and land use and management, with flexible simulation models based on those processes, may help to predict and to identify the biophysical causes of desertification at local, national and regional levels. This is a required previous step for a rational land use planning, and for the selection and development of short and long term strategies and technologies to reduce or to control land degradation processes leading to desertification, and to the related social economic and security problems. There is proposed an integrated framework for the development of this kind of approach, with potential application to predict and prevent desertification processes under Mediterranean semiarid environmental conditions.

References

Dupre, M. 1990. "Historical antecedents of desertification: climatic or anthropological factors?". In *Strategies to Combat Desertification in Mediterranean Europe*, J.L. Rubio and R.J. Rickson eds. 2-39. CEC. Luxembourg

EC. 2003. *Mediterranean desertification. Framing the policy context*. Research results. Project EVK2-CT-2000-00085. Office for Official Publications of the European Communities. Luxembourg

Imeson, A.C. and I.M. Emmer. 1992. "Implications of climate change on land degradation in the Mediterranean". In *Climate Change and the Mediterranean*. 95-128. L. Jeftic et al, eds.:Edward Arnold. London (UK)

Palutikof, J. P. and T. M.L. Wigley. 1996. "Developing climate change scenarios for the Mediterranenan Region". In *Climatic Change and the Mediterranean.* Vol 2 . L. Jeftic and J.C. Pernetta, eds. 27-55. Edward Arnold. London (UK):

Pla, I. 1997. A soil water balance model for monitoring soil erosion processes and effects on steep lands in the tropics. In:" Soil Erosion Processes on Steep Lands" . Special Issue of Soil Technology. (I. Pla, ed).11(1):17-30.Elsevier. Amsterdam

Pla, I. 2002. Hydrological approach to soil and water conservation. In: "Man and Soil at the Third Millenium". (J.L. Rubio et al,ed). I: 65-87. Geoforma Ed. Logroño (Spain).

Pla, I. 2005. Hydrological approach for assessing desertification processes in the Mediterranean region. In : Desertification in the Mediterranean Region. A Security Issue. Springer. Heidelberg (Germany)

Pla, I. and S. Nacci. 2001. Impacts of mechanization on surface erosion and mass movements in vineyards of the Anoia-Alt Penedés.Area (Catalonia, Spain) In: "Sustaining the Global Farm". (D.E.Scott et al , ed).812-816.Purdue Univ.-USDA, ARS. West Lafayette, In.(USA)

Pla, I. and S. Nacci. 2003. Tradicional compared to new systems for land management in vineyards of Catalonia (Spain). In: Techniques Traditionnelles de GCES en milieu mèditerranien. (E. Roose et al, ed). Bulletin Reseau Erosion 21:213-223. Montpellier (France)