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Variation of infiltration rate through karstic surfaces due to land use changes: A case study in Murgia (SE-Italy)

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Abstract

Groundwaters of the Murgia carbonate aquifer represent the main groundwater resource of the Apulia region (SE Italy). In the highlands (Alta Murgia) karst crops out in different forms and textures which have been preserved up to the 1970s: little evolved agriculture and sheep rearing produced only a marginal modification of the epikarst while a high degree of division into parcels by drystone walls helped in preserving soils from erosion. In the last years the original scenery of the Alta Murgia changed due to widespread transformations of surface karstic textures for agricultural purposes, with undeniable negative consequences on the hydrogeological balance, concerning both the infiltration and the runoff terms. Stone shattering led to flattening and deep alteration of a large part of the original karstic landscape and to demolition of drystone walls.

In a study area of about 139 km^2 located in the Alta Murgia, the comparison of aerial photos related to the period 1950–2001 indicated that stone shattering had occurred for about 42% of the area.

The hydrological behaviour of the first soil layer of experimental parcels representing both shattered stone and natural karstic surface textures was analysed by using the numerical model Hydrus-2D with the aim of estimating the variation on infiltration rate due to stone shattering. Intensive field and laboratory measurements concerned soil texture, soil water content, pressure head, saturated hydraulic conductivity, pan evaporation and meteorological parameters.

Keywords: Karst; Surface textures; Stone shattering; Evapotranspiration; Infiltration rate; Groundwater

1. Introduction

The middle part of the Apulia Region (SE Italy), named Murgia (Fig. 1), holds a huge karstic aquifer, which constitutes the main water resource of the entire region. The Alta Murgia, due to its position, elevation, climatic conditions, surface karstic textures and morphology, constitutes the main recharge area of the aquifer. Up to the end of the 1970s, pastures or mainly uncultivated soil characterized Alta Murgia land use, while a small amount of cereal growing was only carried out in the morphologic depressions with significant amount of soil. To make lands suitable for cultivation, for centuries farmers practiced the so called process of *spietratura* (stone removal): this consisted of manually collecting the stone elements from the surface and subsequently using them for constructing drystone walls, sheep pens, small rural buildings and fences for protecting and pasturing the animals. This system created only a marginal modification of the epikarstic textures. An important feature of the territory was its dense parcelling, where a very developed network of drystone walls acted as borders. The drystone walls, made up by two well-squared faces and an inner filling of tout venant, have a high filtering power and capacity of holding the soil. They had in the time the role of protecting the scarce soil from erosion and retarding the runoff, thus contributing to reduce the flood risk downhill: sometime this was precisely the purpose of their presence. In the whole, such

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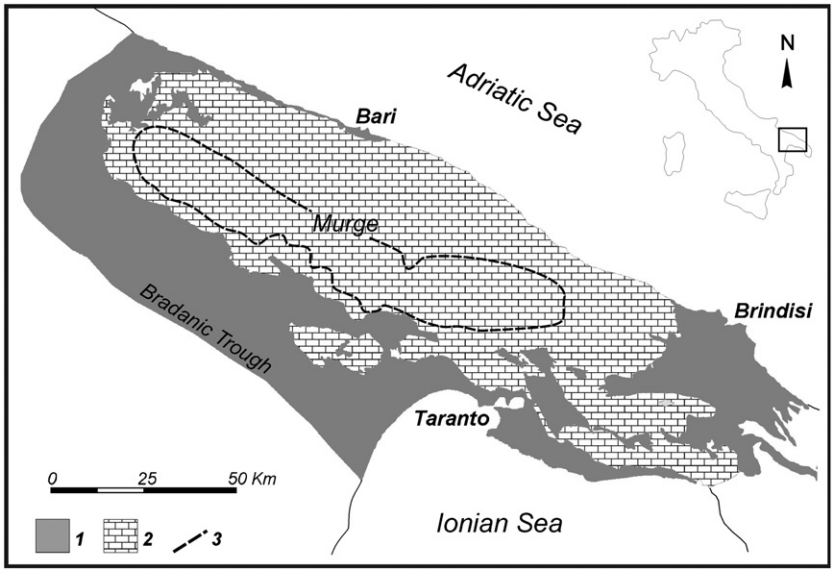

Fig. 1. Schematic geological map of the Murgia. 1) Plio-Pleistocene (Bradanic Trough cycle and terrace deposits); 2) Meso-Cenozoic carbonate units of the Apulian foreland with some local Quaternary cover; 3) Boundary of the "Alta Murgia" area.

type of human work was always in equilibrium with the environment: hence, the human presence during a long period contributed to the conservation of the karst environment and the safeguard of groundwater.

Human impact on many karstic environments has been largely noticeable in the last few decades (Akdim and Amyay, 1999; Burri et al., 1999; Nicod and Salomon, 1999; Gillieson and Thurgate, 1999), with main reference to its damaging consequences on soil erosion and groundwater quality. Parise and Pascali (2003) synthesize the worldwide causes of karst environment degradation and main consequential effects. Especially the passage from traditional agricultural practices (animal rearing and dairy farming) to modern intensive agriculture is the primary cause of karst landscape change and of negative implications for the hydrological properties of its surface (Drew, 1996).

The need to improve the typical poor traditional agriculture in the karstic areas of medium and high elevations, activated also in Murgia agricultural transformations more and more significant according to the availability of new techniques, with inevitable repercussions on the environment.

Following the emigrations of the 1950s and 1960s, the mechanization of agriculture and the reduction of sheep breeding caused the progressive abandonment of the soils of the Alta Murgia and the loss of identity of the inherent features of the Murgia landscape. At the end of the 1970s, the public financial support promoted the forage production to increase the animal breeding activity by transformation of pastureland into arable land by means of a process named "*spietramento*" (stone shattering): surface layers of rock were dismantled by heavy machinery that lever out large blocks, shattering the largest ones on the spot, grinding the fragments, reducing them to the size of a few millimetres and mixing them with scarce residual soils and/or improvers (Fig. 2). The production of forage was also promoted, even in land not connected to animal breeding farms, but with trees (olive groves and almond groves to a lesser extent). In the period 1984–1987, 307 farms benefited from the economic incentives and 13,444 of the 35,306 ha of the territory were subject to stone shattering.

In the Alta Murgia the mechanization of agricultural practices implied also the shattering of drystone walls and small rural buildings; in addition, the improvement of yields required the use of fertilizers and conditioners. The stone shattering practices have immediate effects on the erosion, because soils lose their primary structure and acquire a new component (rock fragments) that behaves as inert material. Moreover, the typical wheat cultivation leaves the soil exposed, for large part of the year and especially during summer, to the erosive action of rainfall; as a consequence, the physical environment and its hydrological behaviour are in a perennial unsteady state (Canora et al., 2005a).

Towards the end of the 1980s, in the same years when the "stone shattering" practice started to undergo widespread use, the Alta Murgia became a Natural Protected Area and finally a National Park. By establishing the Park, the geomorphologic, geological and hydrogeological features, the biotic components of the territory and the natural environmental resources, including that of water, and the important ecological, historical and cultural value of the countryside, had to be safeguarded.

In 1991, the regional loan program for land improvement ended. However, the stone shattering practice, in spite of the establishment of the National Park, continued with the EC support to allow cultivation of additional land. There were no regulations against the practice of stone shattering; it remained popular throughout the entire Alta Murgia. In addition, the Alta Murgia became also a receptacle of water treatment sludge used as soil improvers.

The stone shattering, although providing immediate economic advantages, induced significant changes in the karst ecosystem of the Alta Murgia territory. This practice, masked by