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Runoff, erosion, and water quality of agricultural watersheds in central Navarre (Spain)

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ABSTRACT

Two experimental watersheds, La Tejería (1.69 km^2) and Latxaga (2.07 km^2), appointed by the Government of Navarre (Spain) for assessing the effect of agricultural activities on the environment, were monitored during 10 years (1996–2005). Both watersheds are roughly similar with regard to soils, climate (humid sub Mediterranean) and land use (almost completely cultivated with winter grain crops). The first results for both sites on runoff, exported sediment, nitrate and phosphate are presented.

Most runoff, sediment, nitrate and phosphate yields were generated during winter, when variability was also the highest of the whole year.

La Tejería had much higher sediment concentrations and sediment yield than Latxaga. Nitrate concentrations were also significantly higher at La Tejería, with values constantly over the critical threshold (>50 mg NO_3 l^{-1}). However, phosphate concentrations were similar in both watersheds and corresponded to water with a significant risk of eutrophication. Differences in watershed behaviour could be mainly due to differences in morphology, topography, and amount of stream channel vegetation between both sites.

This is an unprecedented research for the region and the generated dataset is of paramount importance for research issues such as hydrology, erosion and water quality. The results highlight the complexity of Mediterranean agricultural landscapes and the need for further analyses to better ascertain the processes behind them.

1. Introduction

Non-irrigated arable lands cover approximately 30% of the area of Europe (EEA, 2005) and an important proportion of the world as well (FAOSTAT, 2005). These areas are frequently cultivated with crops of great social and economic importance to many regions. The peculiarity of the conventional arable land cropping system is that the soil surface remains uncovered during long periods of time, corresponding to the soil preparation and crop establishment phases, which frequently occur during the wettest seasons. As a result, soil erosion problems are a common feature of these areas (Casalí et al., 1999; Poesen et al., 2003; Auzet et al., 2004; De Santisteban et al., 2006). Erosion causes soil degradation and also severely affects water resource

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quality (PAP/RAC, 1997), which nowadays constitutes a very serious threat to the environment. It is thought that a quarter of Europe's agricultural land exhibits some erosion risk (EEA, 2005).

Furthermore, arable lands are a major source of water pollutants (OECD, 2001; Iital et al., 2005; Angás et al., 2006). The latest data on the quality of European water resources highlight the detrimental impact of over-fertilization on the quality of ground and surface waters at present (EEA, 2005). The so-called diffusive or non-point-source pollution, especially, is predominant in agricultural areas, with nitrate and phosphate being the main problem. For instance, it has been reported that agriculture is the source of 46–87% of the nitrate and 20–40% of the phosphate incorporated into European continental waters (EEA, 1999). Diffusive contamination pollutes waters, causes their eutrophication and offers significant health risks originating from high agrochemical concentrations in drinking water. As a consequence, most governments and environment agencies in developed countries have recently created directives and regulations to reduce the presence of nutrients (mainly nitrate) in surface and ground water (EC, 1991; US EPA, 2000). However, their implementation has not been completely successful so far due to several technical and policy difficulties such as the designation of vulnerable areas, the monitoring and assessment of the effectiveness of measures or their contraposition to agricultural productivity criteria (EEA, 1999).

In this context, the need for clear and accurate soil erosion and water quality measurements in agricultural areas is vital as a reliable basis for any understanding of the underlying processes, the assessment of their significance and the consequent development of prevention plans (PAP/RAC, 1997; EEA, 1999). Measurements can be obtained at plot, small watershed or large watershed scale. At a plot scale, these measurements are usually adequate enough to analyze processes and evaluate soil conservation practices or erosion models. However, obtaining representative information about larger areas can be impossible with the plot approach (Parsons et al., 2004), and in large watersheds too, defining sediment and pollutant transport processes can entail a high degree of complexity (De Vente et al., 2006), thus failing to identify the sediment and nutrient sources and the significant processes. Therefore, the monitoring of erosion and water quality variables can best be approached in small sized watersheds (0.5–2.0 km^2) (PAP/RAC, 1997; Hyer et al., 2001; Quinn, 2004). Several initiatives have been conducted to develop soil erosion and water quality measuring station networks at the watershed scale over agricultural landscapes (Walling and Webb, 1996; Renard et al., 2003).

Non-irrigated arable lands also cover an important part of Spain, approximately 25% (EEA, 2005), as well as a significant area of the region of Navarre, approximately 30% (Gobierno de Navarra, 2001). Furthermore, soil erosion phenomena are a common feature of Navarre's agricultural lands (Casalí et al., 1999; De Santisteban et al., 2006). As a result, the Department of Agriculture, Livestock and Food of the Government of Navarre decided to establish a network of experimental agricultural watersheds. The main objective of the network was to provide data for assessing the effect of agricultural activity on the water resources, and, consequently, for identifying and implementing environmentally sound land management practices. Additionally, the data collected at the experimental watersheds are of great utility for the evaluation of several modelling tools. The experimental watershed network consists of four watersheds. Two of them, Latxaga and La Tejería, are located within high productivity winter grain farming areas, the third watershed, Oskotz, is in an area of intensive cattle-breeding, whereas the fourth, namely Landazuria, is an irrigated, intensively cultivated area. The Latxaga and La Tejería watersheds have been investigated since 1995, Oskotz since 2000, and Landazuria since the present year. The instrumentation in each watershed includes: one automatic meteorology station; several non-recording rainfall gauges distributed throughout the watershed; and one discharge measuring station where discharge, turbidity and water quality parameters are measured (Del Valle de Lersundi and Donézar, 1995; Donézar and Del Valle de Lersundi, 2001). The geological material is impervious within each watershed, which ensures a suitable control of the water balance.

In this paper, data recorded at Latxaga and La Tejería watersheds are analyzed and studied in detail. These watersheds can be considered as being representative of wide areas of Navarre and Spain as regards their morphology, soils, climate, land use and management. It should be noted that the information already available covers a 9-year period, with continuous observations from 1 September 1996 to 31 August 2005. Rainfall, runoff, sediment, nitrate and phosphate data are presented and discussed.

The two remaining watersheds, i.e., Oskotz and Landazuria, are not analyzed herein. The reason for that is twofold. First, we still have a dataset of these watersheds with an insufficient amount of recorded years. Secondly, the land uses of these watersheds are much different between them and between those at La Tejería and Latxaga. The fact that, La Tejería and Latxaga share a similar land use facilitates our study and analysis as a first approach.

The main objectives were (1) to analyze the behaviour of agricultural experimental watersheds in terms of discharge, sediment, nitrate and phosphate yield and concentrations, and (2) to study the controlling factors underpinning that behaviour.

2. Description of the experimental watersheds

2.1. *Latxaga watershed*

Latxaga watershed covers an area of 207 ha and is located in the central eastern part of Navarre (Spain) (Fig. 1). The geographical coordinates of the watershed outlet are 42°47′7.5″N and 1°26′11.4″W. The main morphological characteristics of the watershed are shown in Table 1. Its climate is humid submediterranean, with an average annual precipitation of 835 mm, distributed over 95–100 days of rainfall, and an average annual temperature of 12 °C (Gobierno de Navarra, 2001). The valley bottom minimum slopes are about 5–7%, whereas the hill slopes can reach up to 30%. Geologically, the area is underlined by clay marls and Pamplona grey marls (Gobierno de Navarra, 1997). A detailed soil map of the Latxaga watershed is provided in Fig. 2, and information on soil properties in Table 2. The prevailing soil class is *Paralitic*