*Geogr. Fis. Dinam. Quat.*
*31 (2008), 21-36, 9 figg., 8 tabb.*

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# LAND UNITS OF SARNO RIVER BASIN (SOUTHERN ITALY) FOR LAND EVALUATION

**ABSTRACT:** DE PIPPO T., DONADIO C., PENNETTA M., PETROSINO C. & TERLIZZI F., *Land Units of Sarno River basin (southern Italy) for land evaluation*. (IT ISSN 1724-4757, 2007).

In order to identify the Land Units of the Sarno river basin, research was conducted by analyzing the different environmental characteristics and drawing up thematic maps and synthesis GIS maps.

In geomorphological terms, the study area has great carbonatic structures which, together with the Somma-Vesuvius volcanic complex, delimit a Plio-Pleistocene depression filled by transitional environment deposits and grooved by an extensive hydrographic network.

Analysis of various aspects concerning the morphology, lithology, soil, vegetation and human impact on the area led us to identify 32 Land Units with homogeneous geolithologic, morphometric and geomorphologic attributes.

The Map of Land Units is derived from the construction and synthetic overlay of various thematic maps comprising the Slope Map, the Lithologic Map, the Vegetation Map, the Soil Map, and the Land Use Map. It is an extremely useful innovative document both in environmental analysis and in land use planning in that it allows us to extract basic physical, biotic and impact themes to be elaborated for applicational uses.

KEY WORDS: GIS, Land System, Pedology, Sarno River Basin, Southern Italy.

**RIASSUNTO:** DE PIPPO T., DONADIO C., PENNETTA M., PETROSINO C. & TERLIZZI F., *Unità di Terra del bacino del Fiume Sarno (Italia meridionale) per l'analisi del territorio*. (IT ISSN 1724-4757, 2007).

Sono state condotte ricerche al fine di identificare le Unità di Terra del Bacino del Fiume Sarno mediante l'analisi delle differenti caratteristiche ambientali e la redazione di cartografia tematica e di sintesi.

L'area in studio, dal punto di vista geomorfologico, presenta potenti strutture carbonatiche che, insieme all'apparato vulcanico del Somma-Vesuvio, delimitano una depressione plio-pleistocenica colmata da sedimenti di ambienti di transizione e incisa da una articolata rete idrografica.

L'analisi dei diversi caratteri morfologici, litologici, pedologici, vegetazionali ed antropici del territorio, ha portato all'individuazione di 32 Unità di Terra, caratterizzate da omogenei attributi geolitogici, morfometrici e geomorfologici.

La Carta delle Unità di Terra è derivata dalla costruzione e sovrapposizione sintetica di diverse carte tematiche tra le quali la Carta delle Acclività, la Carta Litologica, la Carta della Vegetazione, la Carta Pedologica, la Carta dell'Uso del Suolo.

Essa costituisce un documento innovativo di estrema utilità sia nell'analisi ambientale sia nella pianificazione territoriale in quanto consente di estrarre i tematismi fisici, biotici ed antropici di base da elaborare per usi applicativi.

TERMINI CHIAVE: GIS, Sistema di Terra, Pedologia, Bacino del Fiume Sarno, Italia Meridionale.

## INTRODUCTION

The term *land* indicates the place where people live and develop their activities; it is a natural resource that is gradually being depleted especially due to the increase in human pressure and consequent poor land management. Strictly interrelated to the Earth's physical and biotic components are its socio economic aspects: variations in quality and quantity affect its exploitation which may thus be more or less suited to a certain use. Such variability may be mapped by dividing the area into homogeneous zones (Cooke & Doornkamp, 1974). It is thus possible to determine the land use suitability of part of the area and the response of the land system when it is subjected to a specific land use purpose.

According to the FAO (Food and Agriculture Organization) definition the term *land* stands for part of the Earth's surface that includes not only soil, vegetation and topography, but also the local characteristics of the atmosphere, its geology and hydrogeology, the fauna and the effects of past and present day human activities (Ongaro, 1998). Hence the *land* is a complex system, dominated by a non linear dynamic, and each individual component is a

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*The authors are very grateful to Prof. L. Brancaccio both for the precious suggestions and discussions as well as the careful revision of the manuscript.*

sub-system. For example the soil, insofar as it is itself a complex system, includes organic and inorganic matter, plants and animals, energy exchanges, etc. In brief, each attribute of the *land* is at the same time a constituent and factor of the ecosystem which, in turn, depends on other attributes and influences them.

Studying the area not only in its individual aspects, but as a final result of mutual interactions among geological, geomorphologic, climatic, soil and vegetation factors in relation to land use, means adopting a multidisciplinary approach. To this effect, formulation of *Land Units* represents a valid tool for territorial analysis.

The study area is the hydrographic basin of the Sarno river, one of the most important economic areas in Campania region, southern Italy; its evolution, conditioned by intense exploitation of natural resources (Cutolo, 1998), is a useful applicative example of the identification of Land Units for area analysis.

## GEOGRAPHICAL AND PHYSICAL FEATURES

The Sarno river hydrographic basin (fig. 1) extends for about 439 km$^2$, which represents about 4% of the surface area of Campania region, straddling the provinces of Avellino, Naples and Salerno. The basin is bounded to the north by the Somma-Vesuvius volcanic complex, eastward by the Sarno massif (Mts. Picentini), southward by the carbonatic reliefs of the Sorrento Peninsula (Mts. Lattari), and westward by the Bay of Naples.

The main watercourse, about 24 km long, debouches into the Bay of Naples, between the municipalities Torre

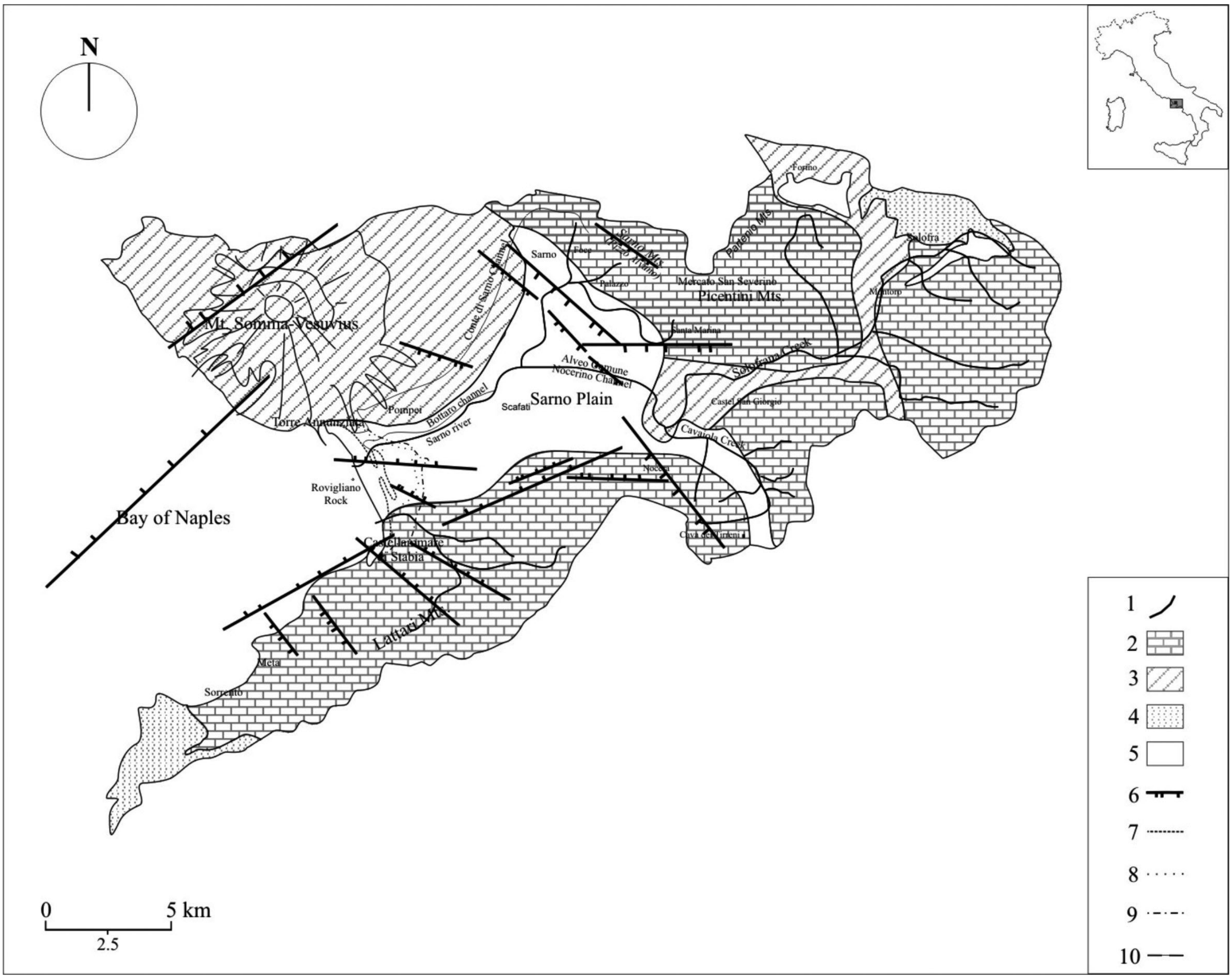


FIG. 1 - Geological simplified scheme of the Sarno River basin: 1) hydrographic network; 2) Mesozoic calcareous-dolomitic rocks; 3) lavas and pyroclastics; 4) late Mesozoic and Tertiary calcareous-marly-clayey flysch; 5) coastal, lagoon and river Quaternary deposits; 6) main faults; 7) Versilian coastline (Messigno); 8) proto-historical coastline (Bottaro-Pioppaino); 9) Roman period coastline (1st century AD); 10) basin watershed.

Annunziata (NW) and Castellammare di Stabia (SE). It has two main tributaries: one fairly long (Solofrana stream) and the other shorter (Cavaiola stream); both flow into the Nocerino artificial channel which, in turn, flows into the channel of the Sarno river (Petrosino, 2003).

The river's source lies at 30 m a.s.l. and is fed by some karstic springs at the base of the carbonatic massif of the Sarno area. Their summit (Pizzo d'Alvano) is the highest point of the western Picentini (1133 m). The springs of Santa Maria la Foce, Mercato Palazzo (chiefly of a mineral nature) and Santa Marina are the main active sources of the Sarno river and are situated in the surroundings of the town of Sarno (De Pippo & *alii*, 2005). The springs are chiefly fed by the reservoirs of the powerful carbonatic complexes of the Campanian Apennines, and secondarily from those of the Somma-Vesuvius volcanic edifice and the surrounding alluvial plains (Celico, 1990). A smaller flow comes from direct rainwater and from groundwater flow from aquifers in the limestone massifs outside the basin area (Celico, 1991).

The study area falls within the temperate Mediterranean climatic belt, characterised by frequent, often intense and localised rainfall, concentrated chiefly at the end of the summer and reaching their peak in autumn. Conditions become stormy when they come on top of regional perturbations (Mennella, 1967). This is due to persistent high humidity conditions, caused by the dense network of land reclamation and irrigation channels that cross the plain, and the morphology of the basin with substantial massifs that intercept hot and humid masses from the sea.

The small size of the basin and the steep slopes of the secondary basins lead to short inflow times and bankful discharges, in response to exceptional heavy rainfall of short duration (a few hours). The widespread inadequacy of sections along the watercourse, due to intense human impact along the banks, causes natural lamination of bankful discharges related to flooding, chiefly after burst banks.

In periods of low flow, the Sarno river system has very limited natural feeding, which is why flows chiefly consist of industrial and domestic effluent.

## GEOLOGICAL FRAMEWORK

The Sarno river alluvial plain (fig. 1) represents the southern part of the wide Campanian Plain overlying the Campanian *Graben*. It comprises an extensive subsiding tectonic depression filled by some thousands of metres of volcanoclastic, alluvial, fluvial, marine and lagoon deposits, which stretches from the eastern margins of the Sorrento Peninsula as far as Mt. Massico. NW of the Somma-Vesuvius volcanic complex (Bellucci, 1994; De Pippo & *alii*, 1996; Ortolani & Aprile, 1985). This depression was established between the end of the Pliocene and beginning of the Pleistocene (Cinque & *alii*, 1987) in relation to major tectonic uplift events of the lower and middle Pleistocene along the margins of the Apennine Chain, culminating in the carbonatic structures outcropping at the western and southern edge of the Sarno river plain. The structures consist of Triassic dolomites, Jurassic limestone and dolomitic limestones, and fractured and karstified Cretaceous limestones.

In transgression on the carbonatic formations, in the middle Sarno valley as far as Mercato San Severino, on the lower stretches of the lesser valleys of the Cavaiola and Solofrana and in the western part of the Sorrento Peninsula are outcrops of Miocene deposits in *facies* of flysch and travertine deposits.

Distensive fault lines perpendicular to the Sorrento Peninsula, generated during tectonic uplift, have created a further depression in a barycentric position (between Meta di Sorrento and Sorrento), later filled by Campanian Ignimbrite deposits, about 50 m deep, laid about 39000 years BP (De Pippo & *alii*, 2004). All the carbonatic successions are displaced by direct faults which lower the blocks towards the depocentre of the plain and the Tyrrhenian Sea (SW), with displacements of over 2000 m. The most depressed sector of the monocline is delimited seaward by a morphological high whose surface expression is the limestone islet of Rovigliano close to the mouth of the Sarno river (La Torre & *alii*, 1983). The plain's eastern boundaries often coincide with the isoipse of +50 and +25 m, while the remaining parts have heights lower than +25 m (Cinque & *alii*, 1987).

The slopes are covered with volcanoclastics alternating with detritic limestone and disturbed pyroclastics. The widespread presence of tuff, lapilli, scoria and ash is chiefly due to the intense explosive activity of the Somma-Vesuvius (Santacroce, 1987) and the Phlegrean Fields (Cioni & *alii*, 1996) volcanoes.

The gradual sinking of the Sarno plain was accompanied by its filling with a cover of continental, marine, transitional and volcanoclastic sediments about 1400 m thick. Finding beach deposits in the subsoil below -10 m allowed an average sedimentation rate to be obtained, at least for the middle upper part, of about 1.2 mm/year (Cinque & *alii*, 1987).

## GEOMORPHOLOGICAL FEATURES

During the Upper Pleistocene-Holocene the Sarno Plain was affected by transgressions and regressions controlled by glacial-eustatic variations and by the interaction between processes of subsidence and sedimentation. The period of the more recent ingression in the upper Sarno valley dates back to the last Interglacial (125 ka BP).

Following the glacial-eustatic lowering in the Würmian (25-18 ka BP) and substantial pyroclastic sedimentation related to volcanic explosive activity in the Naples area, the shoreline of the lower plain advanced considerably. At the end of the Pleistocene Pleniglacial, up to about 14-15 ka BP, the coastline was located about 10 kilometres further offshore and about -120 m lower than the present day (Brancaccio & *alii*, 1995). In the plain, the torrential rivers of the Lattari and Sarno mounts deposited at their mouths huge quantities of detritus, forming broad dejection fans, whose base was buried by more recent pyroclastics. The fans show no signs of tectonisation, although they are arranged along the main structural fault lines. This would testify to the plain's substantial tectonic stability during the past thousands of years (Cinque & *alii*, 1987). At the end of the volcanic activity of Vesuvius and Würmian alluvial deposition, the Sarno river carved out a small valley about 20-30 m below the current sea-level, later filled by transitional, fluvial and marine deposits.

During the Holocene, the whole Sarno Plain underwent coastline variations related to marine transgression and subsidence phenomena. Shortly before 5.6 ka BP the Sarno coastline ceased to advance, attested by traces of palaeo shorelines along the stretches of the Stabian cliff which remained in contact with the sea, at the height of Scafati, outlining a palaeo bay inland. The coastal palaeo cliff (Castellammare di Stabia) is carved into dejection fans; the altitude of the plain below rises locally due to the presence of short colluvial and pyroclastic *talus* and depressed fans (Cinque, 1992).

Between 5.6 and 4.5 ka BP the coastline was positioned between the hill of ancient Pompeii and the Gragnano trench (Messigno), while between 3.6 and 2.5 ka BP it was between Bottaro and Pioppaino, where a dune ridge was found with a sandy beach at its base. Lastly, in the Roman period, before the 79 AD eruption, the shoreline was one hundred metres further off than the present day one (fig. 1). Between the coastal fossil ridges and those of the Roman age was a lagoon open towards the mouth of the Sarno river, which gave Pompeii's inhabitants access to the sea (Barra & *alii*, 1989). Marsh sediments are found up to +1.2 m, i.e. at the base of 79 AD pyroclastics, indicating that there was a wetland in the plain even when the shoreline had already advanced several kilometres towards SW. The overall magnitude of the coast advancement, from 79 AD to the present-day, has been about 1.3 km, coastal accretion locally reached as much as 10 m, due to the accumulation of Vesuvian pyroclastics in this period (Cinque & Russo, 1996).

What characterises the current morphology of the Sarno Plain is its flatness and the low longitudinal gradient, 0.05° along E-W direction. Indeed, at the base of the more inland marginal slopes 17 km from the shoreline, heights reach +20 m. This structure may be correlated both to subsidence phenomena and to the small flow of solid discharge in the Sarno river. By contrast, the Solofrana stream, whose catchment area is in the Mts. Picentini, has a considerable sediment flow: however, this is deposited in the intramontane depressions of Montoro and Castel San Giorgio, upstream of the confluence with the Sarno river.

## STUDY METHODS

By the term *Land Unit* (Battelli & *alii*, 1993; Delli, 1997) we mean part of an area which may be represented and mapped starting from a scale of 1:25 000 or lower. The units are homogeneous in natural properties such as the geolithological substrate, morphology and morphometry, soil and morphodynamics, represented by one or more separate areas or polygons. The land unit does not refer to a specific taxonomic level, but may be represented by any hierarchical level of a land classification system and may be associated to other land units to represent different (or combinations of different) taxonomic levels. The size of a unit may vary from a few square meter surfaces up to enormous sizes in the case of homogeneous areas. Hence it is not possible to indicate a suitable scale for all purposes.

A group of topographic units in strict relation, consisting of physically homogeneous parts of the area, comprises a *Land System* (Ongaro, 1998). The latter is represented with scales of less detail; homogeneity in this case mainly concerns physiographic, geomorphologic and geolithologic aspects. Despite its high degree of inner variability, identification of Land Systems is an excellent study tool from the holistic point of view. It must be borne in mind that the Land System is a geographic abstraction, given that geological limits are difficult to recognize, in that they are often uncertain or discontinuous.

The Land Units map of the Sarno river basin was obtained with the GIS intersection of a series of appropriately constructed thematic maps, both basic and derived. The first represent a land attribute analytically (geology, gradient, etc.) acquired by indirect and direct measurements (aerial photos, field measurements, laboratory analyses, etc.) and examination of bibliographic sources (Marini, 1993). The resulting maps come from the synthesis of one or more area attributes. Obtained by elaborating one or more basic attributes, this synthesis was performed through the incorporation or intersection of such attributes.

In particular, the first step for identifying Land Units was landscape analysis. The guidelines used for defining the latter are lithology, morphology, geomorphic processes, hydrology, soil cover and use, natural vegetation, crops and pastures. Environmental parameters (soil, morphology, vegetation, soil use, etc.) were measured in integrated fashion: the series of multidisciplinary observations effected at the same point which, in its nature and size, corresponds to a single Land Unit (Geneletti, 2003a).

The landscape is the more immediate picture of the *land*: just as different landscapes correspond to different lands, homogeneous landscapes indicate the presence of homogeneous lands. The type of landscape was identified both in the field (measurements and observations) and from indirect data (aerial photos and satellite images).

Once identified and recognised as a holistic object, part of the area was sampled and described analytically (Zonneveld, 1972 and 1989). Creation of a Land Units map involved a certain number of steps, according to a logical sequence summarised in three main phases: (1) preparation of preliminary map, (2) area survey, (3) preparation of a final map and relevant documents, including area assessment.

Direct surveys were supported by a critical analysis of the available data and information for the study area, such as satellite images, aerial photos, topographic maps, thematic maps and bibliographic references. Considerable assistance was supplied photogram analysis that allowed definition of the morphology, size and position of objects of any size (Giordano, 1989). In the case of zones subject to changes (Donadio & Sgrosso, 2001) in volume (landslides, lava flows, etc.) and shape (river channels, coastlines, etc.) it has the advantage over classic topographic techniques of measuring a high number of points, obtaining an appropriately representative area document of the process studied. Interpretation of aerial photos was again supported by field measurements that confirmed or modified the working hypotheses and highlighted any problems in the area.

## DATA ANALYSIS

The Sarno river basin Land Units were identified by the analysis of different environmental characteristics and by drawing up thematic and synthesis GIS maps. The thematic maps were constructed by digitalization and elaboration using various GIS tools, with digital restitution at a scale of 1:25000. Starting from DTM representations the Slope Map (fig. 2) was drawn up. On the basis of morphological features the landscape was subdivided into three main slope classes. The first (low gradient: 0-10%), comprises the areas of the Sarno Plain *strictu sensu,* the plains of the Cavaiola and Solofrana streams, Forino and the Sorrento Plain; the second (medium gradient: 10-30%) was identified in the Somma-Vesuvius area and the Sorrento Peninsula; the third (high gradient: >30%) includes some reliefs and cliffs of the Sorrento Peninsula, and the mounts of Sarno and Irpinia.

The Lithological Map (fig. 3) was drawn up with the aid both of the Geological Map, at scale 1:10.000 (Autorità di Bacino del Sarno, 2003), and field measurements. The Lithological Map results from grouping the different outcropping terrains on the basis of common lithologic features irrespective of age. Each lithologic complex was identified by an abbreviation (tab. 1). As shown by figure 3, the largest area is occupied, in the central part of the basin, by alluvial deposits in the Sarno river plain (*APS*). The same lithotype is found only marginally in the eastern sector, where it coincides with the plains of the Solofrana and Cavaiola torrents, the palaeo channel of the Sarno river and the deposits of the endorheic basins (Forino Plain and Mt. Sant'Erasmo). At the margin of the above plains alluvial fan deposits are

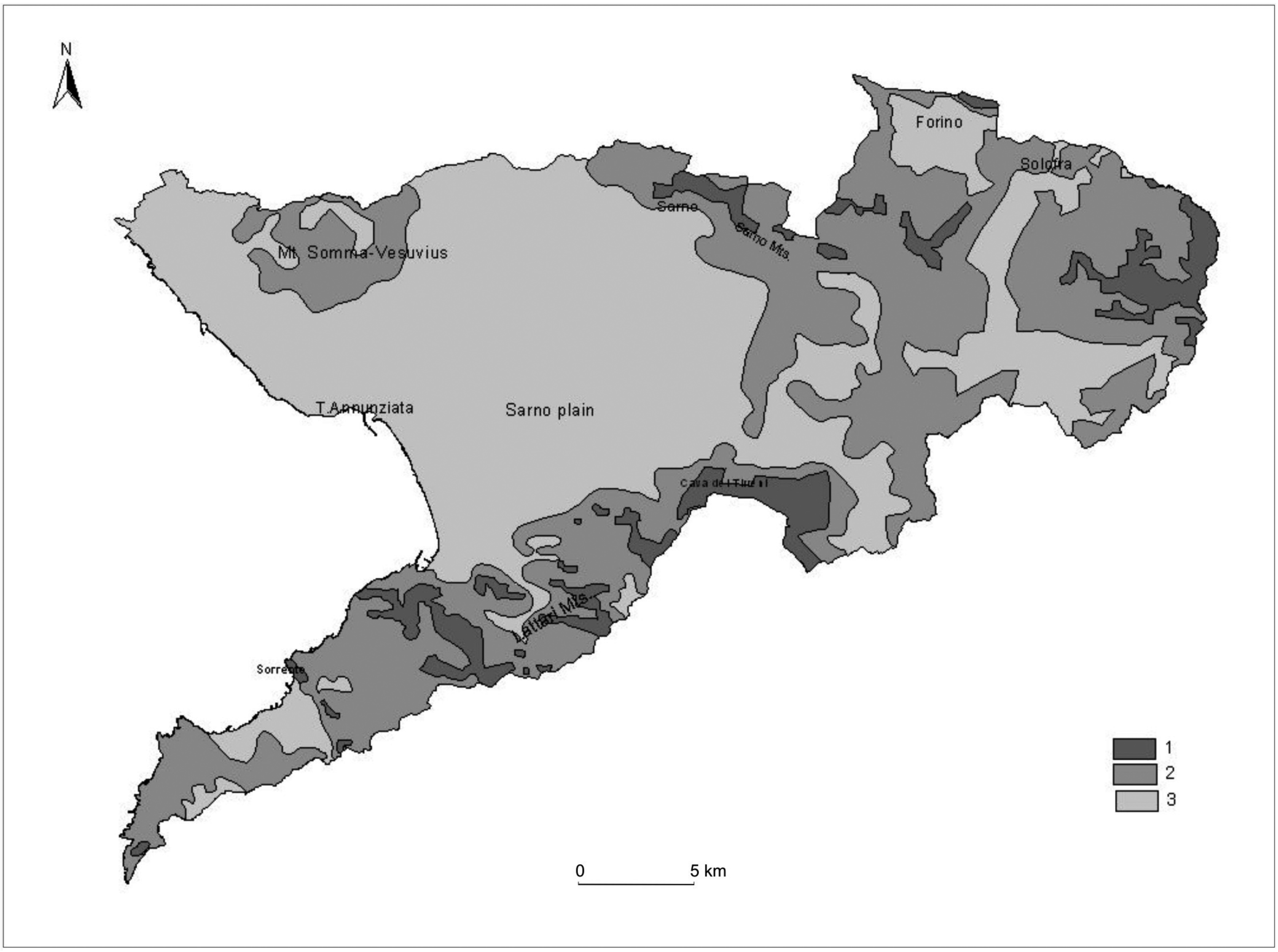


FIG. 2 - Gradient Map of the Sarno River Basin: 1) high; 2) medium; 3) low.

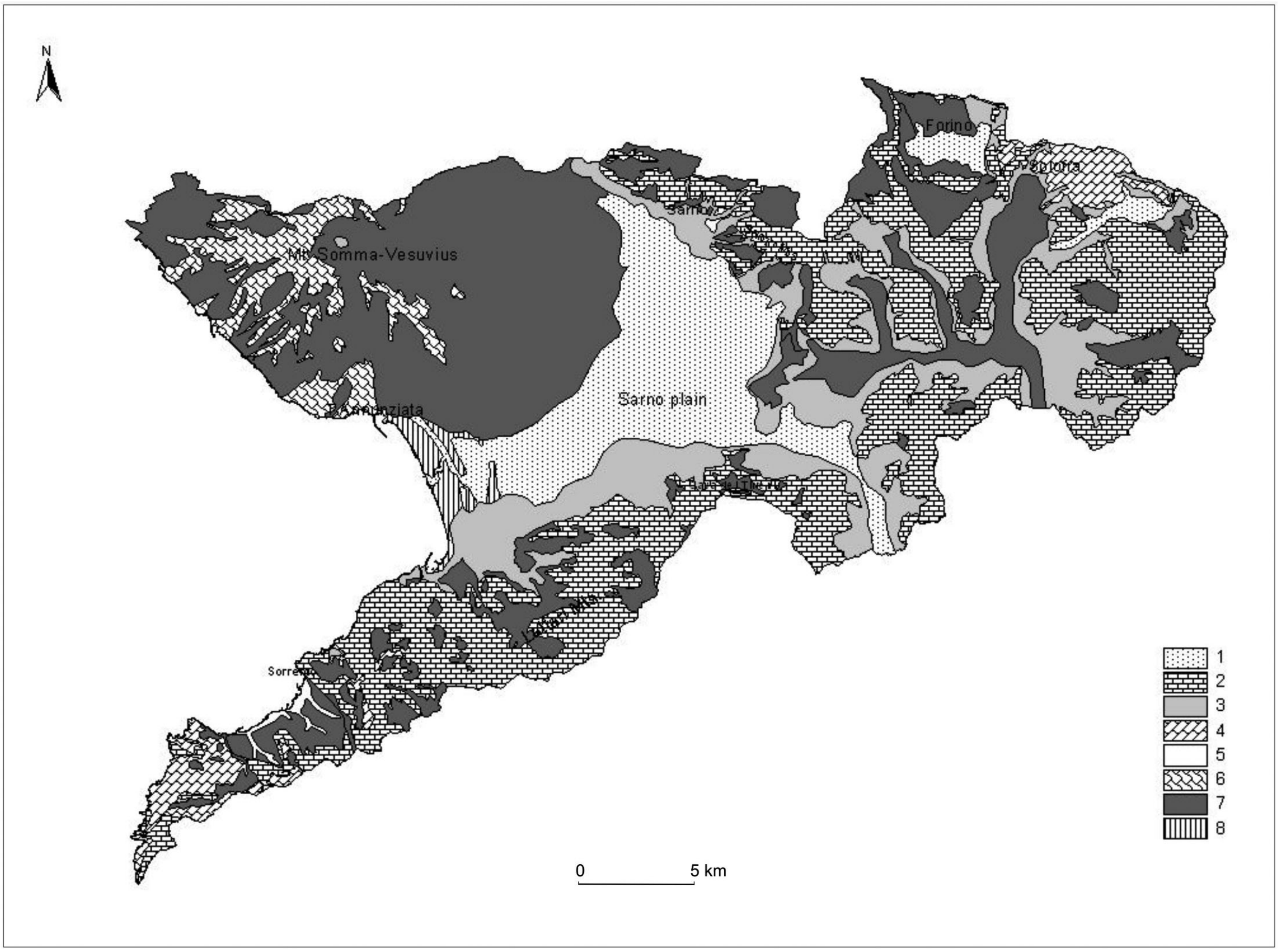


FIG. 3 - Lithological Map of the Sarno River Basin: 1) APS; 2) CCD; 3) DBC; 4) FLS; 5) IGC; 6) LSV; 7) PFV; 8) SCD (see table 1).

TABLE 1 - Symbols identifying the main outcropping terrain complexes according to common lithological nature for construction of the Lithological Map

| | |
|---|---|
| ***URB*** | deposits, waste material and artificial in-fill in urban and industrial zones |
| ***SCD*** | beach deposits and buried dune ridges |
| ***APS*** | alluvial deposits, at time terraced, of the plains of the River Sarno, the Solofrana and the palaeo-channel of the Sarno; endorheic basin deposits (Forino Plain and Mt. Sant'Erasmo) |
| ***DBC*** | deposits and/or relict of re-incised alluvial fan and covered with Phlegrean and Somma-Vesuvian pyroclastics; conglomerates and talus |
| ***PFV*** | Phlegrean and Somma-Vesuvius pyroclastic deposits |
| ***IGC*** | *Campanian Ignimbrite* |
| ***LSV*** | Lava from Mt. Somma-Vesuvius |
| ***FLS*** | Turbiditic alternance, marly limestones, clayey marl, marly clays and argillites in *flysch facies* |
| ***CCD*** | limestones, dolomitic limestones and dolomites |

recognised, covered by Phlegrean and Somma-Vesuvian pyroclastics (*DBC*). By the same token, Phlegrean and Somma-Vesuvian pyroclastics outcrop throughout the basin (*PFV*), from the Vesuvian area to the Sorrento Peninsula, from the Sarno area to Forino as far as Montoro zone. The limestone ridges and dolomitic limestones of the basin (Picentini and Lattari mounts, Island of Capri - *CCD*) are also considerable, while a smaller area is occupied by the lithotypes *FLS*, *IGC*, *LSV*, *SCD*, as described in table 1.

The subsequent phase consisted in recognising the areas with different vegetation cover: due consideration was always given to the complex arrangement of agricultural and vegetated zones in gently sloping and pediment areas, often densely settled. The various vegetational types and the various farming activities conducted in the Sarno basin, grouped into a single vegetation type according to the same influence on the soil and the subsoil structures, comprise the Vegetation Map (fig. 4). With reference to the literature (Howard & Mitchell, 1980; Marini, 1993) and land surveys, the vegetated areas were identified with

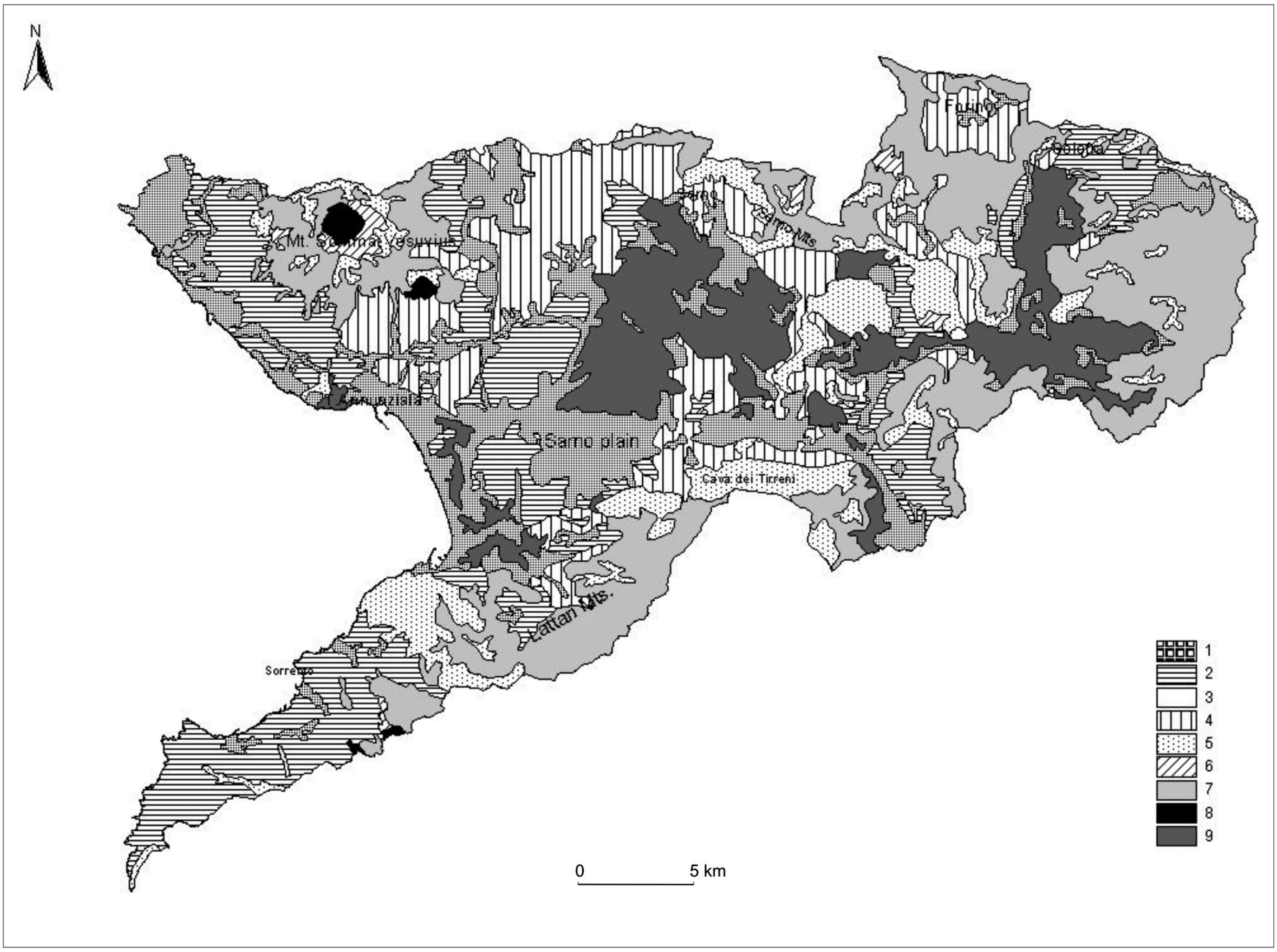


FIG. 4 - Vegetation Map of the Sarno River Basin: 1) AA; 2) ACN; 3) AE; 4) AFV; 5) AV; 6) BCP; 7) BO; 8) RNA; 9) SE (see table 2).

different symbols that indicate the main phyto sociological features and farming organisation of basin (tab. 2).

TABLE 2 - Symbols identifying the main vegetational and agricultural features of the Sarno River Basin for the construction of the Vegetation Map

| | |
|---|---|
| *AA* | continuous and discontinuous urban fabric, urban green areas, industrial, business, port, sports and recreational zones |
| *ACN* | farm crops with natural spaces, crop systems and plot complexes, annual crops with perennial crops |
| *AE* | active and inactive mining areas, and building sites in the basin area |
| *AFV* | set of spaces devoted to tree crops, such as fruit and olive orchards, and vineyards |
| *AV* | natural pastures and upland meadows, areas with sparse vegetation, sclerophyll vegetation, woodland and shrubland |
| *BCP* | Stable grassland, heathland and bushes |
| *BO* | broadleaf woods, conifer woods and mixed woodland |
| *RNA* | bare rocks, cliffs and rock outcrops |
| *SE* | irrigated and rainfed cropland |

Figure 4 shows the presence of extensive urban settlements concentrated especially on the coast and the area around Vesuvius (*AA*). Along the Basin's montane zones are areas of natural vegetation consisting of broadleaf and coniferous woods (*BO*). Wide arable zones (*SE*) have been planted from the low gradient areas of the alluvial plains as far as the coast. Of intermediate features between the above two vegetation units are farmland areas with residual natural spaces (*ACN*): the area around Vesuvius, on the Sarno plain, at the margins of the Cavaiola plain, around the town of Solofra and in much of the Sorrento Peninsula. In all, 21 vegetation types were grouped into 8 vegetation units (tab. 3) to be related to the Vegetation Map (fig. 4).

The different soil types in the study area were then analysed. Colonised by vegetation, the soil was hardly ever visible. When covered, only the surface characteristics were recognised and defined. Hence we relied on the indirect evidence of other characterising factors, such as geology, landscape, morphology and vegetation cover, which

TABLE 3 - Symbols identifying the 8 vegetation units in which the study area was divided

| | |
|---|---|
| **ACN** | farmland (orchards and vineyards) with natural spaces (chestnut coppices, beechwoods) |
| **ACP** | farmland with perennial crops (tree crops, vegetables and floriculture; vineyard, arboreus gardens, olive orchards, fruit trees, forage crops) |
| **APU** | partly urbanised farmland with vegetable gardens and orchards |
| **CAV** | mining areas with little or no residual vegetation, native or alien |
| **FUI** | heavily urbanised and industrialised areas with little vegetation (residual, native and/or alien) and/or green spaces |
| **LSC** | area with psammophile vegetation of the littoral and dune environment |
| **PFU** | partly or heavily urbanised areas with orchards, gardens and or green spaces |
| **VEN** | areas with natural vegetation: woodland (mixed mesophile woodland, mixed broadleaf wood, chestnut woods, coppice woods, *Pinus pinea* reafforestations, Mediterranean maquis, broom shrubland) |

are strictly correlated to soil formation processes at different times and extents.

We recognised and mapped various soil types or *soil units*, according to Quantin's taxonomic classifications (1990, adapted) and FAO (FAO, 1976; Soil Survey Staff, 1980; FAO - UNESCO, 1990), which were compared with one another (tab. 4). Using European and world soil maps (Commission of the European Communities, 1985; FAO - UNESCO, 1990; Geneletti, 2003b), in the Sarno basin we identified five pedological groups: *Andosols*, *Leptosols*, *Cambisols*, *Gleyisols*, *Anthrosols*. The lithologic types recognized in the zone of limestone slopes covered by pyroclastics (see *RCA1* and *RCA6* ff.), on the high slopes of the volcano (see *SVE2*), in areas with low gradients (see *PED2* and *SVE3*) and the alluvial plain (see *PAL*) were ascribed to the group of *Andosols*, soils formed by volcanic material often with a dark surface horizon (Sanesi, 1977; FAO - UNESCO, 1979). *Leptosols*, soils with weakly developed soil layers, were recognised in high or medium sloping soils (for example, the current cone of Vesuvius: see *SVE1*). Soils of variable colour, structure and consistency, referred to as *Cambisols*, are found in zones of varying gradient and chiefly on the low slopes of Mt. Somma. Soils with excess water, known as *Gleyisols*, were found in the coastal belt of the Sarno plain. *Anthrosols* is the term used to describe the soils affected by human activities, comprising mining zones, industrial areas and urban settlements. This soil type ranges from simple soils, with a normal sequence of horizons (*Haplic*), or very thin soils (*Lithic*), through high saturation eutrophic soils (*Eutric*), rich in limestone (*Calcaric*) or volcanoclastic (*Vitric*), to soils whose main element is urban waste (*Urbic*), widely found in urbanised and mining areas (tab. 4).

TABLE 4 - Soil taxonomic classifications according to QUANTIN (1990, modified) and FAO (1990) and the soil unit identified

| Taxonomy (QUANTIN, 1990) | FAO classification | soil unit |
|---|---|---|
| *Loamy Eutric Hapludands* | *Haplic Andosols* | ***RCA1*** |
| *Loamy Lithic Haploxerands* | *Andi-Eutric Leptosols* | ***RCA3*** |
| *Loamy-skeletal Lithic Xerorthents* | *Lithic Leptosols* | |
| *Scoriae Vitrandic Xerorthents* | *Andi-Eutric Leptosols* | ***SVE1*** |
| *Loamy Typic Ustochrepts franchi* | *Andi-Eutric Cambisols* | ***RCA4*** |
| | | ***RCA6*** |
| *Sandy-loam Typic Ustivitrands* | *Vitri-Mollic Andosol* | ***PED2*** |
| | | ***SVE3*** |
| *Loamy-skeletal Lithic Xerochreptsi* | *Eutric Leptosols* | ***RCA7*** |
| *Loamy-Cindery Typic Vitrixerands* | *Vitric Andosol* | ***SVE2*** |
| *Sandy-loam Vitrandic Ustochrepts* | *Andi-Eutric Cambisols* | ***SVE4*** |
| *Loamy-sand Vitrandic Ustochrepts* with ash and lapillus cover from 1944 | Buried phase of *Andi-Eutric Cambisols* | ***PED1*** |
| *Loamy-sand-clay Typic Ustochrepts* | *Calcaric Cambisols* | ***RCA8*** |
| *Loamy-sand-clay Typic Ustivitrands* | *Vitric Andosol* | ***PAL1*** |
| *Loamy Aquandic Endoaqualls* | *Andic Gleyisols* | ***PCO1*** |
| *Loamy-sand HumicUdivitrands* with tick surface horizon | *Vitri-Mollic Andosol* | ***RCA2*** |
| *Loamy-clay Typic Udivitrands* | *Vitri-Mollic Andosol* | ***RCA5*** |
| *Typic Psammaquents* | *Areno-Eutric Gleyisols* | ***PCO2*** |
| *Urbic Anthrosols* | *Urbic Anthrosols* | ***TMR*** |

In pedological terms, each Land Unit is generally characterised by a single soil type: it has a certain inner homogeneity. In some cases individual units consist of associations or pedological complexes. Each soil unit was identified to construct the Soil Map (fig. 5); the map required detailed geolithologic knowledge of the area. Using helpful bibliographic data concerning soils in the Naples area (Di Girolamo, 1984; Rosi & Sbrana, 1987; Di Gennaro & *alii*, 1995; Ermice, 1999; Buondonno & *alii*, 2003; 2007; Odierna & *alii*, 2006), together with lithologic data and targeted surveys, we were able to also define area soil units in the previously unmapped provinces of Avellino and Salerno.

For each soil unit we recorded both the altitude range and their average thickness. Finally, to complete soil characterisation, we determined the average depth from the ground surface of the piezometric surface in the subsoil of plain and pediment areas. When possible, the piezometric level was controlled in some wells, with values obtained between 0.4 and 1 m on the alluvial plain and between 2 and 243 m in upland areas with prevailing carbonatic and volcanic lithologies (Uehara & Gillman, 1980).

The soil systems show features that can be easily recognised by various observers belonging to many disciplines. Each soil system may in turn be subdivided into relatively homogeneous parts as regards the nature of the terrain and landscape characteristics. Such homogeneous areas or soil units may indicate productive aptitudes, the most appropriate management techniques in agro forestry (woodland, shrubland, arboreus gardens, orchards and field crops), recreation (urban gardens, parkland) and conservation (Mediterranean maquis, reafforestation).

Methodological investigation allowed us to identify in the Sarno area geographical zones or soil systems within which, on the basis of genetic factors, we discriminated 18 soil units (tab. 5) identified with a specific symbol. Much of the basin is occupied by industrial and densely urbanised areas (*URB*), chiefly concentrated along the coastal belt. Lastly, soils in urban and industrial areas and those of

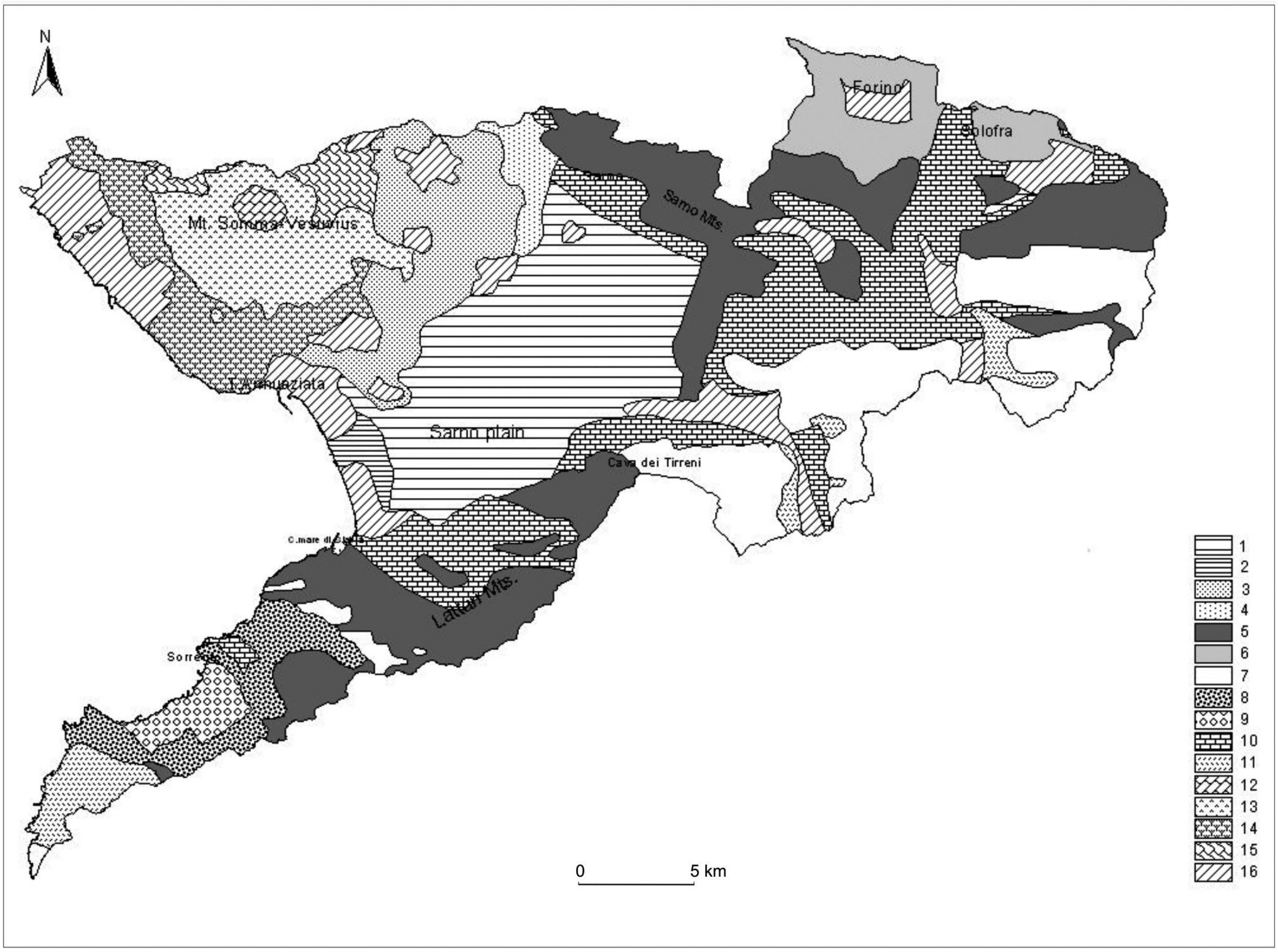


FIG. 5 - Soil Map of the Sarno River Basin: 1) PAL; 2) PCO; 3) PED1; 4) PED2; 5) RCA1; 6) RCA2; 7) RCA3; 8) RCA4; 9) RCA5, 10) RCA6; 11) RCA7; 12) SVE1; 13) SVE2; 14) SVE3; 15) SVE4; 16) URB (see table 5).

active or disused quarries are indicated by *TMR* and consist of disturbed soil and landfill. They may be found chiefly along the Vesuvius coastal strip, the mouth of the Sarno river and the plains of the Solofrana and Cavaiola.

The alluvial soils of the Sarno and the Solofrana (*PAL*), the fluvial, marine and marshy soils of the coastal plain (*PCO1*), and those of pocket beaches (*PCO2*) develop on a limestone foundation. Two soil types were also found on Mt. Somma: volcanoclastic foothill soils (*PED1*), and the pediment close soils (*PED2*), consisting of pyroclastic fall and volcanoclastic deposits. By contrast, Vesuvian soils (*SVE*) are grouped into four classes: soils of the present day cone consisting of pyroclastic fall deposits mixed with scoria and lavic effusion (*SVE1*); soils on the volcano's upper slopes consisting of pyroclastic fall deposits (*SVE2*); soils on the lower slopes consisting of pyroclastic fall deposits, pyroclastic and volcanoclastic flow (*SVE3*); soils on the slopes of Mt. Somma consisting of pyroclastic fall deposits that cover the dykes and lava flows and, in the lower part, volcanoclastic deposits (*SVE4*). Calcareous soils (*RCA*) were distinguished into eight types variously distributed in the area. In particular, a considerable area is occupied by the soils of bare limestone slopes and of the flat summits covered with Phlegrean and/or Somma-Vesuvian pyroclastites (*RCA1*) found along the reliefs of the upper course of the Sarno river and on the Sorrento Peninsula, by soils of the bare limestone reliefs, locally covered by pyroclastites (*RCA3*), framing the Solofrana and Cavaiola, and by the pyroclastic soils of the lower slopes locally mixed with limestone detritus (*RCA6*), which may be recognised in the central zone of the basin as far as the Sorrento Peninsula.

Finally, on the basis of information on socio-economic activities in the study area we drew up the Land Use Map (fig. 6): the various industries, the many farming activities conducted in the area and various residual natural spaces were grouped into seven main Soil Use Units (tab. 6) at a scale of 1:25000. It is a useful aid for land use planning: it

TABLE 5 - Symbols identifying the 18 soil units identified in the study area

| | |
|---|---|
| ***PAL*** | soils of the alluvial plain of the Rivers Sarno and Solofrana, consisting of alluvial deposits mixed with pyroclastic material, at times terraced, of moderately fine texture, non-limestone on the surface and limestone at depth, neutral pH |
| ***PCO1*** | soils of the coastal plain of the River Sarno, consisting of deposits from rivers, marine and river lakes, and interdunal lagoons, at times terraced, mixed with pyroclastic material, of moderately coarse texture, moderately alkaline limestone |
| ***PCO2*** | soils of the littoral around the mouth of the River Sarno and Vesuvius, pocket beaches of the Vesuvian coast and Sorrento Peninsula, consisting of beach and local wind erosion deposits (a dune buried in historical times), both limestone, often mixed with pyroclastic material (Sorrento Peninsula), and volcanoclastic (Vesuvian coast), fine to coarse texture, alkali pH |
| ***PED1*** | soils of the Mt. Somma pediment consisting of coarse-texture volcanoclastic deposits, strongly to moderately acid |
| ***PED2*** | soils of distal zone of Mt. Somma pediment, consisting of moderately coarse pyroclastic ejecta and volcanoclastic deposits, moderately acid |
| ***RCA1*** | soils of the limestone slopes and flat summital surfaces with pyroclastic cover, wooded and north-facing, consisting chiefly of pyroclastic deposits from the 79 AD Somma-Vesuvius eruption, or older (Phlegrean and Somma-Vesuvius) and/or recent (Vesuvian), covering the limestone substrate, moderately coarse texture, moderately acid |
| ***RCA2*** | soils of intramontane valleys, consisting of Phlegrean and Somma-Vesuvius pyroclastic deposits with limestone-pumice detritic levels in between, covering the limestone substrate, moderately coarse texture, moderately acid |
| ***RCA3*** | soils of bare limestone reliefs, chiefly south and south-west facing, consisting of limestones and locally by the thin residual pyroclastic cover, moderately coarse texture, neutral pH |
| ***RCA4*** | soils of the terraced slopes consisting of pyroclastic deposits, locally mixed with detritus of limestone and sandstone, moderately coarse texture, neutral pH for non-calcareous soils, highly basic for limestone soils |
| ***RCA5*** | soils of the Ignimbrite valleys, consisting of pyroclastic deposits that cover *Campanian Ignimbrite* (*Campanian Grey Tuff*), moderately fine texture, neutral |
| ***RCA6*** | soils of the lower slopes on talus, consisting of pyroclastic deposits interlayered with calcareous deposits, moderately coarse texture (medium where the 79 AD pyroclastic cover has been eroded), moderately acid |
| ***RCA7*** | soils of the moderately steep sandstone reliefs, consisting of moderately fine texture sandstones with calcareous cement, from neutral to moderately alkali pH |
| ***RCA8*** | soils of the arenaceous slopes, consisting of moderately fine texture sandstones with calcareous cement, moderately alkali |
| ***SVE1*** | soils of the current cone of Vesuvius, consisting of pyroclastic deposits interlayered with scoria and lavic effusions, coarse texture, neutral |
| ***SVE2*** | soils of the upper slopes of Vesuvius, consisting of pyroclastic deposits, coarse texture, moderately acid |
| ***SVE3*** | soils of the lower slopes of Vesuvius, consisting of pyroclastic deposits, pyroclastic flow and volcanoclastics, moderately coarse texture, moderately acid |
| ***SVE4*** | soils of the Mt. Somma slopes, consisting of pyroclastic deposits covering the dykes and lava flows, in the lower part by volcanoclastic deposits, moderately coarse texture, moderately acid |
| ***TMR*** | soils of urban areas, industrial areas and active or disused quarries, consisting of heterogeneous disturbed soils, heterometric texture |

TABLE 6 - Symbols identifying the 7 land use units recognised in the Sarno River Basin

| | |
|---|---|
| *AU* | Urban and heavily industrialised areas |
| *BC* | Woods and bushes |
| *AG* | Farmland |
| *CP* | Perennial crops |
| *SE* | Arable crops |
| *SC* | Cropping systems and complex plots |
| *SP* | Beaches and shore dunes |

shows the relation between natural features, such as the main vegetation classes, and human activities.

## MAP OF LAND UNITS

On the basis of the above thematic maps we recognised seven Land Systems indicated with capital letters (fig. 7). Land Systems A and C were further subdivided into subsystems in relation to chief morphotype (tab. 7).

The map was calibrated from analysis of aerial photographs, satellite images and both from literature and existing datasets and a consistent field work throughout

TABLE 7 - Land Systems and Land Subsystems identified in the Sarno River Basin

| Land System | | Land Subsystem | |
|---|---|---|---|
| | | **A1** | Steep-sloping zone |
| **A** | Slope zone | **A2** | Medium-sloping zone |
| | | **A3** | Low-sloping zone |
| **B** | Terraced area | | |
| | | **C1** | Alluvial plain |
| | | **C2** | Coastal plain |
| **C** | Gently-sloping area | **C3** | Levelled surface |
| | | **C4** | Intramontane plateau |
| | | **C5** | Ignimbritic plateau |
| **D** | Buried sand ridge | | |
| **E** | Mining zone | | |
| **F** | Urban zone | | |
| **G** | Industrial zone | | |

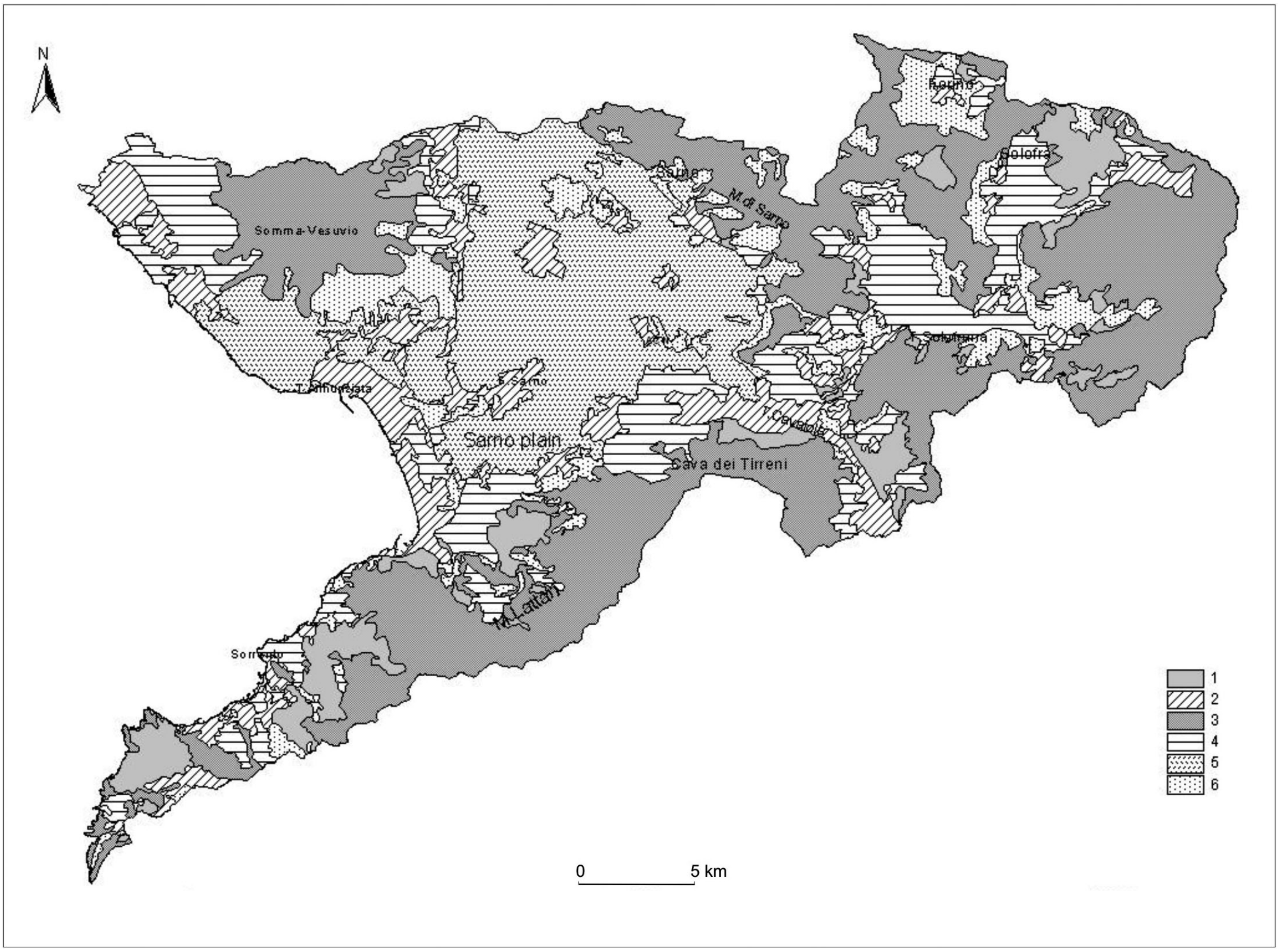


FIG. 6 - Land Use Map of the Sarno River Basin: 1) AG; 2) AU; 3) BC; 4) CP; 5) SC; 6) SE (see table 6).

observations and surveys. The different map layers, with their relative attributes, were overlayed with the aim to classify the Land Units and to construct georeferenced thematic maps.

In particular, from analysis of the different morphological, lithologic, soil, vegetation and impact factors, taking account of the different land systems and sub-systems identified, we recognised, labelled and mapped 32 Land Units (tab. 8).

The different gradient in *Land System A* allows us to define three environments with different morphodynamics. The lower limit of 30% (~16.7°) for the third class was considered on the basis of the slope value beyond which movements of mass are possible. The latter involve the soil cover along the slopes of the perimetral belt reliefs of the Sarno basin. High slope values generally indicate Meso-Cenozoic monoclinal highs that develop along the perimetral zones of the extended alluvial plain and in the Sorrento Peninsula.

*Land System B (Terraced area)* comprises the areas defined by natural and/or man made terraces. The latter, modelled in carbonatic or pyroclastic successions, are generally distributed in the transition zone between medium low gradient upland areas and plains. They are often found on gently sloping Quaternary patches of a marine origin displaced at current heights by Pleistocene tectonic events, or on carbonatic surface layers at sub-horizontal attitude. The terraces used for vineyards or various arable crops assume importance for economic purposes.

*Land System C (Gently sloping area)* corresponds to weakly sloping zones, with a slope up to 10% (<4.5°). It includes a vast part of the Sarno basin, in which five Land Units were distinguished.

*Land System D* (*Littoral and buried dune ridges)* corresponds to the shoreline of the Gulf of Castellammare di Stabia, the Somma-Vesuvius volcanic pediment and the small pocket beaches of the Vesuvian coast and the Sorrento Peninsula; the slope does not exceed 30%. Overall, such areas are small, due partly to major human impact on the coastal strip.

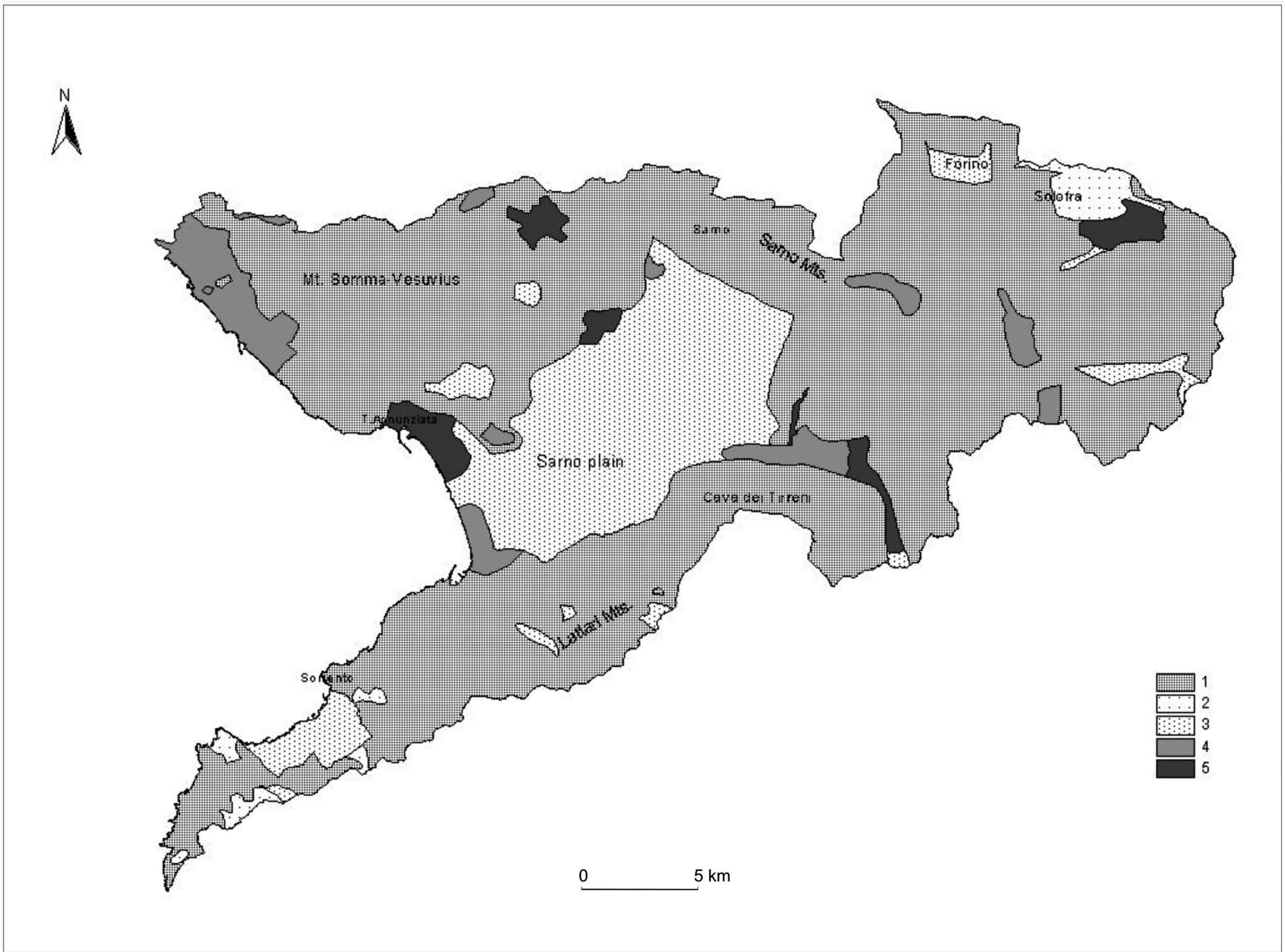


FIG. 7 - Land Systems Map of the Sarno River Basin: 1) A; 2) B; 3) C; 4) D; 5) E (see table 7).

*Land System E* (*Mining zone*) with a slope lower than 30% includes the areas with open cast mines. Some limestone quarries are still active in the foothill zone of Sarno and Nocera, while pyroclastic material is mined on the south eastern slopes of Mt. Somma-Vesuvius, volcanic sand near Castel San Giorgio. In the latter zone and in Sorrento, the quarries of Campanian Ignimbrite are abandoned, as are the dolomitic limestone quarries along the Sorrento Peninsula (Castellammare di Stabia, Vico Equense, Meta di Sorrento, Sorrento and Massa Lubrense).

*Land System F* (*Urban zone*) with a <30% slope refers to urban agglomerates, chiefly consisting of the Vesuvian towns, the Solofra area and the Nocera-Cava industrial area.

*Land System G* (*Industrial zone*) with a <30% slope includes development areas for various industries such as leather and tanning, agrifood, canning, textiles, graphics, paper, pharmaceutical and engineering.

Finally, the Map of Land Units (fig. 8) obtained represents the area in question divided by polygons (Land Units); each includes homogeneous geolithologic, morphometric and geomorphologic attributes. The map was produced by overlaying the various maps used and recognising the geographical sites on the basis of topographic maps of the Sarno basin in *raster* format.

All the features of the various units are reported in table 8; in figure 9 the various units (soil, vegetation, land systems and land units) are subdivided.

## CONCLUSIONS

The impact of land use always affects the system in some way. For example, simple changes in the number of stock grazing on an area of semi natural vegetation may affect the soil, microclimate, surface hydrology and, generally, the energy and nutrient cycle, whose greatest effects will appear in a long term perspective. The Map of Land Units is a document of extreme usefulness in territorial analysis, hence, in land use planning

TABLE 8 - Description of the 18 Land Units and their subunits identified

| | |
|---|---|
| **$A1_1$** | area with soil types RCA1 - ANh (cfr. tab.3), thickness <2 m, height 250-1400 m a.s.l.; vegetation type ACN (cfr. tab. 4), due to the presence of coppiced chestnut woods and beechwoods mixed with arboreus gardens and orchards. Found especially S-SE of the Forino Plain and N of the Municipality of Sarno |
| **$A1_2$** | area with soil types RCA3 - LPha and LPq, thickness 30-75 cm, height 0-850 m a.s.l.; vegetation type VEN, due to the exclusive presence of natural environments (maquis and xerophile grassland), with no human impact. Found in the sub-basins of the Rivers Solofrana and Cavaiola, in small patches in the Sorrento Peninsula and N of the Municipality of Bracigliano |
| **$A1_3$** | area with soil types RCA4 - CHha, thickness 0.5-2 m, height 0-350 m a.s.l.; vegetation unit APU. Found in limited zones of the Sorrento Peninsula |
| **$A1_4$** | area with soil types RCA6 - ANmz, thickness <1 m; height 30-250 m a.s.l.; vegetation unit VEN and ACN. Found at several points in the Sorrento Peninsula at the NW end of the River Solofrana sub-basin |
| **$A1_5$** | area with soil types RCA7 - LPe, thickness 30-75 cm, height <400 m a.s.l.; vegetation unit VEN (mixed broadleaf wood, areas with Mediterranean maquis and xerophile grassland). Found in the Sorrento Peninsula and east E of the River Cavaiola sub-basin, in the Fisciano area |
| **$A1_6$** | area corresponding to the current cone of Vesuvius with soil types SVE1 - LPha, thickness 30-75 cm, height 800-1180 m a.s.l.; vegetation unit VEN (chiefly broom *maquis*). Found only along the E slope of the cone of Vesuvius |
| **$A1_7$** | area corresponding to the upper slopes of Vesuvius, with soil types SVE2 - ANz, thickness <2 m, height 350-800 m a.s.l.; vegetation unit VEN (broom shrubland, holmoak maquis and *Pinus pinea* reafforestation) |
| **$A2_1$** | area corresponding to the distal parts of Mt. Somma pediment, with soil types PED2 - ANmz, thickness <1 m, height 30-250 m a.s.l.; vegetation unit ACP. Situated north of the Sarno sources and in the Sorrento Peninsula |
| **$A2_2$** | area with soil types RCA1 - ANh), thickness <2 m, height 250-1400 m a.s.l.; vegetation unit ACN. More extensive N-NE of the Sarno plain, Bracigliano - Montoro, Solfora Plain and the Sorrento Peninsula in the area of Corbara, Pimonte and Tacciano |
| **$A2_3$** | area with soil types RCA3 - Lpha, LPq, thickness <10 cm (at some points 35-75 cm), height 0-850 m a.s.l.; vegetation unit VEN, (maquis and xerophile grassland). Common in SW: Mercato San Severino, Calvanico, Monte Caruso, between the Municipality of Nocera and Roccapiemonte, and along the River Cavatola |
| **$A2_4$** | area with soil types RCA4 - CHha, height 0-350 m a.s.l. spessori 0.5-2 m; vegetation unit APU. Recognised in the Forino plain, in the Vico Equense - Sorrento sector and in almost all the island of Capri |
| **$A2_5$** | area with soil types RCA6 - ANmz, thickness <1 m; height 30-250 m a.s.l.; vegetation unit: VEN and ACN. Found in Mercato San Severino, Castel San Giorgio, Nocera Inferiore, Lettere and Casola di Napoli |
| **$A2_6$** | area with soil types RCA7 - Lpe, thickness 30-75 cm, height 400 m a.s.l.; vegetation unit VEN. Common almost only in the Sorrento Peninsula, from Massa Lubrense to almost Punta Campanella, and in limited zones of the Municipality of Cava de' Tirreni |
| **$A2_7$** | similar to Unit $A1_6$ but medium gradient. Found only near the current cone of Vesuvius |
| **$A2_8$** | similar to Unit $A1_7$ but medium gradient |
| **$A2_9$** | area corresponding to the slopes of Mt. Somma, with soil types SVE4 - Chha, height 200-850 m a.s.l., thickness 0.5-2 m; vegetation unit ACP. Identified only in the area around Vesuvius |
| **$A3_1$** | area with soil types PED1 without (CHha) or with ash and lapillus cover from 1944 (CHha1); thickness 20-50 cm; height 50-150 m a.s.l.; piezometric surface –43 m from ground level; vegetation unit ACP. It falls in the foothill area of Mt. Somma: San Giuseppe Vesuviano - Poggiomarino - Terzigno - Boscoreale - Pompei |
| **$A3_2$** | area with soil types PED2 - ANmz, thickness <1 m, height <50 m a.s.l.; piezometric surface -17.5 m from ground level; vegetation unit ACP. Found in the distal parts of the foothill area of Mt. Somma east of the previous area (Striano) |
| **$A3_3$** | area with soil types RCA6 - ANmz, thickness <1 m, height 30-250 m a.s.l.; piezometric surface –41.5 m from ground level; vegetation unit VEN and ACN. Common throughout the basin with minimal or limited areas |
| **$A3_4$** | area corresponding to Units $A1_7$ and $A2_8$ of low gradient. Found in the area around Vesuvius and the Sorrento Peninsula (Monticchio) |
| **$A3_5$** | area of the low slopes of Vesuvius with soil types SVE3 - ANmz, thickness <1 m, height 10-350 m a.s.l.; piezometric surface –68 m below ground level; vegetation unit ACP. Found especially along the stretch of coast between Torre del Greco and Torre Annunziata |
| **$A3_6$** | area with soil types SVE4 - CMha, thickness 0.5-2 m, height 200-850 m a.s.l.; vegetation unit VEN. Found in the area around Vesuvian, west of the cone in limited areas around the Vesuvian Observatory and east of the cone near Santa Maria la Scala |
| **B1** | area with chiefly man-made terraces and slope up to 10%, with soil types RCA4 - CMha, thickness 0.5-2 m, height 350 m a.s.l.; piezometric surface –243 m below ground level; vegetation unit ACP. It occurs only in the Sorrento Peninsula in three small areas, the largest being at Punta del Capo west of Sorrento. |
| **C1** | corresponds to the central part of the basin (River Sarno alluvial plain) and the north-eastern sector (Solofrana alluvial plain), undisturbed, in which the soil type still occurs and is recognisable. Consisting of alluvial deposits mixed with pyroclastic material, containing calcareous detritus at the base and at times patches of river and marine terraces and lagoons. The soil types are PAL - ANz, thickness <2 m, height 10-20 m a.s.l., piezometric surface from 1.5-2 m below ground level; vegetation unit ACP due to the presence of market garden crops and floriculture |
| **C2** | area with soil types PCO1 - GLa, thickness 1-2 m, height ≤3 m a.s.l.; piezometric surface 0.4-1 m below ground level; vegetation unit ACP. Represents a small gently-sloping area of terrain consisting of deposits of transition environments, at times terraced, mixed with pyroclastic and calcareous material. The type of deposits shows that they were formed in low-energy sedimentation environments. Also in this case these are areas with severe human impact, with industrial and urban sites almost on top of relic littoral ridges. The unit falls within the coastal zone around the mouth of the Sarno river in which most of the urban and industrial sites are concentrated |

| | |
|---|---|
| **C3** | area with soil types RCA1 - ANz, height 500-1400 m a.s.l., thickness <2 m; vegetation unit ACP. Recognisable in the Calvanico area, in the suburbs of Nocera Inferiore and at several points of the Sorrento Peninsula (Piani di Sant'Erasmo, Pimonte, Sant'Agata dei due Golfi) |
| **C4** | corresponds to extensive low-lying, low-gradient areas between the hills and mountains forming intramontane depressions, with soil types RCA2 - ANmz, thickness <2 m, height 520-650 m a.s.l.; vegetation unit ACP. It coincides with the Forino plain and the area around Banzano |
| **C5** | groups the low-gradient areas in which there are outcrops of soils ascribable to ignimbrite pyroclastic formation and its surface alteration products (the Sorrento plain) with soil types RCA5 - ANmz, thickness <2 m, height 30-50 m a.s.l.; vegetation unit ACP |
| **D1** | shoreline and dunal buried ridge corresponding to the littoral around the Sarno river mouth and Somma-Vesuvius, and to the pocket beaches of the Vesuvian coast and the Sorrento Peninsula with soil types PCO2 - GLea, thickness ≤2 m, height ≤3 m a.s.l., piezometric surface 3 m below ground level; vegetation unit LSC |
| **E1** | zone with soil types TMR - ATu; thickness ~0.5 m, height 0-500 m a.s.l., piezometric surface 68 m below ground level; vegetation unit CAV |
| **F1** | urban zone with soils TMR - ATu, thickness ~0.5 m; height 0-500 m a.s.l., piezometric surface 68 m below ground level; vegetation unit PFU. Recognised in small areas (south of Ottavaiano, San Sebastiano al Vesuvio and Striano) and large areas (San Giorgio a Cremano, Portici, Ercolano, Torre del Greco, Pompei, Boscotrecase, Boscoreale, in the province of Naples; Bracigliano, Siano, Mercato San Severino, Nocera and Cava de' Tirreni in the province of Salerno) |
| **G1** | industrial zone with soil types TMR - ATu), thickness <50 cm, height 0-500 m a.s.l., piezometric surface 68 m below ground level; vegetation unit FUI. It includes industrial sites at San Giuseppe Vesuviano, Terzigno, Poggiomarino, Torre Annunziata and Castellammare di Stabia in the province of Naples, the tanneries of Solofra in the province of Avellino, the industrial zone of Lancusi, Nocera Superiore and Cava de' Tirreni, in the province of Salerno |

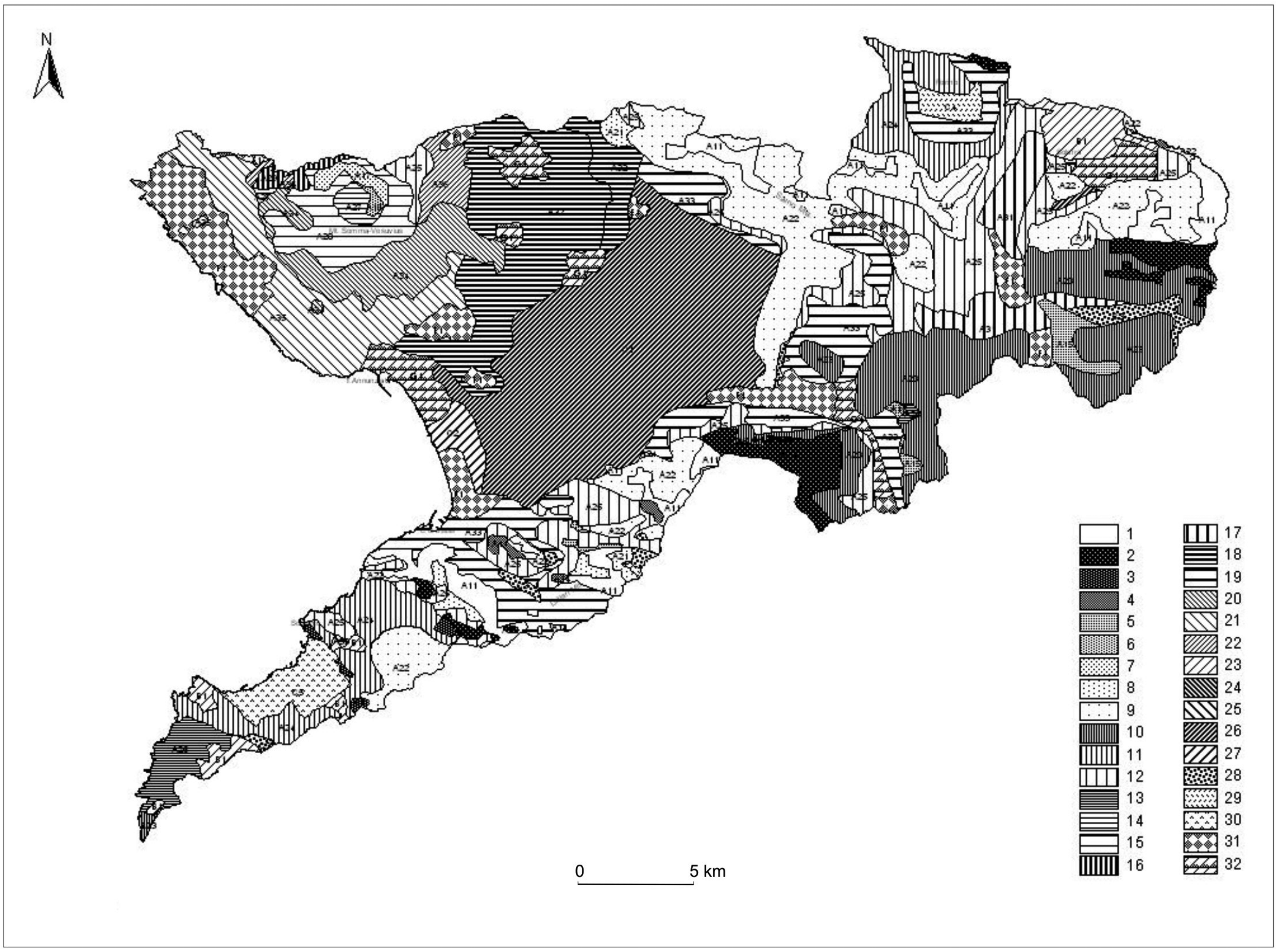


FIG. 8 - Land Units Map of the Sarno River Basin: 1) A11; 2) A12; 3) A13; 4) A14; 5) A15; 6) A16; 7) A17; 8) A21; 9) A22; 10) A23; 11) A24; 12) A25; 13) A26; 14) A27; 15) A28; 16) A29; 17) A31; 18) A32; 19) A33; 20) A34; 21) A35; 22) A36; 23) B1; 24) B2; 25) B3; 26) C1; 27) C2; 28) C3; 29) C4; 30) C5; 31) F1; 32) G1 (see table 8).

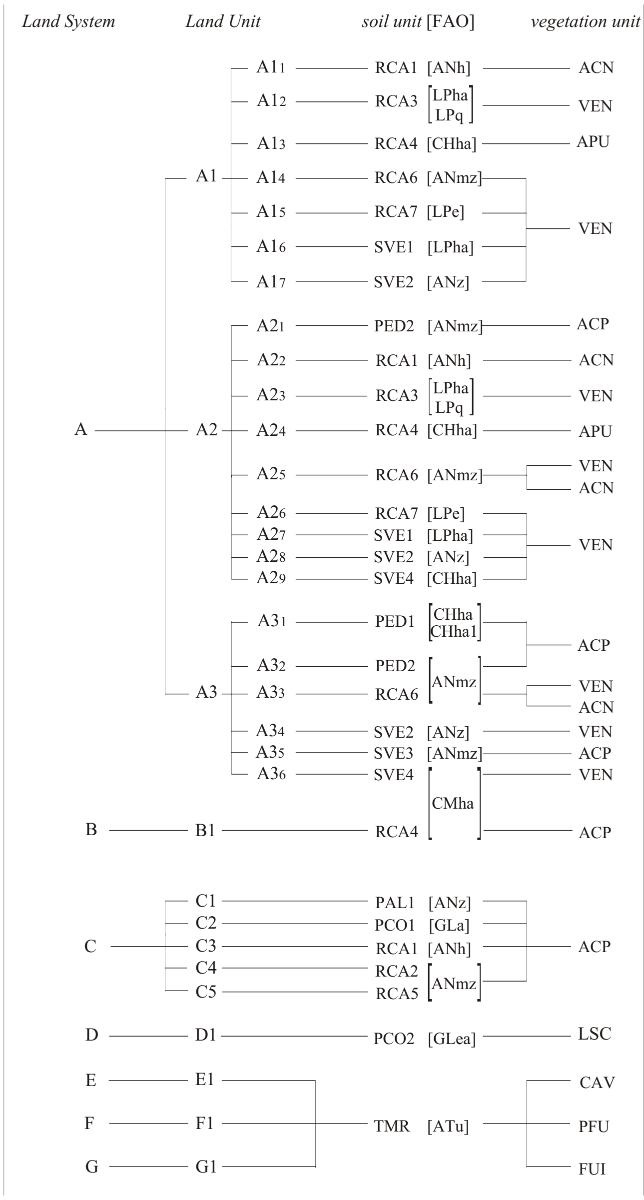


FIG. 9 - Tree diagram of the hierarchical subdivision of Land Systems into Land Units and Land Subunits, and relative soil units (after FAO, 1990) and vegetation.

in that it may be used to extract more simple features to be elaborated for applicative purposes (Rossiter, 1994; Maryland Department of Natural Resources, 2003; Di Feo, 2004).

Through a multidisciplinary scientific approach applied to studying the Sarno basin we formulated Land Units as the ultimate product of interactions between geology, geomorphology, climate, soil and vegetation in relation to soil use. This approach is a useful tool for territorial analysis to be applied profitably to other seemingly complex areas.

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*(Ms. received 15 April 2007; accepted 30 December 2007)*