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Assessment of the impact of anthropogenic activities on the groundwater hydrology and chemistry in Tarsus coastal plain (Mersin, SE Turkey) using fuzzy clustering, multivariate statistics and GIS techniques

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SUMMARY

Tarsus coastal plain (TCP) is an economically and ecologically important area situated in between the fertile fluvio-deltaic plains of two rivers, Deliçay and Tarsus (Mersin, SE Turkey), where anthropogenic activities (agricultural, industrial, and domestic) are very intense. Twenty-four water quality parameters were surveyed at 193 groundwater and 10 surface water sites during August 2008. The objective was to characterize the physico-chemical properties of groundwaters in TCP, assess the impact of anthropogenic activities on the groundwater hydrology and chemistry, and identify the major hydrogeochemical processes occurring in the area. Groundwater samples were grouped into hydrochemically distinct and spatially continuous four water classes (i.e., C1, C2, C3, and C4) using the fuzzy *c*-means (FCM) clustering method, where membership values were interpolated using the ordinary kriging technique. Principal components analysis (PCA) was used to decipher various underlying natural and anthropogenic processes creating these distinct water classes. Four principal components (PCs) were extracted in PCA which explained more than 73% of the total variance in water quality. Major factors responsible for the variations in chemistries of water classes are identified as: (1) water–rock interaction and nitrate contamination; (2) salinization by seawater intrusion and evaporite dissolution; (3) geogenic/anthropogenic Cr, Fe, and Mn; and (4) anthropogenic Zn pollution. Overexploitation of the aquifer is clearly evident, especially at settlements located near the coastal zone, where the water table is lowered 2–5 m below the sea level. Salinization is well known in the area and is attributed not only to seawater intrusion, but also to dissolution of evaporitic series from the Handere formation. Hydrochemical evidence also suggest that in the area subsurface paleo-river channels and the deposits infilling the ancient lagoon area within Quaternary–Recent alluvial deposits act as significant hydrological features where preferential groundwater flow occurs along them.

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1. Introduction

In both inland and coastal areas of Turkey, groundwater resources play an increasingly vital role in supply of potable water as population continues to grow steadily. Nevertheless, nationwide monitoring studies conducted by the government agencies (i.e., Baltacı et al., 2008) raise concern over an increasing trend for deterioration in quality of water supplies mainly due to anthropogenic activities. Moreover, in the forthcoming decade, the climate change is projected to exacerbate the pressure on the hydrologic system (especially in the Mediterranean region), along with the natural habitats associated with it (Ministry of Environment and Forestry, 2009). This situation calls for an urgent need for an effective strategy to reduce the pressure on the hydrologic system, including both its living and non-living components. Contrary to common belief, groundwater and associated hyporheic zones is not completely devoid of life, but support diverse subsurface fauna and microbiota (Hancock et al., 2005 and references therein) that are responsible for a myriad of (bio)geochemical reactions, imperative for a fully functioning system. It is also known that even minute changes in the chemical characteristics of groundwater can broadly disrupt many important ecological processes (Moore, 1999; Murgai et al., 2001). Therefore, sustainable management of groundwater resources requires a good understanding of both groundwater circulation patterns and hydrologic/hydrochemical processes that affect their chemistry, in order to ensure a reliable supply for all life forms.

In Mersin province (2009 population > 1,640,000) of Turkey, the majority of dense human settlements are generally confined to narrow coastal strips or to relatively wide and flat-lying delta areas located between the Taurus Mountains and Mediterranean Sea. Since the historical periods, nearly flat topography combined with a mild climate made these coastal areas very attractive for human inhabitation and a variety of land uses. Being fed by four major

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perennial rivers (Göksu, Lamas, Tarsus, and Seyhan) and numerous ephemeral streams originating from the Taurus Mountains, the delta areas have abundance of water that supports terrestrial, limnic, and marine ecosystems of international importance (Yılmaz, 1998). Tarsus coastal plain (TCP) is one of the most important one of these coastal environments and provides space not only for delicate natural habitats but also for agriculture, heavy industry, settlement, as well as transportation (Fig. 1). However, due to rapid industrial growth (Güler, 2009), unplanned urbanization, land use/land cover (LULC) changes (including modification of the drainage patterns and basin hydrology) (Gürbüz, 1999; Sandal and Gürbüz, 2003), excessive use of synthetic chemicals in agriculture (Kumbur et al., 2008), together with overexploitation of the coastal aquifers (Demirel, 2004) have collectively resulted in qualitative and quantitative degradation of the groundwater resources in TCP. The lack of basin-wide management strategies and occurrence of pollution from various point and diffuse sources only add complexity of the problem. The current situation exerts a huge pressure on the TCP ecosystem resulting in loss of critical habitats, decrease in biodiversity (MEDASSET, 2001, 2009), and degradation of water/soil quality in the area (Yılmaz et al., 1998; Demirel, 2004; Koleli and Halisdemir, 2005; Çelik et al., 2006). Such a situation necessitates comprehensive studies that will characterize and diagnose the present condition of this coastal environment.

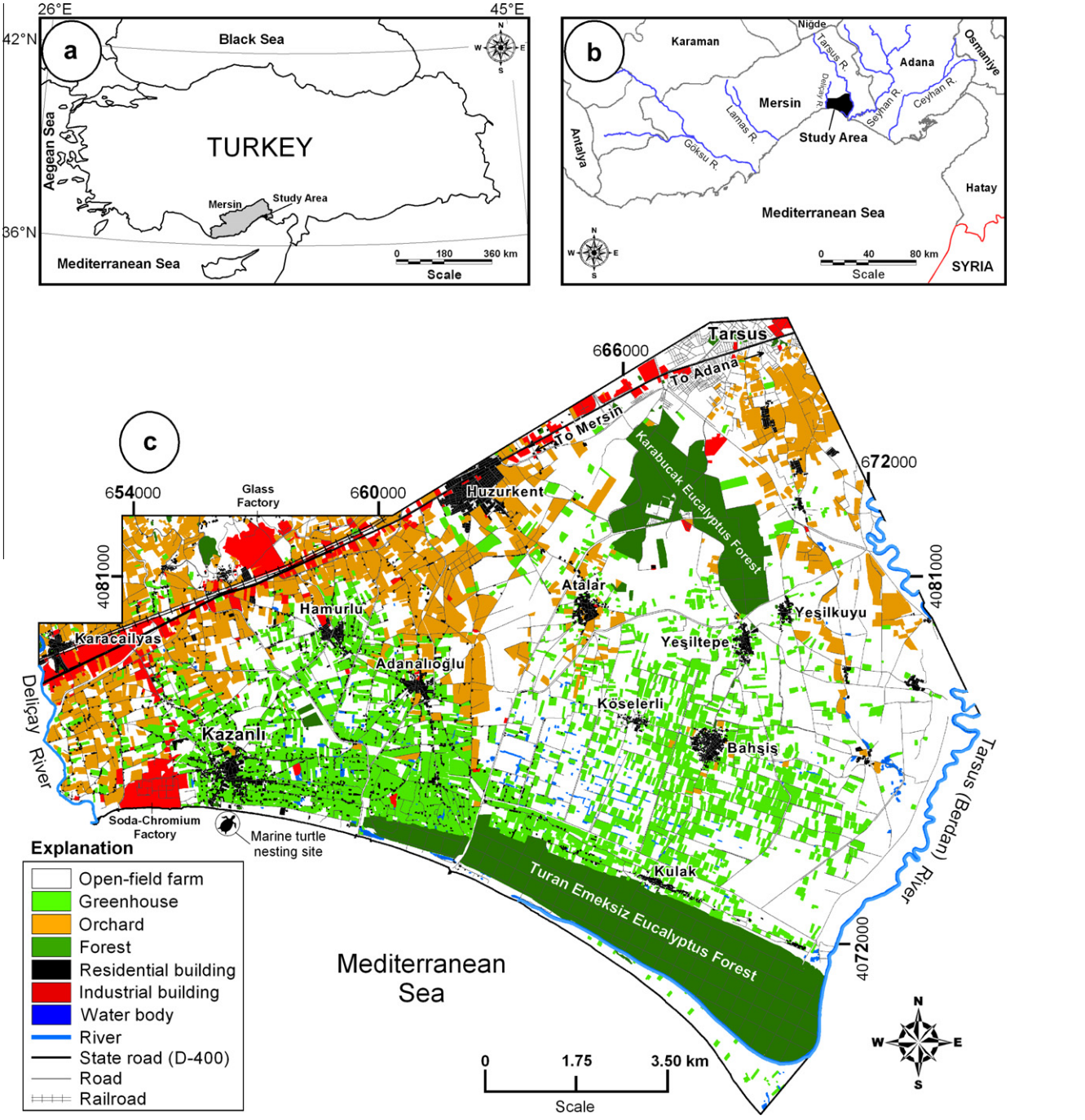

Fig. 1. (a) Location of the Mersin province within the Turkey, (b) detailed map showing the Tarsus coastal plain (TCP) area and major perennial rivers draining to the Mediterranean Sea, and (c) land use/land cover (LULC) map of the TCP (digitized from Quickbird satellite images acquired in 2004).

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