

**SOIL DEPLETION DUE TO URBANISATION IN THE AREAS
NEAR THE PO RIVER (MUNICIPALITY OF CASTEL S. GIOVANNI,
SORBOLO, BONDENO - ITALY)**

**CONSOMMATION DU SOL DUE À L'URBANISATION DANS DES AIRES
ADJACENTES AU FLEUVE PÔ (COMMUNES DES CASTEL
S. GIOVANNI, SORBOLO, BONDENO - ITALIA)**

**PERDITA DI SUOLO PER URBANIZZAZIONE IN AREE LIMITROFE
AL FIUME PO (COMUNI DI CASTEL S. GIOVANNI,
SORBOLO, BONDENO - ITALIA)**

Massimo Gherardi*, Samantha Lorito, Gilmo Vianello, Livia Vittori Antisari

Department of Agroenvironmental Sciences and Technologies - CSSAS
University of Bologna, Italy).

* Corresponding author: E.mail: massimo.gherardi@unibo.it

Abstract

The loss of soil resources in Italy is particularly evident in the vast plain of the Po River Valley, where urbanisation has led to a progressive depletion of land surface. Built-up areas now cover around 9%, on average, of the total surface area, but in the most densely inhabited communities, lying mainly along the major artery of the Via Emilia, this figure may exceed 20%. The trend shows no signs of relenting, above all because of the demand for large surfaces generated by the tertiary sector. The phenomenon thus needs to be carefully controlled, especially as regards land located near the Po River and its main effluents. The soils in these areas have different pedogenetic and micro-morphological characteristics and support particularly demanding agronomic activities; though the levels of agricultural productivity match the highest levels in Europe, management of the land generally entails the maintenance of efficient water regulation networks. In this context there is a pressing need to investigate the dynamics of changes in land use in relation to soil quality, particularly areas that have undergone urban development.

Key world: *GIS; soil depletion; Po river.*

Résumé

La dégradation évidente du sol dans la Plaine du Pô est représentée par sa consommation progressive due à l'urbanisation, qui a atteint une valeur moyenne de 9% env. ; dans les communes à densité de population élevée, pour la plupart le long de l'axe représenté par la Via Emilia, les surfaces imperméabilisées peuvent excéder 20% du total. Cette tendance ne montre aucun signe de fléchissement, à cause de la demande d'amples surfaces couvertes surtout de la part du secteur tertiaire. Ce phénomène exige d'être attentivement contrôlé, notamment lorsque les aires concernées sont proches du cours du Pô et de ses affluents majeurs. En effet sur les sols de ces zones, très variables en considération aussi bien des conditions

pédogénétiques que micromorphologiques, ont lieu des activités agronomiques particulièrement exigeantes et, bien que l'exploitation agricole affiche une productivité élevée, comparable à celle des régions européennes les plus avancées du secteur, on est confronté au maintien d'un réseau efficace en matière hydraulique. De là s'ensuit l'exigence de mettre en rapport l'évolution de l'utilisation des sols, tout particulièrement par rapport au système habitatif, et les caractéristiques de la qualité des sols.

Mots-clés: *consommation du sol ; S.I.G.; fleuve Pô.*

Riassunto

Nella pianura padana un evidente fenomeno di degrado della risorsa suolo è rappresentato dal suo progressivo consumo per urbanizzazione, che ha raggiunto valori medi intorno al 9%; nei comuni ad alta densità abitativa, per lo più collocati lungo l'asse della Via Emilia, le superfici impermeabilizzate possono superare il 20% del totale. Tale trend mostra di non arrestarsi a causa della richiesta di ampie superfici da parte soprattutto del settore terziario. Il fenomeno richiede un attento controllo, in particolare nei casi in cui i territori interessati ricadano in prossimità dell'asta del fiume Po e dei suoi affluenti maggiori. I suoli di queste zone, variabili sia per condizioni pedogenetiche che micromorfologiche, ospitano infatti attività agronomiche particolarmente esigenti e pur presentando un tipo di utilizzazione agricola ad elevato livello di produttività, in linea con le regioni europee più avanzate nel settore, sono per lo più condizionati dal mantenimento di efficienti reti di regimazione idraulica. Ne deriva pertanto la necessità di porre a confronto la dinamica di trasformazione dell'uso del suolo (in stretta relazione allo sviluppo del sistema insediativo) con le caratteristiche di qualità dei suoli interessati.

Parole chiave: *consumo di suolo;GIS; fiume Po.*

Introduction

The development of large urban centres, the growth of the industrial, handicrafts and tertiary sectors and the extension of road networks are some of the major causes that have contributed, since the end of the second world war, to the progressive depletion of arable land surfaces, particularly in plain areas where the soils are best suited to agricultural use. The absence of adequate land planning exposes such areas to considerable damage, both from an environmental and social standpoint, and mainly to the detriment of agriculture. As vast surfaces are covered by buildings and roads, the consequences are not only an irreversible depletion of soil resources but also a progressive reduction in ground absorption capacity, which leads to major hydrogeological imbalances. This phenomenon is particularly evident in the vast plain areas of the Po River Valley, where as a result of urbanisation built-up areas now cover around 9% of the total land surface; in some cases, along the Via Emilia, a major route, the figure exceeds 20% (Fig. 1).

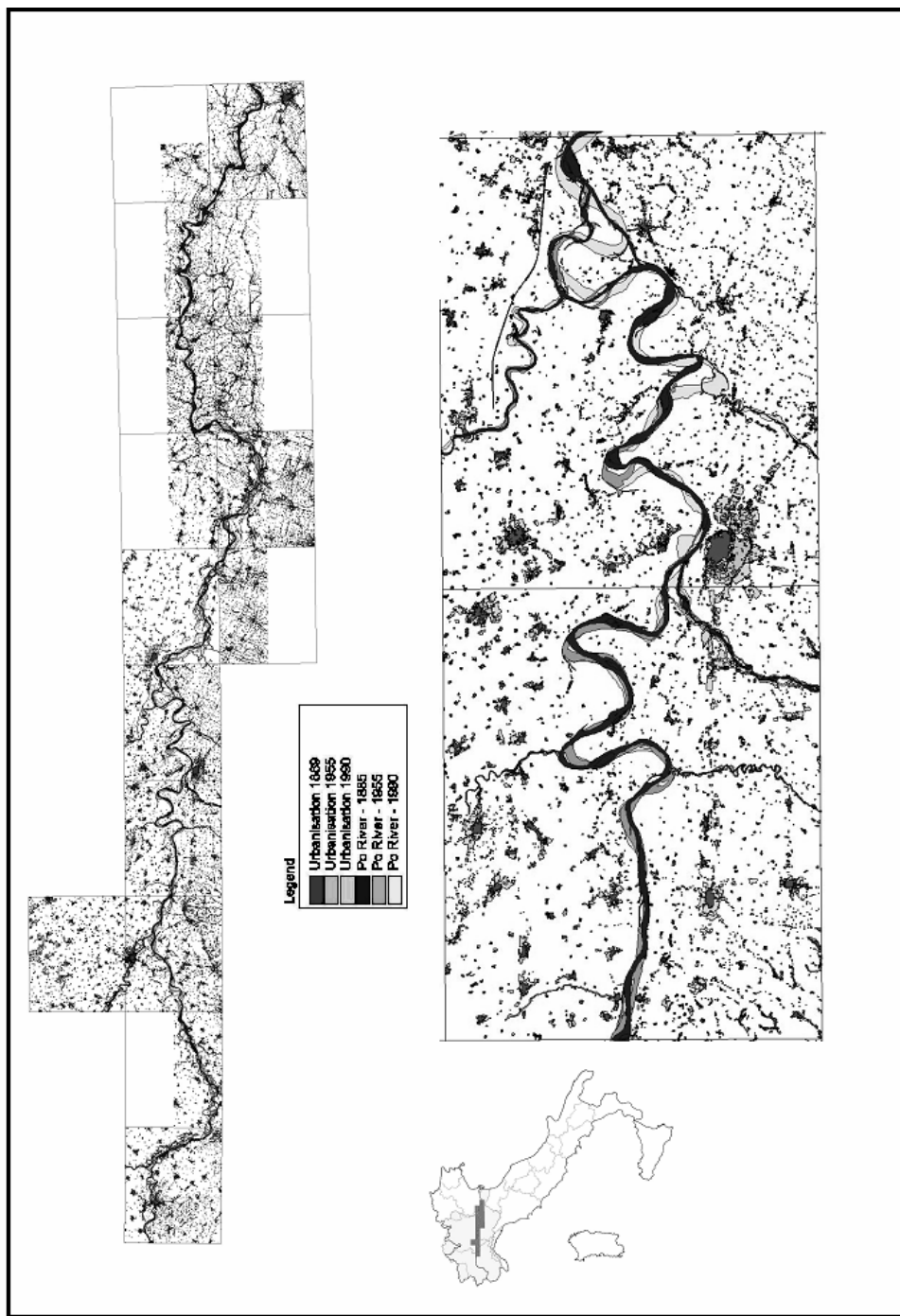


Figure 1 - Fluvial and Urban dynamics

The present study took into account a surface area of approximately 650,000 hectares, including the coastal towns of the Po Delta area, from Melegnano to Ferrara.

For the entire area, an evaluation was made of the patterns of urbanisation in the period between 1885 and 1995, while the subsequent analysis, aimed at a qualitative and quantitative determination of soil depletion, was limited to several areas within the region of Emilia.

Methodology

Farmland conversion trends were qualitatively and quantitatively evaluated in relation to urbanisation. The evaluation entailed a sequence of steps.

In the first stage, multi-temporal land use maps were generated by means of a suitable geographical information system; different sets of mapping data on a scale of 1:25,000 were overlaid and their relationship was analysed in order to evaluate urban development patterns and trends.

The information used for this purpose was derived from the following sources:

- topographic maps on a scale of 1:25,000, series 25V and 25N of the Italian Military Geographic Institute (IGMI), referring to the periods 1885-1890, 1933-1969, 1980-1995;
- technical maps on a scale of 1:25,000 and 1:10,000 of the Regions of Emilia-Romagna, Lombardy, Piedmont and Veneto, referring to the period 1985-1995;
- aerial surveys of the IGMI (GAI survey flight-1954/55) and the General Aerial Photography Company of Parma (Italy survey flight – 1994);
- municipal boundaries defined on the basis of the databank of the Po River Basin Authority.

The second stage consisted in a pedological evaluation of the study areas; the information used for this purpose was retrieved from the databank of the Region of Emilia-Romagna (www.gias.net).

Using GIS procedures, the map of urbanisation patterns obtained in the first stage of the study was compared with the soils map. In this manner it was possible to assess net soil depletion directly in relation to urban expansion occurring within these areas. The agronomic characteristics of the soils thus diverted from other uses were likewise analysed. This enabled a qualitative assessment of soil depletion; the resulting information may be usefully exploited by policymakers to improve land-planning tools so as to ensure more prudent use and promote conservation.

In the initial stage of the project, the urban boundaries existing in the periods 1885-1890, 1955-1960 and 1990-1995 were manually traced on non-deformable transparent film. This support was first calibrated on the frame on a scale of 1:25,000 of respective geographic attribution and adjusted on the basis of regional technical maps (CTR) for the period 1990-1995 and the IGMI map for the period 1885-1890. The resulting tracings were input into the database via a horizontal plane HP scanner, processed, calibrated and geo-referenced and subsequently

converted to the Arcview shape file format. The various layers were then assembled on a scale of 1:50,000 for printing.

Table 1 – *Soil types present in the municipalities of Castel S. Giovanni (Piacenza), Sorbolo (Parma) and Bondeno (Ferrara), broken down by soil delineations and agronomic qualities of the soils present (official data of the Region of Emilia Romagna).*

| NAME OF DELINEATION (*) | CLASSIFICATIONS FAO (1988) - USDA (1992) | AGRONOMIC QUALITIES |
|-------------------------|---|---|
| BARCO | CHROMIC LUVISOLS TYPIC PALEUSTALFS | Influenced by a high silt content, absence of limestone and presence of gravel |
| BORGHETTO | CALCARIC CAMBISOLS FLUVENTIC USTOCHREPTS | Influenced by the presence of gravel, which mainly affects their physical-hydrological behaviour |
| CALABRINA | HAPLIC CALCISOLS VERTIC USTOCHREPTS | Influenced by a fine texture, moderate availability of oxygen and absence of limestone |
| CASA PONTE | GYPsic VERTISOLS ENTIC CHROMUSTERS | Influenced by a fine texture, imperfect availability of oxygen and salinity at greater depths |
| CASTELVETRO | CALCARIC CAMBISOLS AQUIC USTOCHREPTS | Influenced by a high silt content and hydromorphy due to the vicinity to watercourses |
| CASTIONE MARCHESI | CALCIC VERTISOLS ENTIC CHROMUSTERS | Influenced by a fine texture and moderate availability of oxygen |
| CATALDI | HAPLIC CALCISOLS FLUVENTIC USTOCHREPTS | Influenced by a high silt content, which mainly affects hydrological behaviour |
| CITTADELLA | FERRIC LUVISOLS AQUIC PALEUSTALFS | Influenced by an excess of silt and absence of limestone, such as to affect the ability of water to infiltrate the soil |
| GHIARDO | HAPLIC LUVISOLS AQUIC HAPLUSTALFS | Influenced by an excess of silt and absence of limestone, such as to affect the ability of water to infiltrate the soil |
| MEDICINA | HAPLIC CALCISOLS VERTIC USTOCHREPTS | Influenced by a high clay content and moderate availability of oxygen |
| MONTICELLI | HAPLIC CALCISOLS FLUVENTIC USTOCHREPTS | Do not show any particular problems given their relatively balanced texture |
| MORTIZZA | CALCARIC CAMBISOLS FLUVENTIC USTOCHREPTS | Influenced by a low clay content and presence of horizons characterised by a large particle size |
| RISAIA DEL DUCA | EUTRIC VERTISOLS ENTIC CHROMUSTERS | Influenced by a high content of expandable clays and consequent seasonal water contrasts |
| RIVERGARO | HAPLIC LUVISOLS VERTIC PALEUSTALFS | Influenced by a fine texture and absence of limestone |
| RUINA | CALCARIC CAMBISOLS AQUIC USTOCHREPTS | Influenced by a high silt content, which affects physical and hydrological behaviour |
| SAN GIORGIO | HAPLIC CALCISOLS FLUVENTIC USTOCHREPTS | Do not show any particular problems given their relatively balanced texture |
| SANT'OMOBONO | CALCARIC CAMBISOLS FLUVENTIC USTOCHREPTS | Influenced by a high silt content, which mainly affects hydrological behaviour |
| SECCHIA | CALCARIC CAMBISOLS FLUVENTIC USTOCHREPTS | Do not show any particular problems given their relatively balanced texture |
| STRADAZZA | CALCARIC CAMBISOLS FLUVENTIC USTOCHREPTS | Influenced by a high silt content, which affects hydrological behaviour |
| TEGAGNA | HAPLIC CALCISOLS TYPIC USTOCHREPTS | Influenced by a high silt content, which affects hydrological behaviour |
| TERZANA | CALCIC VERTISOLS ENTIC CHROMUSTERS | Influenced by a fine texture and moderate availability of oxygen |

(*) from the regional catalogue of soil types in the plains of Emilia-Romagna – Region of Emilia-Romagna, Cartography Service - Pedological Division

The second stage of the study entailed the extraction of data relative to the urbanised surface area for each period and each municipal territory. These data were then overlaid on the soil map derived from the database of the region of Emilia-Romagna, with soil types classified according to the FAO-UNESCO method. The database associated with the new overlay maps allowed a calculation to be made of soil depletion in relation to pedological type and urban expansion.

Evaluation of soil depletion due to urbanisation

The results of the analysis conducted on three municipalities, *Castel S. Giovanni (Piacenza)*, *Sorbolo (Parma)* and *Bondeno (Ferrara)* are presented here by way of example. Soil delineations were defined for each, along with the agronomic features of the soils present (table 1).

By overlaying the maps relative to urban expansion on the pedological data it was possible to quantitatively and qualitatively assess the soil depletion for each municipality analysed.

Municipality of Castel S.Giovanni (Piacenza). Castel S.Giovanni is a small municipality (4,260 Ha) situated northwest of Piacenza. The urbanised area has expanded considerably over the past century. In 1889 it represented 2.6% of the total municipal land area, but by 1990 this value had risen to 8.6% (Table 2).

Table 2 - Soil depletion due to urbanisation in the municipalities of *Castel S. Giovanni (Piacenza)*, *Sorbolo (Parma)* and *Bondeno (Ferrara)*, expressed in Ha and as a percentage of the total municipal land area.

| Municipalities | Total surface area (Ha) | Urbanised surface area (Ha) | | |
|-------------------------------|----------------------------|-----------------------------|------------|------------|
| | | 1889 | 1955 | 1990 |
| Castel S. Giovanni (Piacenza) | 4412 | 113 (2.6%) | 119 (2.7%) | 371 (8.6%) |
| Sorbolo (Parma) | 3927 | 46 (1.2%) | 82 (2.1%) | 329 (8.4%) |
| Bondeno (Ferrara) | 17514 | 178 (1.1%) | 267 (1.5%) | 811 (4.5%) |

From a pedological point of view, the municipal territory is characterised by soils that differ both in taxonomic terms and in agronomic quality. Based on indications provided by the Region of Emilia-Romagna, the following soil delineations may be identified (table 3).

The soil delineations most greatly affected by urban development (Fig.2) may be divided into groups according to the types of soils present therein. A first group “Barco-Cittadella-Ghiardo-Rivergaro” is characterised by decarbonated leached soils (Alfisols) with frequent deep gravel layers. From a mechanical standpoint they are well suited to bearing heavy structural building loads; approximately 20% of these soils, equivalent to 5.6% of the entire municipal land surface, have been turned over to urban development.

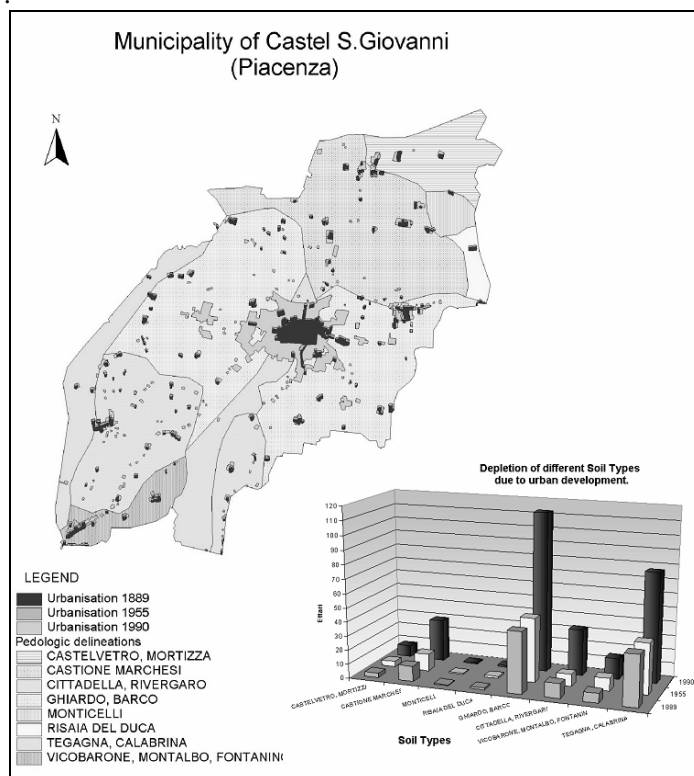
The second group, “Calabrina, Castione Marchesi-Tegagna”, is characterised by very clayey soils (Vertic Inceptisols or Vertisols), which are subject to water stagnation in certain periods of the year. Approximately 7% of these soils, or 2.5% of the entire municipal surface area, have been covered as a result of urbanisation.

The “Monticelli” soils, which display the best agronomic qualities, have been spared by urban development. It is in fact possible to observe a sparse presence of farmhouses, whose number and extension have not changed significantly over the past century.

| Soil delineations | Surface in hectares (Ha) |
|---------------------------------|--------------------------|
| Castelvetro, Mortizza | 39.233 |
| Castione Marchesi | 267.551 |
| Monticelli | 808.637 |
| Risaia Del Duca | 68.651 |
| Ghiardo, Barco | 370.010 |
| Tegagna, Calabrina | 1121.730 |
| Cittadella, Rivergaro | 1270.470 |
| Vicobarone, Montalbo, Fontanino | 157.486 |

Table 3

Quantity in hectares of soil types, grouped into delineations, in the municipality of Castel S. Giovanni (Piacenza).



Municipality of Sorbolo (Parma). Sorbolo is the smallest of the three municipalities analysed (3,927 Ha) and is situated in proximity to the Po River, between the provinces of Parma and Reggio Emilia. Here urban development has had the greatest impact, with the ratio of urbanised areas to total municipal land area rising from 1.18% in 1889 to 8.36% in 1990 (see Table 2). Urbanisation has mainly affected the “Sant’Omobono” soils: in this zone 16% of the available surface area has been developed, equivalent to 5% of total municipal land area.

Sant'Omobono soils have acceptable agronomic qualities (Fluventic Inceptisols), as may be seen from the data reported in Table 1.

From a pedological point of view, this territory is less differentiated than the municipality of Castel S.Giovanni. In addition to the "S.Omobono", the following soil types may be found (table 4). "Risaia del Duca-Medicina-Cataldi" soils are definitely clayey (Vertisols and Vertic Inceptisols), meaning that their structural conditions are susceptible to change due to climate factors. Here about 5% of the soil surface, equal to 3.5% of the total municipal land area, has been lost to urban development.

| Soil delineations | Surface in hectares (Ha) | Table 4 |
|---------------------------------|--------------------------|--|
| Castelvetro, Mortizza | 17.896 | <i>Quantity in hectares of soil types, grouped into delineations, in the municipality of Sorbolo (Parma)</i> |
| Risaia Del Duca | 1717.887 | |
| Sant'omobono | 1158.206 | |
| Medicina, Cataldi | 1031.750 | |
| Cataldi, San Giorgio, Borghetto | 1154.011 | |

Municipality of Bondeno (Ferrara). Situated in the western part of the province of Ferrara, Bondeno is the largest of the municipalities examined (17,514 Ha). As may be observed in table 2, the percentage increase in urbanised surface area is markedly lower than in the other two previously analysed municipalities. This is most likely due to the particular nature of the land, which has served to limit expansion and cause development to be concentrated in areas less prone to hydromorphy. From a pedological viewpoint Bondeno is characterised by the prevalence of "Risaia del Duca – Case Ponte" soils, made up of expandable, oxygen-deficient clay (Vertisols) and "Ruina-Stradazza" soils, which are silty and have poor internal drainage (Aquic Inceptisols).

Approximately 3.5% of the soil surface falling within the "Risaia del Duca – Case Ponte" delineation has been urbanised; this represents 2.9% of the total municipal land surface. By contrast, 8.2% of the available "Ruina-Stradazza" soil surface, representing about 2% of total municipal surface area, has been lost to urbanisation.

| Soil delineations | Surface in hectares (Ha) | Table 5 |
|-----------------------------|--------------------------|--|
| Risaia Del Duca | 1638.000 | <i>Quantity in hectares of soil types, grouped into delineations, in the municipality of Bondeno (Ferrara)</i> |
| Ruina, Stradazza | 4021.574 | |
| Cataldi, San Giorgio | 493.634 | |
| Terzana, Ruina | 1035.774 | |
| Sant'omobono, Secchia | 1672.044 | |
| Risaia Del Duca, Case Ponte | 8474.694 | |

Conclusions

A qualitative and quantitative evaluation of soil depletion due to urban development may undoubtedly contribute to a more rational and responsible use of this resource. The method proposed involves a first stage in which a small-scale investigation is conducted with the aim of precisely identifying the changes that

have occurred as a result of urbanisation over a specific period of time. The second stage consists in a large-scale qualitative and quantitative analysis (at a municipal level) of soil depletion in relation to the urban development recorded. The very fact that the defined study areas coincide with the areas of jurisdiction of the local authorities may enable an immediate implementation of land planning tools aimed at achieving a more judicious use of soil resources and preventing the most fertile soils from being converted to non-agricultural use and from being sacrificed, in particular, to urbanisation, insofar as this is possible.

References

- AMATUCCI M., BUSCAROLI A., ROSETTI P. (1999) Dinamica fluviale ed insediativa di un tratto del fiume Po (Provincia di Cremona). In "Informazioni territoriali e rischi ambientali" Atti 3a Conferenza Nazionale ASITA, 1:103-108, Napoli .
- BENVENUTI S., M.GHERARDI, S.LORITO (2001) Ricostruzione del Sistema ambiente-territorio mediante GIS a fini di programmazione paesaggistica: il caso del bacino del Reno tra Cento e S.Agostino. Atti della 5° Conferenza Nazionale ASITA –Rimini 9-12 Ottobre 2001 3: 193-198.
- BERTOZZI, A. BUSCAROLI, P. CAVALCOLI, M. PIRAZZOLI, G. VIANELLO (1993) Dinamiche e persistenza dell'uso del suolo della Provincia di Bologna: l'applicazione di un sistema informativo geografico. P.F. RAISA-CNR, Genio Rurale, 609(2):11-18.
- BERTOZZI R., BUSCAROLI A., LOCATELLI M., VIANELLO G. (1993) Metodologia d'analisi per individuare le dinamiche e le persistenze dell'uso del suolo correlate al differente grado di fragilità ambientale. P.F. RAISA-CNR, su "L'impatto delle agrotecnologie nel Bacino del Po", cap. 17, pp. 287-296, Franco Angeli Editore.
- BERTOZZI R., BUSCAROLI A., GARDI C. , SEQUI P., VIANELLO G. (1994) Land planning: GIS application in environmental characterization, in local area. F.P. - P.A.N.D.A., subproject 1 , series 2, paper no. 04, Int. Conf. on Land and Water res. manag. in the Mediterranean region, II: 441-456, Valenzano, Bari .
- BLUM W.E.H. (1997) Soil degradation caused by industrialization and urbanization, Proceedings of the International Conference on Problems of Anthropogenic Soil Formation. Moscow (1997), pp. 3-5.
- D'ANGELO, M., ENNE G., MADRAU S. ZUCCA C. (2001) Soil consumption by urbanisation: a case study in northern Sardinia (Italy). In: Camarda, Domenico; Grassini, Laura (a cura di). Interdependency between agriculture and urbanization: conflicts on sustainable use of soil and water. Bari, CIHEAM-IAMB. p. 287-293. ISBN 2-85352-222-9.
- DENG J.S., WANG K., HONG Y., QI J.G. (2009) Spatio-temporal dynamics and evolution of land use change and landscape pattern in response to rapid urbanization Landscape and urban planning, 92(3):187-198.
- EEA - EUROPEAN ENVIRONMENT AGENCY (2000) Down to earth: soil degradation and sustainable development in europe. Environmental issues series no 16 luxembourg: office for official publications of the european communities - ISBN 92-9167-398-6
- GHERARDI M., ROSETTI P., G. VIANELLO G. (1998) Valutazioni relative al consumo e alle trasformazioni dell'uso dei suoli e alle modificazioni chimico-fisiche mediante la procedura del confronto multitemporale. P.F. RAISA-CNR e PANDA-MiPA, su "Sensibilità e vulnerabilità del suolo: metodi e strumenti d'indagine", pp. 193-212, FrancoAngeli Editore.

- GHERARDI M., LORITO S., (2002) I sistemi informativi geografici per l'organizzazione, la gestione e l'analisi dei dati territoriali. Modello integrato di monitoraggio su differenti realtà territoriali collegate ad un sistema informativo geografico – Ed Franco Angeli, 31-42.
- JIE CHEN (2007) Rapid urbanization in China: A real challenge to soil protection and food security *CATENA* 69(1) Elsevier.
- LORITO S., VIANELLO G. (1999) Localizzazione di una stazione ecologica mediante l'utilizzo di un sistema informativo geografico. In "Informazioni territoriali e rischi ambientali" Atti 3a Conferenza Nazionale ASITA, 2:855-860, Napoli.
- LORITO S., P.ROSETTI, G.VIANELLO (2000) Valutazione quali-quantitativa del consumo di suolo in funzione dello sviluppo del sistema insediativo nei territori prossimi all'asta del fiume Po" *Bollettino della Società italiana di Scienza del Suolo* 51(1-2):531-540.
- G. NIZEYIMANA G. W., PETERSEN E. D. WARNER X., SHI M. L., IMHOFF W., LAWRENCE T., RUSSO J.M. (1997) An assessment of soil productivity loss caused by expanding urban land use using remote sensing and soil productivity models AIP conference proceedings; 387:203-208.
- REGIONE EMILIA-ROMAGNA (1990) Catalogo regionale dei tipi di suolo della Pianura Emiliano-Romagnola. Servizio Cartografico – Ufficio Pedologico, Bologna..
- REGIONE EMILIA-ROMAGNA, (1994). I suoli dell'Emilia-Romagna. Servizio cartografico, Ufficio Pedologico, Bologna.
- VIANELLO G. (1993) Il problema della conservazione del suolo nel bacino padano. P.F. RAISA-CNR, su "L'Impatto delle agro-tecnologie nel Bacino del Po", cap. 7, pp. 123-127, Franco Angeli Editore.
- XIA LI, Gar A., ON Y. (2004) Analyzing spatial restructuring of land use patterns in a fast growing region using remote sensing and GIS *Landscape and Urban Planning*, 69(4):335-354.