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Simulation of soil types in Teramo province (Central Italy) with terrain parameters and remote sensing data

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ABSTRACT

Soil surveys are an essential source of information for land management although a limited budget often reduces the amount of data available. Even if the dataset is limited, geostatistics can provide a valid estimation tool through a weighted moving average interpolation (kriging). Often, however, the spatial variability of soil properties appears smoothed and short range variability is underestimated by this kind of interpolation technique. A more realistic distribution of a given variable on the territory can be obtained through models based on stochastic simulation.

The study area was located in Abruzzo region, Central Italy, in the Soil Region 61.3 as defined by the European Soil Bureau, and includes an economically relevant viticulture district (Controguerra "DOCG area of Colline Teramane"). Relationships between soil type distribution and terrain attributes – slope, incoming solar radiation, NDVI, TWI, etc. – were established, and the most significant were used in a multinomial logistic regression to generate simulated maps. These maps, derived from a set of measured point data, auxiliary information from a Digital Terrain Model and Landsat images, were compared with the soil subsystem map 1:250,000, realized by ARSSA. The comparison indicated that the simulated distribution of the soil classes is consistent with the pedological map and fits better with the local morphology.

1. Introduction

Soil maps are essential tools for decision making about land use and management, and their information can be elaborated in thematic maps for specific purposes. However, the complexity of soil variability is such that no soil mapping can be exhaustive: all information needs to be interpolated in space from a finite number of observations, defining and applying a criterion for the inference to the whole territory. Thus, every kind of soil map implies some degree of uncertainty that soil scientists are called to evaluate and deal with.

Traditional soil surveys require an adequate number of samples, and when defining and mapping the soil units pedologists apply a subjective and knowledge-based conceptual model. Furthermore, these techniques are also time-consuming and generally do not provide complete and updated information. Estimation and simulation of probable scenarios using statistical models are adopted to deal with the limits and difficulties of traditional soil mapping. Estimation of variables by geostatistical techniques through moving average interpolation (kriging) has been applied extensively since the '80s (Burgess and Webster, 1980). More recently, specific theories for soil science were developed (Goovaerts, 1997, 1999; Webster and Oliver, 2001). The geostatistical approach is based on the spatial autocorrelation of data; this kind of estimation often tends to smooth the details of soil spatial variability and to underestimate the short range variability to some extent (Curran and Atkinson, 1998; Ping and Dobermann, 2006).

Digital Soil Mapping (DSM) is a hybrid method for producing digital estimated maps of soil properties through geostatistical regression techniques, using measured data combined with auxiliary information from environmentally based variables and remotely sensed images. DSM was developed as a substitute for the traditional polygon soil maps (McBratney et al., 2003). There is an increasing interest in using DSM to predict soil classes and properties worldwide, since this is an important issue to decrease costs and subjectivity of soil maps, allowing researchers to use them in digital programs like GIS.

The main objective of this study was to use a DSM technique, i.e. the multinomial logistic regression (MLR), to produce soil maps of a relatively small area (about 100 km^2), predicting soil classes at the subsystem level according to the European Soil Bureau (2001). MLR has been used successfully to estimate specific soil characteristics rather than soil taxonomic classes (Campling et al., 2002; Kravchenko et al., 2002; Ohlmacher and Davis, 2003), but since soil map units are categorical variables, the MLR may be suitable for predicting the occurrence of soil classes, providing the degree of probability (Giasson et al., 2006). In this paper five different scenarios were built, and the

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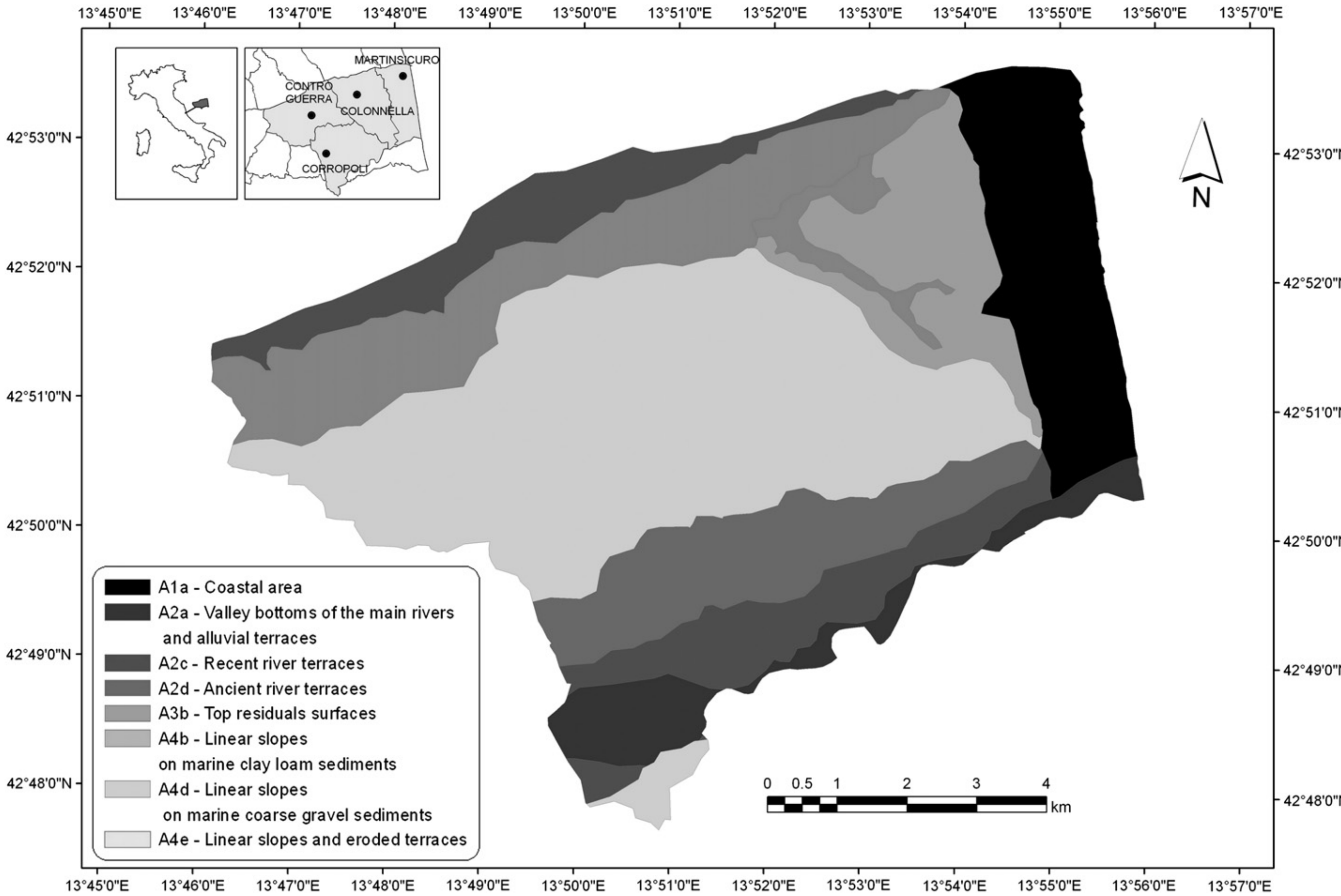

Fig. 1. Map of the soil subsystems occurring in the study area, extracted from the 1:250,000 Soil Subsystem Map of Abruzzo (Chiuchiarelli et al., 2006).

best one was compared with a traditional soil map of the area, in order to provide qualitative and quantitative information about the quality of the predicted map.

2. Materials and methods

The surveyed 100 km^2 area (Abruzzo Region, Central Italy) includes four Municipalities in Teramo province (Controguerra, Corropoli, Colonella and Martinsicuro). The most economically important zone falls into the Controguerra viticultural district (DOCG[1] area of Colline Teramane). The area is located in the Soil Region 61.3 (Righini et al., 2001), as defined by the European Soil Bureau (2001): "Hills of central and southern Italy on Pliocene and Pleistocene marine deposits and Holocene alluvial sediments along the Adriatic Sea". In this framework, soil regions – areas with similar soil-forming conditions and as the largest units of soil description – are defined on the basis of a combination of texture, parent material and main relief.

The main soils of the Soil Region 61.3 are: soils eroded and with reorganization of carbonates (Eutric and Calcaric Regosols; Calcaric Cambisols; and Haplic Calcisols); soils with clay accumulation (Haplic and Calcic Luvisols); soils with vertic properties (Vertic Cambisols and Calcic Vertisols); and alluvial soils (Calcaric, Eutric and Gleyic Fluvisols) (Costantini et al., 2004). The main Land Capability classes are 2, 3 and 4 for erosion and slope, secondly for clay and excess limestone content.

[1] Denominazione di Origine Controllata e Garantita, attesting the origin and the quality of a wine.

The dataset used in this work is made up of 250 georeferenced point samples, collected by ARSSA (the Regional Agency for Agricultural Extension Services of Abruzzo Region) from the surface horizon of agricultural soils (about 50 cm depth), in accessible agricultural lands. These samples are representative of four soil systems essentially (Chiuchiarelli et al., 2006):

- A1 — sandy sediments in the areas close to the present sea shore — it comprises the coastal zone;
- A2 — ancient valley bottoms and terraces of the meso-adriatic alluvial deposits — it borders the main rivers of the region;
- A3 — high terraces of the meso-adriatic plio-pleistocenic reliefs with a sandy–gravelly substrate;
- A4 — meso-adriatic plio-pleistocenic reliefs with clay loam substrate.

Auxiliary data for this area were derived from Landsat 7 TM images (July 26th 2007, cloud cover 0%; 3 visible bands and 4 infrared bands), from a DEM with a 40 m resolution (preferred to the 20 m one for reliability reason) provided by the Abruzzo Region, and from the 1:250,000 Soil Subsystem Map of Abruzzo compiled by ARSSA (Chiuchiarelli et al., 2006). Fig. 1 shows the map of the soil subsystems occurring in the study area, extracted from the regional map. According to this map, eight different soil subsystems as described in Table 1 were defined (A1a, A2a, A2c, A2d, A3b, A4b, A4d, and A4e).

Instead of using directly the spectral bands of satellite image as predictors, since this gave the worst results, the following indexes were derived from them:

1. Grain Size Index, GSI, correlated with the fine sand content of the soil: $GSI = (R-B)/(R+G+B)$, where R is Red, B is Blue, and G is Green (Xiao et al., 2006);