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WEB MUNICIPAL SIS FOR EVALUATION OF HUMAN HEALTH RISK DUE TO SOIL POLLUTION AND URBAN SOIL MANAGEMENT

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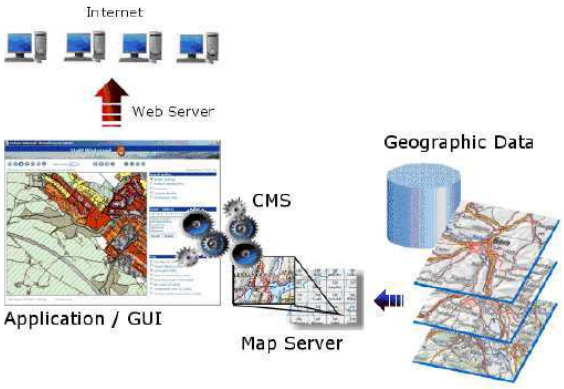

Web Municipal SIS for Evaluation of Human Health Risk Due to Soil Pollution and Urban Soil Management

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Abstract

Governmental institutions have recently given greater attention to the soil, recognising its role and functions in terrestrial environments. Governmental and local institutions have recently become increasingly aware of the threats arising from soil pollution for the welfare of the population. Spatial planning, land management may have important impacts on the potential transfer of pollutants from contaminated soils to humans. Due to the high complexity of environmental-soil datasets, in particular in urban environments, decision makers need reliable support on the effects of the management options they may consider. Tools to apply ecological data in an effective way in daily planning cases are viewed as essential in order to attain a sustainable development in highly pressured areas. In order to make complex scientific data available in daily planning processes a simple and small SIS for municipalities and local authorities was designed and developed in order to include the evaluation of human health risk for soil quality management into municipal land use planning processes. The tool had to be simple to maintain and update and cost affordable. In order to estimate the risk for human health the application was using the Human Health Risk Estimation method, developed as deliverable of Interreg IIIB project - TUSEC-IP. The designed Soil Information System was formed by (i) a database, and (ii) a web mapping application. The database part was designed in order to be simple, easy manageable to store soil related data. It was made by two tools (i) for soil and site information, and (ii) for human health risk data. The web mapping application comprised: (i) Web GIS to display existing soil and health information with an end user map interface for navigation, (ii) Risk Index calculator to apply the human health estimation algorithm, (iii) Data reports to present site information. The mapping application tool accompanying the health risk estimation was designed to be used also by planners not expert in soil science and soil contamination issues. The calculated values should provide more information to decision-makers. The use of a web mapping application is important in order to increase the sharing of the information among experts of different fields. In the future the use of such tools could be extended to public users in order to increase the participation of citizens into planning and environmental decision-making processes.

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Chapter 1

Introduction

1.1 Urban soils, heavy metals pollution and human health risk assessment

The development of urban areas is driven by socioeconomic processes. Land use has always had a particular influence on soils. In most areas, it is the main factor of todays soil qualities (SOWA, 2005). The ecological situation in urban and industrial centres is a decisive factor influencing the quality of life and the health of people (Birke and Rauch, 2000). Contamination, local or diffuse, is one of the main threats to soil quality recognised by the European Soil Strategy (European Commission, 2006). The environmental quality of urban soil is closely related to human health, as urban areas are densely populated (e.g. Bityukova et al., 2000; Li et al., 2001; Romic and Romic, 2003; Stroganova et al., 1997; Tiller, 1992). It is important to gain sufficient knowledge about the effects of different types of land use on soil properties and on the capacities of the soils to fulfil certain functions. Urban environments are the areas where soils interact with human society most intensely (Stroganova et al., 1997). Many authors have highlighted the need for a better understanding of urban soils, focussing on the information needed for soil management (CARACAS, 1998; SAEFL, 2005; Stubenrauch et al., 1997; Wong et al., 2006). Governmental institutions have recently given greater attention to the soil, recognising its role and functions in terrestrial environments European governmental institutions as well as local communities have recently become increasingly aware of the threats arising from soil pollution for the welfare of the population. The contact of humans with soils is more likely in urban than in rural areas, strongly dependent on the land use. Spatial planning, land management may have important impacts on the potential transfer of pollutants from contaminated soils to humans (Romic and Romic, 2003). Heavy metals are the most studied soil pollutants due to their ubiquity, toxicity and persistence. They occur naturally in soils, waters and living organisms (Romic and Romic, 2003). Above certain concentrations all metals have an adverse effect on human health, causing heavy metal poisoning and acting as cofactors in many other diseases (Davydova, 2005; Merian et al., 2004; Pierzynsky et al., 2005). The health of young children is particularly at risk (Groen and Andersen, 2003).

1.1.1 Urban soils and heavy metals pollution

Soils of urban areas are generally considered those soils which occur within the boundary of an urban community (Van-Camp et al., 2004; Visser, 1994). Urban soils are generally structurally and functionally different from natural and undisturbed soils. Natural and undisturbed soils usually exhibit a vertical sequence of layers commonly referred to as A, B, and C horizons. Each of these horizons represents a zone of specific soil properties, functionality, and microbiological activities. Furthermore, the origin of these natural and undisturbed soils can usually be traced back to the natural and geological processes of their parent materials. In an urban setting it is highly questionable that the soils originate from a single source. In fact, soils in the urban environment tend to be highly disturbed due to the intense human activities in the surroundings and may be exogenous. Urban soils do not necessarily exhibit a stratified profile of soil formation nor relate directly to their immediate geological materials. They include natural, man modified and man made soils. Soils of urban areas have specific benefits for quality of life of human beings, such as health, social, economical, technical and environmental qualities. These soils are formed under the influence of both natural zonal and anthropogenic soil-forming factors. Their upper 50-cm layers form as a result of mechanical mixing, burying, and contamination of the original soil with non-soil materials. Unlike soils in rural and suburban areas, in the urban environment open/exposed soils, with or without vegetation, are usually fragmented and small in size (Wong et al., 2006). The need to have local services led to a high density of building with few open areas. Because of urban planning, they are commonly found in greenbelts along roadsides and in leisure and recreational facilities, such as playgrounds and parks, where they are used as a substrate to grow plants for buffering and aesthetic purposes. They can also be found in private backyards, in small plots used to grow food (Bullock and Gregory, 1991; Hough et al., 2004). These leisure facilities are an integral component of healthy urban living. In the urban ecosystem the soil perform variety of ecological functions, according to the different land uses (Figure 3), assuring environmental conditions suitable for human activities of living, housing, sport and leisure and production of goods and services (Vrščaj et al., 2006). Their main features are fertility, suitability for growth of stands, and ability to absorb and fix contaminants, which prevents the pollution of ground waters and atmosphere (Bullock and Gregory, 1991; Stroganova et al., 1997).

1.1.2 Urban soils pollution and human health

The heavy metals, which occur naturally in all soils, waters and living organisms can have severe toxic impact on living systems when present in excessive concentrations. It is important to recognise the boundaries of concentrations that separate healthy from unhealthy organisms or safe food products from those unsuited for human or animal consumption. It is also important to recognise the variations of chemical reactivity and mobility of each pollutant metal in different environments, because this affects the redistribution of heavy metals in soil and the passage in the food chain (Birke and Rauch, 2000; Romic and Romic, 2003). The prolonged presence of the contaminants in the urban environment, particularly in urban soils, and their close proximity

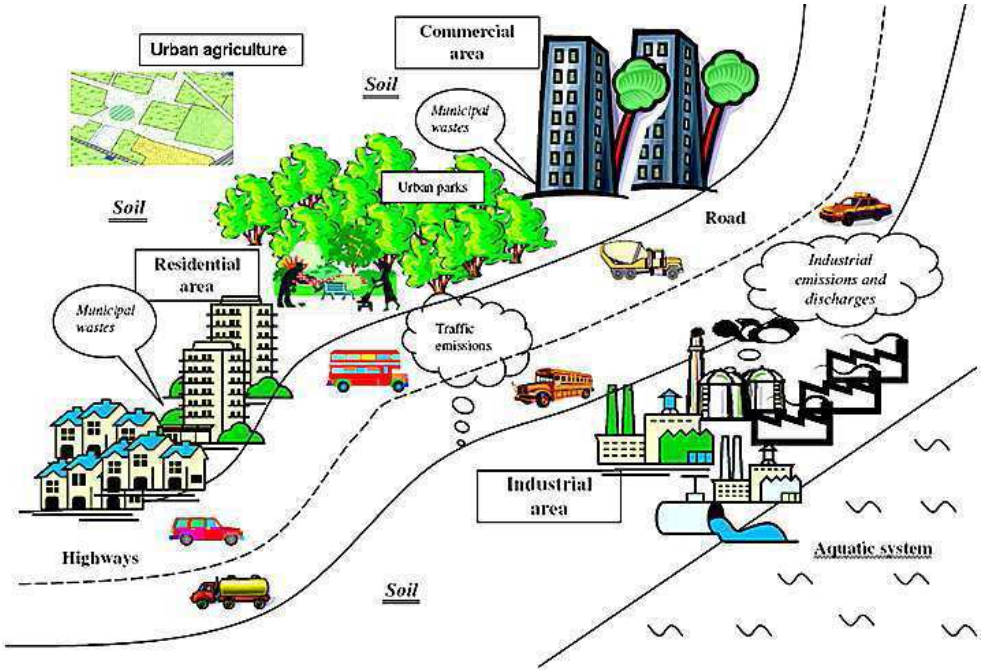


Figure 1.1: The major soil uses in an urban ecosystem.

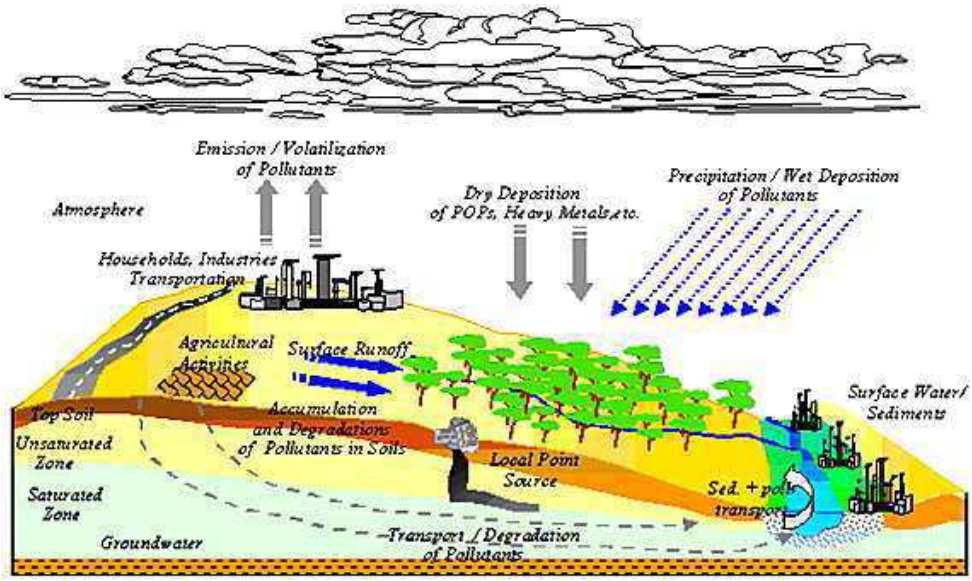


Figure 1.2: Flows of diffuse soil heavy metal pollution.

to the human population can significantly amplify the exposure of the urban population to metals via inhalation, ingestion, and dermal contact. As a result, an increased metal uptake by crops and vegetables grown for human consumption is often observed, as well as direct uptake of human beings. A human health concern is usually associated with excessive exposures to metals that cause toxic effects to biological organisms. It is well known that some metals, such as zinc and copper are essential for most biological systems, including humans, at appropriate levels, while others, such as cadmium and lead are highly toxic to plants, animals and human (Bityukova et al., 2000; Stroganova et al., 1997; Wong et al., 2006). However, generally speaking, the excessive accumulation of most heavy metals and metalloids in soils and plants may pose serious health risks to humans and exert adverse impacts on the ecosystem, including the subsequent migration of the pollutants to receiving bodies of water via urban runoff. This may affect the quality of aquatic ecosystems, potentially causing trace metal contamination of the food chain. The direct health impacts of trace metal contamination of the urban environment are usually difficult to assess due to the complexity of the medical factors involved (Wong et al., 2006). Industrial development has brought prosperity to millions of people, but has also left a legacy of environmental damage that continues to impact natural resources and ultimately the human well-being. A change of environmental quality in the city results in worsening living conditions for its population (van Kamp et al., 2003). The information on the mobilization, dispersion, deposition, and distribution of potentially toxic metals/metalloids in urban ecosystems plays an important role in the assessment of trace metal contamination and in the evaluation of its potential environmental and health implications. Furthermore, it is increasingly recognized that the synchronization of such information into urban planning can facilitate the development of healthy and sustainable urban environments (Wong et al., 2006).

1.1.3 Human Health Risk assessment

Risk assessment provides a qualitative or quantitative evaluation of the risk posed to human health and to the environment by the actual or potential presence of pollutants. It is a set of formal, scientific methods for defining and estimating the probabilities and magnitudes of adverse impacts on plants, animals and/or the ecology of a specified area posed by a particular stressor (NEPC, 1999a). Risk assessment may be defined as the *"characterisation of the potential adverse health effects of human exposures to environmental hazards"* or the *"process of estimating the potential impact of a chemical or physical agent on a specified ecological system under a specific set of conditions"* (Markus and McBratney, 2001). Quantitative guidelines for assessing risks are associated with several scientific problems. There are difficulties in establishing concentrations of contaminants beyond which risks from exposure to these contaminants would be *unacceptable*. This requires not only scientific (toxicological) information on the health effects, but also an element of judgement on what is *unacceptable* risk. In addition, soil is only one of the sources of contaminant exposure, and its effect, and the cost of dealing with it, needs to be kept in proportion with the total exposure to contaminants from all sources. To be simple to use, guidelines that are generally applicable are needed. However, in the case of soil quality,

it is particularly difficult to take account of the variety of soil types and particular site conditions, as well as the ranges of contaminants, contaminant species and contaminant mixtures. Complex assumptions are needed to establish the relationship between the concentration of a contaminant in soil and the effect on a human or other receptor of relevance. All these factors make it difficult to derive generally applicable criteria. *Worst-case* assumptions can be used with care to overcome some of the problems, but they can result in criteria that are impracticable (Wragg and Cave, 2003). Risk assessment of contaminated land usually starts with some suspicion about the presence of soil or groundwater pollution. This qualitative information may lead initially to subjective assessment about environmental risks, and perhaps financial risks for occupiers, buyers, sellers, lenders and others, potentially affected by the site. In order to be more certain about the consequences of pollution, a further investigation may be carried out and contamination levels compared with soil and groundwater criteria. These criteria may be generic or may be derived from site-specific models used to predict adverse effects of pollution and the need for remediation. Model conclusions may be substantiated by actual measurements of exposure or even by epidemiological data. In general, the less prediction the more reliable is the assessment, but the more difficult is the investigation (CARACAS, 1998; CCME, 1999; NEPC, 1999b). The process involves the analysis of contaminants concentrations and releases, the identification of exposed populations, the identification of potential exposure pathways, the estimation of exposure concentrations for each pathway and the estimation of contaminants intakes for each pathway for a range of scenarios and land uses (figure 1.3).

The usual structure of a risk assessment is: Source → Hazard assessment → Target receptors → Pathways → Exposure assessment (CARACAS, 1998; CCME, 1999; NEPC, 1999c; SFT, 1999; US.EPA, 1998). The factors that are more influencing health risk are (NEPC, 1999c):

a) land use;
b) potential child occupancy;
c) potential environmental effects including leaching into groundwater;
d) bioavailability of contaminants;
e) state of the site surface, e.g. paved, with grass or exposed;
f) potential exposure pathways;
g) uncertainties with the sampling and the toxicity assessment.

In national frameworks for health risk assessment generic land use scenarios may be envisioned. They are based on how the soil is used and on how sensitive and dependent the activity is on the land. The definition of each land use accommodates generic conditions and puts boundaries on the receptors and exposure pathways considered for that land use (BBodSchV, 1999; CCME, 1999; DEFRA and Environment-Agency, 2002; NEPC, 1999c; RIVM, 2001; SFT, 1999; US.DoE, 2005; US.EPA, 1991). Despite the different levels of risk sought for individual land uses, an important common principle exists for all land use categories: for each land use, the level of ecological protection provided should ensure that the land has the potential to support the majority of activities associated with that land use. Sensitivity to contamination increases among the ecological or human health components most dependent on the land use

Toxicology assessment with heavy metals example

	Human health				Ecosystem			Groundwater
Receptors	Human beings – adult and child. When both at risk child is considered				Vegetation – Local & ornamental, crops	Wildlife & House Pets	Soil fauna	The pollutants can be leached in the water and enter in contact with different receptors
Exposure	Frequency & Intensity				n.d.	n.d.	n.d.	
Pathways	Ingestion	Food chain	Inhalation	Dermal contact	Direct uptake	Direct contact Ingestion	Direct contact Ingestion	
Assessment	Human Bioaccessibilty fraction	Plant Bioavailability fraction	Estimation through pseudototal fraction	Estimation through pseudototal fraction	Plant bioavailability fraction	Estimation through pseudototal fraction	Estimation through pseudototal fraction	Easy mobilisable fraction Pseudototal fraction + soil parameters
Magnitude	Model	Model	Model	Model	Ecological importance of soil for the primary functions of the considered land use			Model
Limits	Dutch MPR	Dutch MPR	Dutch MPR	Dutch MPR	Phyto-toxicity	Dutch EH50	Dutch EH50	USA EPA Leachable
Land use suitability: The calculated value of magnitude of pollution is compared with existing limits. The suitability is established according to the importance of different pathways for different land use, based on the possibility that each pathways has to occur in the land use.								

Figure 1.3: Toxicological assessment of heavy metals contaminated soil (modified from Poggio, 2007)

activities. According to CCME (1999), a first ranking from the most sensitive land use to the less one can be:

- Agricultural
- Residential / Recreational
- Parkland
- Commercial / Road sides
- Industrial

In order to assess the human health risk it is important to take into account several pathways. The most considered pathways are the food chain, i.e. trough plant uptake and consequent consumption, ingestion and inhalation of soil particles by humans. The adverse effects of heavy metals on the hydrosphere can be evaluate considering the leaching process and the immobilisation capacity of soils (Gupta et al., 1996). The pathways considered are strongly dependent on land uses.

1.2 Spatial structure of data

The soil data produced from laboratory analyses need specific interpretation and presentation for end-users in order to be understood and, consequently applied and used in every day planning procedures. When dealing with environmental geochemical data many questions should be addressed, i.e. probability distribution, descriptive parameters calculations, spatial structure of data, correlation, database management, prediction and decision support (Zhang and Selinus, 1998). Characterisation of soil properties of urban areas is a complex problem, especially when considering pollution. The spatial distribution of the contamination is typically poorly related to soil type and other characteristics (Markus and McBratney, 2001). Urban soils have a highly variable and often unknown history as a result of differences in land use, transfer between sites, mixing in connection with excavations and addition of new soil materials (Linde et al., 2001). In many environmental studies, geographic information systems are routinely applied. However only few studies have used a GIS-based approach to study heavy metal contamination in an urban environment (Li et al., 2004). The reliability of the output of a GIS (Geographic Information System) basically depends upon the quality of the data. As a GIS deal with spatial information, data quality is determined in a significant way by sampling. A poorly designed sampling scheme yields unreliable results (van Groenigen et al., 2000). The danger of applying GIS is that it may show a result in the form of an appealing map that is, on the contrary, of poor scientific value. It is particularly important to indicate the quality of a map, showing the accuracy of the estimation of a property at each location. Misleading information can generate wrong and costly decisions. The interactivity between statistics, geostatistics, GIS and experts judgement are very important in soil surveys. The broadest form of interactivity in a GIS contest is a change in the role of GIS from collecting and storing data for inventory to using this for planning and soil evaluation tools (van Groenigen et al., 1997).

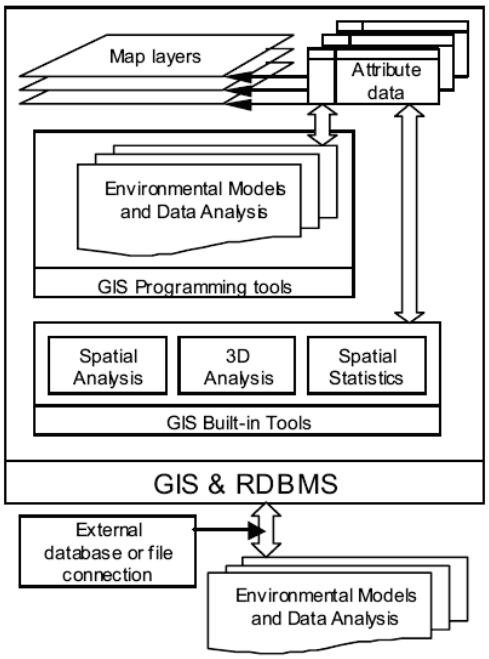


Figure 1.4: Basic structure of GIS model.

1.3 Environmental modelling

Environmental modelling in urban areas was developed to support decision-making process and to mark some common guidelines that can be used in environmental analysis and predictions. Since environmental geochemical variables are spatial variables, their spatial information should be visualised. The sampling locations, symbol maps with sampling locations and distribution maps are available with the aid of GIS. Mapping in environmental geochemistry, especially compiling distribution maps based on discrete sampling is receiving more and more attention (Zhang and Selinus, 1998). GIS can be defined as a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes (Cox, 1998). The basic structure of the project in GIS, focussing on data analysis of environmental problems, is illustrated in figure 1.4.

All data are stored in a database, which is managed by a relational database management system (RDBMS). The GIS contains a huge range of spatial analyses and temporal comparisons, which allow carrying out and display of output data in the GISs layers. A major part of the GIS project represents dynamic modelling, which is developed to make predictions and optimisation. The input data are formed with map layers. Map layers are completed with attribute tables, which contain the experimental data and model outputs. The environmental modelling and analysis is developed with programming tools. These data and modelling tools are completed with other information needed for decision-making process (cadastral maps and entries, public services, etc.). The model solutions are aggregated and analysed together with the raster algebra tools in the frame of the GIS. The raster algebra tools operate with cell-based modelling. Each cell of the input layer contains an attribute (concentration, amount or other

factor). The attribute of the cell in the same position in the output layer is calculated by the algebraic expression from the attribute of the corresponding cells in the input layers. After individual spatial analysis of each layer, the spatial merge is processed together with the results of environmental modelling (Cox, 1998). On the regional and national scales, the geochemical mapping of trace and major elements can be used as a tool for visualization, to make it easier to identify the possible locations of contaminated areas. Furthermore, existing GIS databases may incorporate population density, the locations of utilities and structural features, and topography. This allows the analytical data to be manipulated with this additional information, offering several advantages in trace metal assessments of urban soils. Furthermore, a scale of potential health impacts may be extrapolated by comparing the data with other information available and results from modelling (Wong et al., 2006; Zhang and Selinus, 1998).

1.4 Urban planning and soil quality management options

The development of urban areas follows socio economic processes that are driving forces for the formation of the city as an environment. Urban soils are developed in the urban environment, acting as forming-factor. Land use always had a particular influence on soils. In most areas, it is the main factor of todays soil properties (SOWA, 2005). Threats to soils such as erosion, contamination, humus reduction, sealing, total loss by excavation can be linked to land use. It is therefore important to gain sufficient knowledge about the effects of different types of land use on soil properties and on the capacities of the soils to fulfil certain functions. Urban environments are the areas where soils interact with human society most intensely (Stroganova et al., 1997). This happens on a continual and dynamic basis. It is important to identify the links between soil consumption and human ecosystem dynamics, building the bridge between description and function from a soil perspective and the progression of society, its governance and politics. The variety of urban land uses and soils reflect these diverse human activities and the various natural socio-economic, cultural and historical conditions and circumstances. Many authors have highlighted the need for a better understanding of urban soils with special attention to the lack of information that is needed for soil management (CARACAS, 1998; SAEFL, 2005; Stubenrauch et al., 1997; Wong et al., 2006). During the last few decades, governments in many countries have spent a considerable amount of money to develop large geographical databases describing their territories. Planners already commonly use and access land management documents in electronic format, e.g. plans, laws, regulations, cadastral and topographical data. These data sets have reduced delays in decision-making. Furthermore, they have improved coordination between ongoing projects in the same territory. At the same time, land planning has become increasingly complex. The principles of sustainable development confront land planners with a paradox of two apparently contradictory objectives: nature conservation and economic development. Furthermore, land planning, which previously involved only planners and developers, has now moved into the public arena where different lobby groups also promote their points of view. NIMBY (Not In My BackYard) and LULU (Locally Unwanted Land-Use) controversies illustrate the difficulties that often arise when a development project

significantly modifies its surrounding environment. In this new situation, planners face a double challenge. First, they must design projects and plans that maintain an ecological equilibrium but nevertheless contribute to economic growth. Second, they must be mediators trying to avoid opposition and reduce objections (Joerin et al., 2001). Progress in computing sciences, including Geographical Information Systems and Multi Criteria Decision Analysis can help planners handle this complexity. Three areas of application of land planning are: location choice, land suitability assessment and collaborative decision support systems. Choosing an appropriate location for an activity or a facility is obviously related to decision support and Multi Criteria Decision Analysis. The problem can be generalized as a question of what must be done and where it should be realized. The purpose of planning can involve any type of public facility. Land suitability assessment is similar to choosing an appropriate location, except that the goal is not to isolate the best alternatives, but to map a suitability index for the entire study area. GIS enable computation of the criteria while a Multi Criteria Decision Analysis can be used to group them into a suitability index (Joerin et al., 2001). The request for tools supporting decisions-making has increased over the last few years. Tools to apply in an effective way ecological data in daily planning cases are viewed as essential in order to conserve a sustainable development in highly pressured urban areas. The lack of proper environmental management systems have so far placed great limitations on the conversion of environmental data into a form that can provide sufficient information for decision-making and public awareness (Adriassens et al., 2004). Integration of economic and ecological information in a spatial context is a valuable approach for strategic policy development and decision-making. Several conceptual frameworks encompassing the science, ways of capturing data and responses, and the human-biophysical dimension of problems, have recently arisen as a focus for interdisciplinary research and analysis for the 21^{st} century (Pedersen et al., 2004).

1.4.1 Land use planning

Demands for land use planning are based on two criteria:

a) The amount of land is fixed: the extension of one land use type inevitably results in the reduction of others.
b) Land is immovable: it is impossible to bring it to another place.

The objective of land use planning is to decide which type of land use will be located at which place. This decision should consider site characteristics such as present status of soils and which soils there will be in future. Demands are driven by socio-economy, technology and ecology factors. Soils should be included into economic, social, technological, health, wellness, and ecological processes by land use planning. For this purpose, information about soils and its contamination has to be worked out in a way that it can be incorporated in the various types of land use planning. It can also serve as planning base. There is a high diversification of land use planning such as object planning (for example traffic way, environment protection area, nature reserve area), subject planning (for example, ground water protection, traffic, housing, recreation, sport), landscape planning, land utilisation planning, area development planning.

The types of land use plans are highly dependent on the national or local regulation. In Italy the most important planning instruments in which soil could be considered are:

Piano Territoriale Regionale (Regional territorial plan). It is a general overview of the regional territory with guidelines and indication on how to manage the most important problems arising.

Piano Territoriale di Coordinamento (Provincial coordination plan of the territory). It is an overview of the planning problems at the provincial scale. The protection of soils is intended as the reduction of soil consumption for urban uses and the reduction of the fragmentation of the ecosystems due to the dispersion of urban sprawl.

Piano Regolatore Generale (Urban planning instrument). It is the most important document for each municipality. It describes how to manage the territory in the future years, with the planned interventions.

Specific sites studies: e.g. acoustic classification, urban plan for traffic and hydrogeological aspects.

1.4.2 Risk management

By providing risk-based information to users, management decisions can be made to reduce the risk to an acceptable level. Such information allows the decision making to be based on the risk the user is willing to assume along with the associated cost for risk reduction (Mays et al., 1997). They can help to answer questions like : What can an end-user do with the assessed risk? Or How can a planner utilize the assessed risk index for a management decision? There are three general cases: (i) The risk index is small and acceptable for implementation of the planned land use; (ii) The risk index is so high that the best decision would be to select another location; (iii) The risk index is high but one may implement an assessment to find an intervention which would result in an acceptable smaller risk with reasonable extra costs. The planners can choose the option in accordance to the risk they are willing to accept. The role of the soil scientist is to present the possible options for consideration and assist the decision-maker in choosing the best management option with acceptable cost and risk (Mays et al., 1997).

1.5 Information systems and tools for urban soil quality management

An essential prerequisite to identify and reduce possible risk for human health is a substantial pool of information about soil contamination in the considered area (Möller et al., 2005). The management of contaminated soils often requires estimates of concentration at unsampled points (Rawlins et al., 2005). The consideration of the spatial component in the description of soil contamination in urban areas can be very important for a more sustainable soil management and planning ((van Groenigen et al., 1997). Due to the high complexity of environmental-soil

datasets, in particular in urban environments, decision makers need reliable support on the effects of the management options they may consider. Tools to apply ecological data in an effective way in daily planning cases are viewed as essential in order to attain a sustainable development in highly pressured areas (Adriassens et al., 2004). The lack of proper environmental management systems have so far placed great limitations on the conversion of environmental data into a form that can provide sufficient information for decision-making and public awareness. Integration of economic and ecological information in a spatial context is a valuable approach for strategic policy development and decision-making. Environmental modelling and its application into GIS environment in urban areas are important to support decision-making process (Pedersen et al., 2004).

1.6 Web mapping

There are a number of terms which describe the electronic illustration of maps on the Internet - among the more commonly used are: Internet Map, Web Map, net-based e-map, Cyber Map etc. Mitchell (2005) also defined three general terms to be used for these types of maps: GIS online is used as a collective term for all types of GIS applications which are available through a network. Internet-GIS narrows this focus to network technology based on specific protocols. In most cases the term can be even further defined by assuming the existence of a specific client (the web browser), leading to the term WebGIS. On the other hand, the terms WebMapping and WebGIS are also used to classify the electronic illustration of maps on the Internet. Web Mapping is derived from the term Web Map although it is more strongly associated with the map production process. Web Mapping includes not only the visual presentation of maps on the Internet, but also simple viewing features such as Zooming, Panning as well as Layering. However, these features are not yet considered "GIS adequate" (Erle et al., 2005; Schral and Tochtermann, 2007). The term WebGIS is used to indicate a users ability to modify attributes beyond the usual Web Mapping functions, as well as to perform additional GIS operations (such as keyword searches, search functions, area and distance measurements). However, since basic GIS analysis functions such as attribute searches are also associated with Web Mapping, it becomes clear that a clear demarcation line between Web Mapping and WebGIS does not exist (Erle et al., 2005; Mitchell, 2005). Web mapping applications are classified into static and interactive maps, depending on their degree of interactivity (Schral and Tochtermann, 2007). Static maps or view-only maps are ready-made maps which are integrated into the website as a stand-alone picture. In the early stages of web mapping development paper copies of maps were scanned and subsequently shown on the Internet in bitmap format. This resulted in a considerable on-line collection of static maps, which is still widely in use today. The introduction of interactive maps provided users with the option to adjust map sections to suit their individual needs, as well as to obtain additional information by panning images, zooming in, activating other map layers or requesting map-related information. At each change the map section is redrawn and displayed with the new information. From a technical view the distinction between static and interactive mapping illustrations is not an easy one to make. For

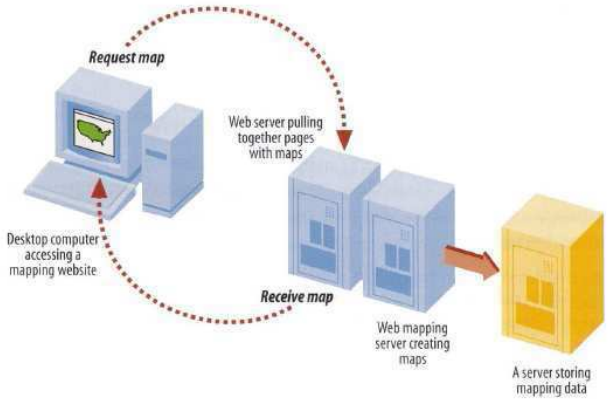


Figure 1.5: Architecture Client - Server

example, a map which has been altered by panning and/or zooming would still be considered a static map if the zooming function merely changed the scale of the map without revealing any new detail ie. information.

1.6.1 Architecture

The client-side server model forms the basis of Web Mapping and WebGIS applications, whereby a web browser becomes the client communicating with the web server. Figure 1.5 illustrates this process: the client requests a map by sending an inquiry to the web server. The web server directs the inquiry to the map server which evaluates the inquiry, searches for the relevant geographical data and generates the corresponding map. The map is then sent to the web server, where it is integrated into a HTML page and sent back to the client browser (Mitchell, 2005; Schral and Tochtermann, 2007).

On the client side, the existence of a web browser is the only prerequisite for using a web mapping application. A standard browser will usually be able to illustrate raster data in GIF, JPG and PNG format. However, vector data ara not yet supported by all browsers. One example is Mozilla Firefox (Version 2.0) which supports the SVG 1.1 specification. Because this type of SVG standard is not yet widely supported by web browsers, vector data does not figure significantly in current web mapping applications. On the server side, a web server (e.g. Apache) along with a specific map server is required. The UMN MapServer is a free and very popular map server which communicates with the web server via a Common Gateway Interface (CGI). Many web mapping applications are based on the UMN MapServer.

1.6.2 User interface of web mapping

Generally speaking, the user interface of web mapping applications consists of the following components (figure 1.6):

- **Main Map**
  The basic component of every application. It contains one or more layered raster or vector graphics as well as additional components placed into the map.

Figure 1.6: Most important components of Web Mapping Application.

- **Overview Map**
  Displays the main map (usually showing the full geographic dimensions) in the form of a smaller navigable reference map and highlights the current view portion of the main map. The purpose of this map is to assist the users orientation, allowing for a good overview of the maps at hand.
- **Pan/Zoom Bar**
  Includes panning arrows as well as a zoom tool with a slider for changing zoom levels.
- **Layer Overview**
  Lists all available map layers along with an option to turn layers on or off.
- **Toolbar**
  Contains buttons and menu options for activating various (GIS) functions (e.g. Navigation, Analysis, Queries and Printing).
- **Scale Bar**
  Shows the current scale in form of a bar, description field or check box.
- **Legend**
  Explains the colours and symbols used in the map, often in conjunction with the layer overview.

With the growth of the Internet and the growing popularity of web mapping applications the concept of interactivity has become a fundamental component in the development and usability of mapping applications (Schral and Tochtermann, 2007). Critical to this development is the ability to navigate around a map, allowing the user to adjust the map by using Drag&Drop per mouse click. By clicking on the panning arrows the map can also be panned in predefined increments. Changing the zoom level of a map can be done in a variety of ways: clicking on the + or button, double-clicking on the map, using the mouse to open a zoom box, moving of zoom slider or mouse wheel. Some web mapping applications also offer panning and zoom navigation options using the keyboard. Often the user can also change the view of the currently selected map portion in the overview map (by mouse click or Drag&Drop), which will also

change the main map accordingly. In the same cases, the overview map is updated along with changes made to the main map. In the layer overview, interactivity includes the ability to turn layers on and off by means of check boxes or buttons, and to combine layers into one main layer. Toolbar functions represent varying degrees of interactivity, including the already mentioned pan/zoom functions as well as options related to printing, querying, object selection, distance measurements and getting directions. Two additional interactive features in web mapping applications are represented by cursors showing the current ground location, and individually adjusted map sizing. Some web mapping applications also offer users the ability to make queries about geographically referenced objects or obtain more information on other items, thereby creating a highly interactive environment. All of the above-mentioned features contribute to the interactive nature of a web mapping application. The increasing trend towards Web 2.0 and AJAX has also resulted in noticeable interactivity improvements in the web mapping area. One of the highlights in this area is the asynchronous data transfer through the XMLHttpRequest object, as it allows websites to be refreshed in the background instead of having to be re-loaded after every modification. Because of this technology, a web mapping application is able to execute a users command in a fairly short time period, as the necessary steps can be completed in the background. As a result, the usability of interactive web mapping applications is approaching the features of classic Desktop(GIS) applications (Mitchell, 2005; Schral and Tochtermann, 2007).

Aim

The aim of the present study was to to design and to set up a simple and small Soil Information System (SIS) for municipalities and local authorities in order to include the evaluation of human health risk for soil quality management into municipal land use planning processes. The SIS has to:

- Make complex scientific data available in daily planning processes;
- Be simple to maintain and update;
- Be cost affordable;
- Allow the interaction between differently involved stakeholders.

Chapter 2

Materials and Methods

2.1 Test Area

The tool was implemented in the municipality of Grugliasco in the hinterland of the large industrial town or Torino in North West Italy. The territory of the municipality is characterised by a regular morphological flat surface with a weak southeast slope. It is located in an alluvial plain. The soils have no limitation to agriculture, being very fertile, deep, structured and well drained. During the urban sprawl between 1950 and 1970, the population increased six-fold in size with the development of the neighbouring manufacturing industry. The agricultural areas diminished and were fragmented to satisfy the needs for housing and traffic spaces. Today the area shows a mosaic of agricultural and residential/ industrial/ services land uses. Soil data and information were taken from a soil survey carried out in the municipality (Poggio, 2007). The selection of sampling points was based on available metadata and maps organised in a GIS project (ArcMap 9.2 ESRI). Fifty-six sampling points were predefined using a regular sampling grid. Additional information was recorded at each sampling site: degree of urbanisation, land use, vegetation, soil description and potential sources of pollution.

2.1.1 Dataset preparation

The list of secondary information available is in (figure 2.1 on the facing page). The datasets and the maps have been organised in a GIS project. Attention was paid to homogenisation and harmonisation of data. Datasets were converted and adapted to a common form, analogue maps were digitised. Homogenisation of coordinates systems has been implemented and conversion tools and procedures were elaborated in ArcMap software (table 2.1 on page 20). All the dataset were converted to Gauss-Boaga projection system (figure 2.2 on page 21), the most used in Italian maps. The main characteristics of the projection systems most used in Italy are summarised in table 2.2 on page 20.

	Scale	Coordinate system (original)	Projected in Gauss Boaga	Source
Aerial Photo				(Regione Piemonte, 2000d)
Climate data				(Regione Piemonte, 2000c)
Corine Land Cover	1:100000	ED50	Yes	(Regione Piemonte, 2000b)
Digital Terrain Model	1:10000	Gauss Boaga		(Regione Piemonte, 1995b)
Geological map	1:25000	Gauss Boaga		(Comune di Grugliasco, 1980)
Historical urbanisation	1:25000	Gauss Boaga		(Comune di Grugliasco, 2000b)
Orthophoto	1:10000	Gauss Boaga, ED50		(Regione Piemonte, 1990c)
Raster Topographic maps	1:10000	Gauss Boaga		(Regione Piemonte, 1990b)
Sampling sites (Site and soil description, Chemical analyses, HM contents)		ED50	Yes	Present study
Shape file of Piano regolatore	1:10000 1:5000 1:2000	Gauss Boaga		(Comune di Grugliasco, 2002)
Soil capability	1:100000	ED50	Yes	(Regione Piemonte, 2000a)
Soil capability	1:50000	ED50	Yes	(Regione Piemonte, 2005)
Soil carbonates (top & subsoil)	1:50000	ED50	Yes	(Regione Piemonte, 2005)
Soil map	1:50000	ED50	Yes	(Regione Piemonte, 2005)
Soil permeability	1:50000	ED50	Yes	(Regione Piemonte, 2005)
Soil pH (top & subsoil)	1:50000	ED50	Yes	(Regione Piemonte, 2005)
Soil protection for groundwater	1:50000	ED50	Yes	(Regione Piemonte, 2005)
Soil stoniness (top & subsoil)	1:50000	ED50	Yes	(Regione Piemonte, 2005)
Soil texture (top & subsoil)	1:50000	ED50	Yes	(Regione Piemonte, 2005)
Soil use	1:25000	Gauss Boaga		(Regione Piemonte, 1990a)
Survey of urban green	1:10000	Gauss Boaga		(Comune di Grugliasco, 2002)
Trafic	1:10000	Gauss Boaga		Provincia di Torino.
Vector topographic maps	1:10000	WGS84	Yes	(Regione Piemonte, 1995a)

Figure 2.1: Secondary data

Table 2.1: Coordinates conversion.

From ED50 to Gauss Boaga	From Gauss Boaga to ED50
INPUT	INPUT
PROJECTION UTM	PROJECTION TRANSVERSE
UNITS METERS	UNITS METERS
DATUM EUR_M	DATUM MOD
ZONE 32	PARAMETERS
PARAMETERS	0.9996
OUTPUT	9 0 0
PROJECTION TRANSVERSE	0 0 0
UNITS METERS	1500000
DATUM MOD	0.0
PARAMETERS	OUTPUT
0.9996	PROJECTION UTM
9 0 0	UNITS METERS
0 0 0	DATUM EUR_M
1500000	ZONE 32
0.0	PARAMETERS
END	END

Table 2.2: Characteristics of datum used in Italian cartography.

	Datum		
	Roma40	ED50	WGS84
Ellipsoid	Hayford	Hayford	WGS84
Orientation	Monte Mario	Medium European	Geocentric
Reference longitude	122708,4 E	Greenwich	Greenwich
Reference latitude	Equator	Equator	Equator
Zones	West, East 630 wide	32, 33 and partly 34	32, 33 and partly 34
False easting	1500 Km W zone 2520 E Zone	Always 500 km	Always 500 km
Scale factor	0.9996	0.9996	0.9996

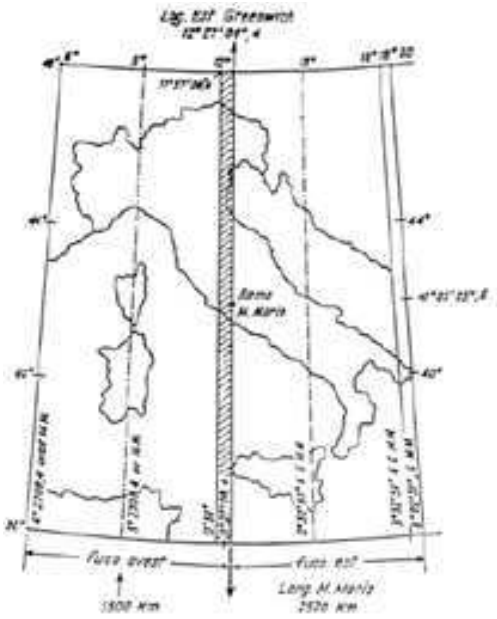


Figure 2.2: Gauss-Boaga projection system.

Coordinates system

A geographic coordinate system (GCS) uses a three-dimensional spherical surface to define locations on the earth. It includes an angular unit of measure, a prime meridian, and a datum (based on a spheroid). A point is referenced by its longitude and latitude values. Longitude and latitude are angles measured from the earth's centre to a point on the earth's surface. The shape and size of a geographic coordinate system's surface is defined by a sphere or spheroid. While a spheroid approximates the shape of the earth, a datum defines the position of the spheroid relative to the centre of the earth. A datum provides a frame of reference for measuring locations on the surface of the earth. It defines the origin and orientation of latitude and longitude lines. A local datum aligns its spheroid to closely fit the earth's surface in a particular area. A point on the surface of the spheroid is matched to a particular position on the surface of the earth. This point is known as the origin point of the datum. The coordinates of the origin point are fixed, and all other points are calculated from it. The coordinate system origin of a local datum is not at the centre of the earth. Because a local datum aligns its spheroid so closely to a particular area on the earth's surface, it's not suitable for use outside the area for which it was designed. The European Datum of 1950 (ED 1950) is a local datum, created for use in Europe. A projected coordinate system is defined on a flat, two-dimensional surface. Unlike a geographic coordinate system, a projected coordinate system has constant lengths, angles, and areas across the two dimensions. A projected coordinate system is always based on a geographic coordinate system that is based on a sphere or spheroid. In a projected coordinate system, locations are identified by x,y coordinates on a grid, with the origin at the centre of the grid. Each position has two values that reference it to that central location. One specifies its horizontal position and the other its vertical position. The two values are called the x-coordinate and y-coordinate. A

Table 2.3: Rules for site selection.

24	25	10	11	12
23	9	2	3	13
22	8	1	4	14
21	7	6	5	15
20	19	18	17	16

map projection uses mathematical formulas to relate spherical coordinates on the globe to flat, planar coordinates. Different projections cause different types of distortions. A map projection systematically projects locations from the surface of a spheroid to representative positions on a flat surface using mathematical algorithms, creating one or more points of contact called point (or line) of tangency.

2.1.2 Sampling campaign

The principles followed for the determination of the sampling location were:

- covering the whole Grugliasco territory
- covering all different land uses
- more intensive sampling where soil is more fragmented, as in the historical centre

The selection of sampling points was based on secondary data and maps organised in a GIS project (ArcMap 9.2 ESRI). In Grugliasco case study, 54 points were selected using a judgemental selection of sites within a predefined regular grid of 500x500m covering the whole territory of the municipality. Each 500m square was further divided in 25 squares (100x100m), used to guide the selection of the sampling sites. A grid of 250x250m, further divided in 25 squares 50x50m, was used to increase the density of the sampling points in the centre of the municipality, where soils are more fragmented and, possibly, more heterogeneous (figure 2.3 on the facing page).

If possible, the sampling site was selected in the centre of the wider grid. If the soil was unavailable in the central point, the site was moved in one of the neighbour cells according to the scheme represented in table 2.3 where numbers indicate the priority for the location of sampling sites, 1 being the highest priority and 25 being the lowest. The predefined sampling sites were moved if soil was unavailable for sampling. The new coordinates were recorded with the help of a GPS (Global Position System) device. During the sampling additional information were collected, namely morphology, urbanisation, land use, vegetation, soil description and potential sources of pollution, using the form previously presented. Soil was sampled in two depths; topsoil in (0-10cm) and subsoil (10-20cm). The samples were composite of 5 subsamples collected in 4 m2 following a cross shape. In two areas a denser sampling was used in order to get information on the variability at small scale. In these areas six samples were collected on a surface of 1 hectare.

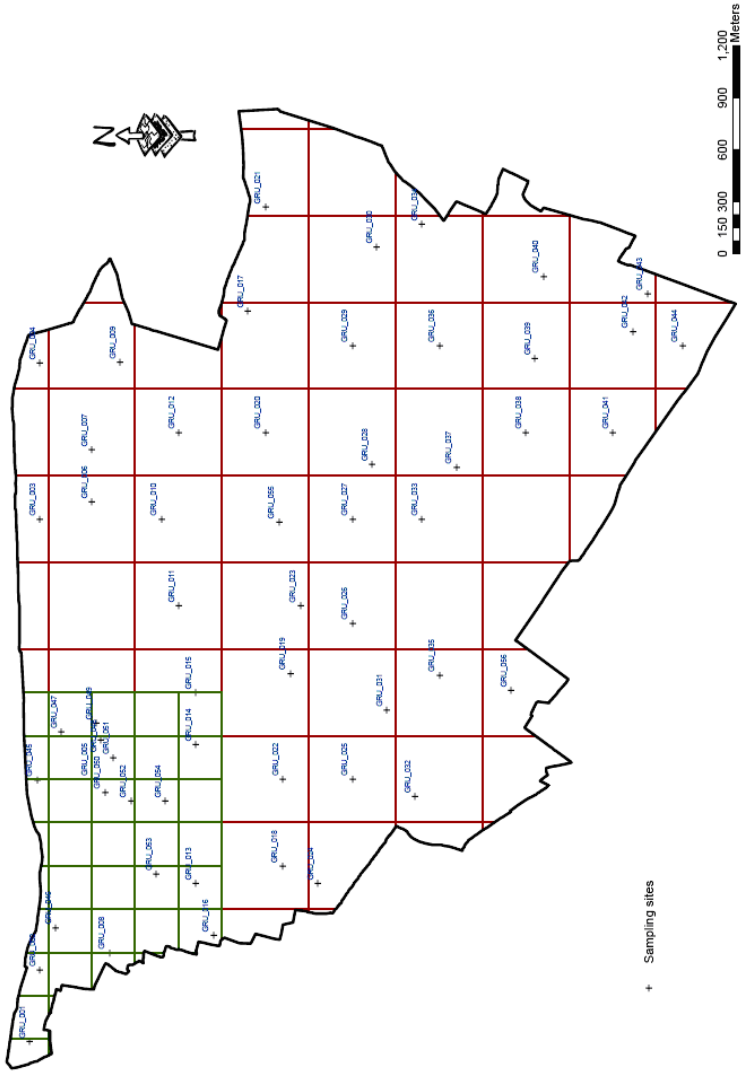


Figure 2.3: Sampling strategy and sampled sites.

Table 2.4: Analytical methods used.

Measured parameter	Method
pH	CaCl2 solution, 1:5 soil:solution ratio (ISO10390, 1994)
Carbonates	Dietrich Fruhling calcimeter
Total C and N	CE Instr. NA2100 elemental analyser (ISO10694, 1995)
Organic matter content	OM = 1.72 TotC
Cation Exchange Capacity	$BaCl_2$ at pH 8.1 (ISO13536, 1995)
Exchangeable cations	$BaCl_2$ at pH 8.1 (ISO13536, 1995)
Particle size distribution	hydrometer method (Gee and Bauder, 1986)
Pseudototal content	aqua regia (HCl/HNO_3, 3:1 solution)
Plant bioavailable fraction	DTPA 0.005 M + TEA 0.01M at pH 7.3 (Lindsay1969)
Human bioaccessible fraction	SBET (Ruby et al., 1996; Yang et al., 2003)
Easy mobilisable fraction	Acid acetic 0.11M/l (Davidson et al., 1998)

2.1.3 Analytical determinations

All soils were dried at room temperature, disaggregated and sieved through a 2mm plastic sieve. An analytical control scheme was implemented with duplicates, reference materials and reagent blanks. Each sample was characterised for its general physico-chemical parameters. Each sample was characterised with general parameters as pH, organic matter content and particle size distribution. Metals were analysed by flame atomic absorption spectrometer in various extracts: aqua regia (HCl/HNO_3, 3:1 solution), DTPA (Lindsay and Norwell, 1969) and modified PBET (Oomen et al., 2003; Yang et al., 2003). The methods used are summarised in table 2.4.

2.2 Database

Unlike many other kinds of data handled routinely by modern information systems, geographical data are complicated because they refer to the position. The internal and external topological connections of the phenomena are recorded. The relational database is widely used for environmental purposes. In a relational database the data are stored in simple records (tuples) that are sets of fields each containing an attribute. Tuples are grouped together in two-dimensional tables, known as relations. Each table or relation is usually a separate file. Identification codes are used as unique keys to identify the records in each file. Data are extracted from the database through a user defined relation appropriated for the query. The new table is constructed using methods of relational algebra, rules of Boolean logic and mathematical operations (Burrough and McDonell, 2000). In Grugliasco a database system was established in order to organise the data and to automatize and simplify their management. All the data from soil survey and analytical determination were included. Different input masks were created to facilitate and organise the input of data. Reports were created in order to present the information collected with the sampling forms.

The tools used were:

- MySQL 5.0 Server for setting up the application
- PHPMySQL-Admin for web-based management and updating

2.2.1 MySQL

MySQL is a multithreaded, multi-user SQL database management system (DBMS) which has more than 11 million installations. The program runs as a server providing multi-user access to a number of databases. MySQL was owned and sponsored by a single for-profit firm, the Swedish company MySQL AB, now a subsidiary of Sun Microsystems, which holds the copyright to most of the codebase. The project's source code is available under terms of the GNU General Public License, as well as under a variety of proprietary agreements. MySQL is popular for web applications and acts as the database component of the LAMP, BAMP, MAMP, and WAMP platforms (Linux/BSD/Mac/Windows-Apache-MySQL-PHP/Perl/Python), and for open-source bug tracking tools like Bugzilla. Its popularity for use with web applications is closely tied to the popularity of PHP, which is often combined with MySQL. PHP and MySQL are essential components for running popular content management systems. MySQL is written in C and C++. The SQL parser uses yacc and home-brewed lexer. MySQL works on many different system platforms, including AIX, BSDi, FreeBSD, HP-UX, i5/OS, Linux, Mac OS X, NetBSD, Novell NetWare, OpenBSD, eComStation , OS/2 Warp, QNX, IRIX, Solaris, SunOS, SCO OpenServer, SCO UnixWare, Tru64, Windows 95, Windows 98, Windows ME, Windows NT, Windows 2000, Windows XP, and the 32-bit version of Windows Vista. Libraries for accessing MySQL databases are available in all major programming languages with language-specific APIs. In addition, an ODBC interface called MyODBC allows additional programming languages that support the ODBC interface to communicate with a MySQL database, such as ASP or ColdFusion. The MySQL server and official libraries are mostly implemented in ANSI C/ANSI C++. To administer MySQL databases one can use the included command-line tool (commands: mysql and mysqladmin). Also downloadable from the MySQL site are GUI administration tools: MySQL Administrator and MySQL Query Browser. Both of the GUI tools are now included in one package called tools/5.0.html MySQL GUI Tools. In addition to the above mentioned tools developed by MySQL AB, there are several other commercial and non-commercial tools available. phpMyAdmin is a free software webbased administration interface implemented in PHP.

2.2.2 PHPMySQL-Admin

phpMyAdmin is an open source tool written in PHP intended to handle the administration of MySQL over the Internet. Currently it can create and drop databases, create/drop/alter tables, delete/edit/add fields, execute any SQL statement, and manage keys on fields. The software, which is currently available in 54 different languages (languages list), is still being maintained by The phpMyAdmin Project and it is cross-platform.

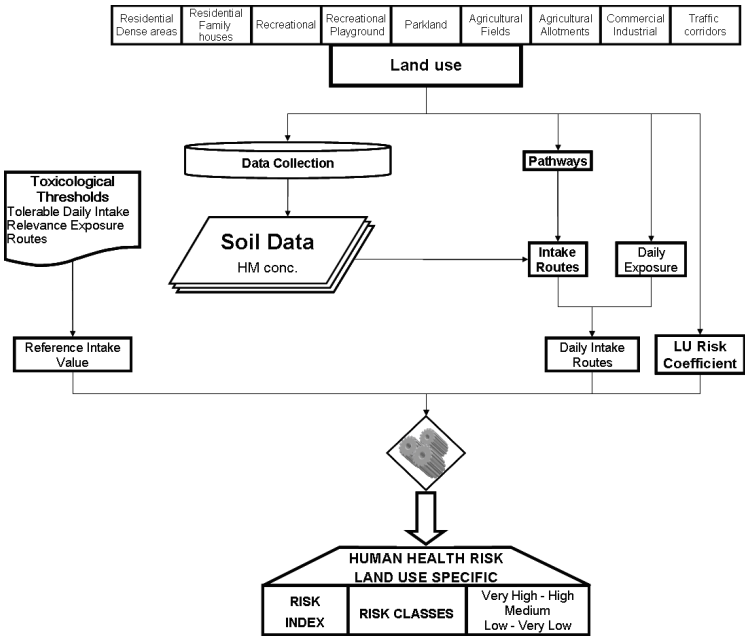


Figure 2.4: Flow chart of HHRE method

2.3 HHRE algorithm and methods

The Human Health Risk estimation (HHRE) method was developed during the Interreg IIIB project TUSEC-IP (Techniques For Urban Soil Evaluation in City Region - Implementation Procedures). It is extensively described and discussed in Poggio et al. (2006), Poggio (2007) and Poggio et al. (2008). The most important features relevant to the present study are summarised in this section. The HHRE method is a land-use based method for the evaluation of human health risks arising from heavy metal contaminated urban soils, addressing in particular the influence of planning measures and land use changes on such risks. The method accounts for the role of the bioavailability of soil metals as a key factor in health risk assessment (figure 2.4). In order to increase the method applicability a step-by-step procedure and a calculation-tool were elaborated. The method can be used to identify areas in which the current or planned land use is associated with unacceptable health risks and to optimise the allocation of a certain land use to areas which are best suited and where the risks are minimum. A risk index is calculated for the evaluated area, considering the land use, as sum of the risks from different exposure pathways and different heavy metals. For those areas where risk is identified as unacceptable, alternative planning or management options should be defined to achieve a maximum risk reduction in a cost effective way. The HHRE method was implemented for:

a) Continuous surface mapping: a procedure for spatial evaluation of risk results into a GIS system was developed and implemented in a AML routine written on purpose (figure 2.5).
b) Site-by-site calculation: the calculation tool site-by-site is implemented in an excel file, using a VBA routine in order to perform batch calculations. The tool is described in section 3.2.2 on page 39.

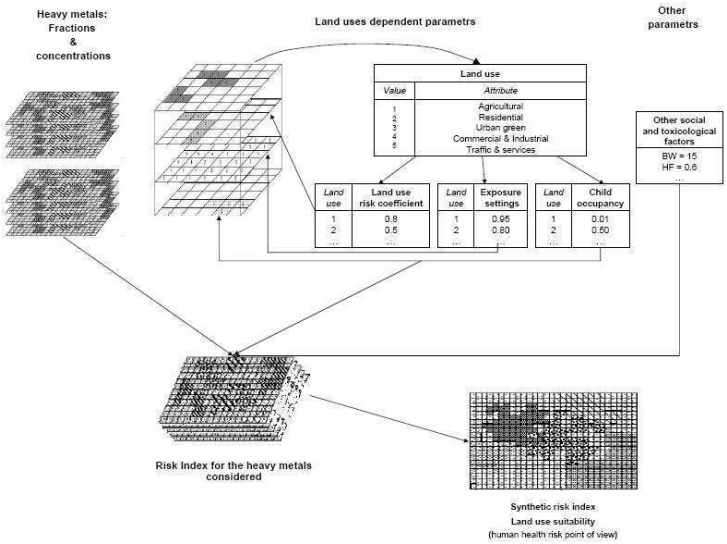


Figure 2.5: GIS implementation of HHRE method (modified from Poggio, 2007)

2.4 Web Planning tool

The tool was implemented using the following software systems:

a) Web Server: Apache (2.2.8)

b) Map Server: UMN mapserver 4.10

c) Graphical interface: p.mapper 3.1

2.4.1 Web Server

The Apache HTTP Server, commonly referred to simply as Apache, is a web server notable for playing a key role in the initial growth of the World Wide Web. Apache was the first viable alternative to the Netscape Communications Corporation web server (currently known as Sun Java System Web Server), and has since evolved to rival other Unix-based web servers in terms of functionality and performance. It is often said that the project's name was chosen for two reasons:

1) out of respect for the Native American Indian tribe of Apache, well-known for their endurance and their skills in warfare, and
2) due to the project's roots as a set of patches to the codebase of NCSA HTTPd 1.3 - making it "a patchy" server although the latter theory is a lucky coincidence

Apache is developed and maintained by an open community of developers under the auspices of the Apache Software Foundation. The application is available for a wide variety of operating systems, including Unix, FreeBSD, Linux, Solaris, Novell NetWare, Mac OS X, Microsoft Windows, OS/2, TPF, and eComStation. Released under the Apache License, Apache is characterized as free software and open source software. Since April 1996 Apache has been the most popular HTTP server on the World Wide Web. However, since November 2005 it has experienced a steady decline of its market share, lost mostly to Microsoft Internet Information

Services. As of April 2008 Apache served 50.42% of all websites. Apache supports a variety of features, many implemented as compiled modules which extend the core functionality. These can range from server-side programming language support to authentication schemes. Some common language interfaces support mod_perl, mod_python, Tcl, and PHP. Popular authentication modules include mod_access, mod_auth, and mod_digest. A sample of other features include SSL and TLS support (mod_ssl), a proxy module, a useful URL rewriter (also known as a rewrite engine, implemented under mod_rewrite), custom log files (mod_log_config), and filtering support (mod_include and mod_ext_filter). Apache is primarily used to serve both static content and dynamic Web pages on the World Wide Web. Many web applications are designed expecting the environment and features that Apache provides. Apache is the web server component of the popular LAMP web server application stack, alongside MySQL, and the PHP/Perl/Python programming languages. Apache is used for many other tasks where content needs to be made available in a secure and reliable way. One example is sharing files from a personal computer over the Internet. A user who has Apache installed on their desktop can put arbitrary files in the Apache's document root which can then be shared. The server can be easily configured with a text file were the various option can be set.

2.4.2 Mapserver

MapServer is an open source development environment for building spatially-enabled internet applications. It can run as a CGI program or via Mapscript which supports several programming languages. MapServer was developed by the University of Minnesota. MapServer was originally developed with support from NASA, which needed a way to make its satellite imagery available to the public. MapServer supports Open Geospatial Consortium (OGC) standards, including Web Map Service (WMS) and Web Feature Service (WFS). MapServer works with PostgreSQL and its PostGIS extension, MySQL and its MyGIS extension, and supports proprietary GIS formats including ESRI's Shapefile format. MapServer uses OGR and GDAL libraries to translate files from one file format to another, and libproj to translate between coordinate systems and datums. MapServer exists in Common Gateway Interface (CGI) form as well as MapScript, an extension interface for scripting and customization in PHP, Python, Perl, Ruby, Java, and C#.

Mapfile

The UMN mapserver can be configured through a map file, text file were the different elements and layers are defined and described following the specific language (Kropla, 2005). A brief description of the possible structure of objects in a map file is illustrated in figure 2.7

2.4.3 p.mapper 3.1

Numerous free web mapping client applications are existing in the web. Each has different features for end-users usability and maps visualisation. A comparison among same of most promising applications was carried out. Table XXX is summarising some of the characteristics.

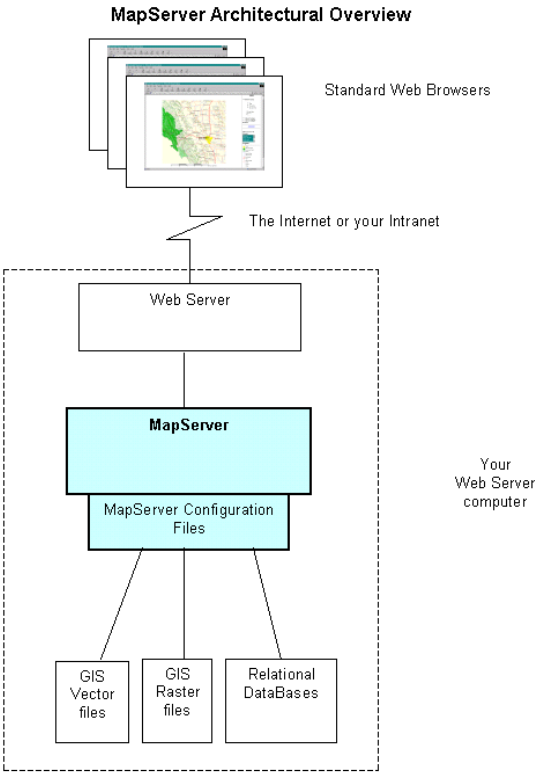


Figure 2.6: Diagram of Minnesota Mapserver

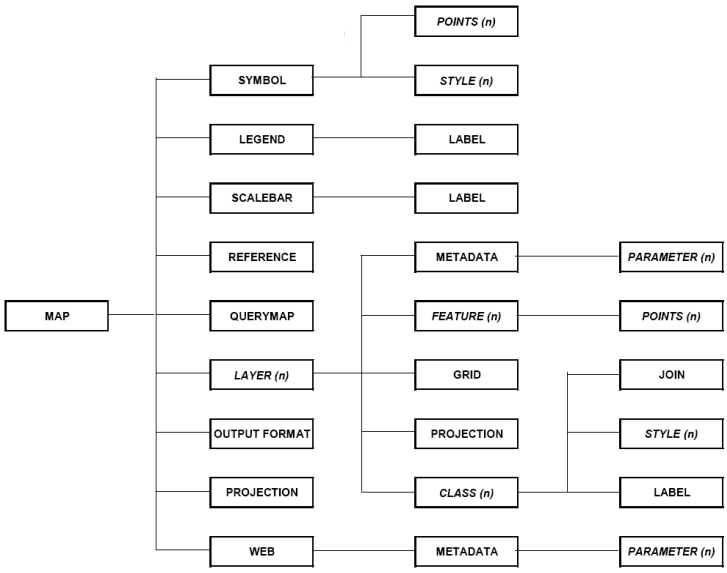


Figure 2.7: Structure of mapfile

Table 2.5: Comparison of Web Mapping Applications

	CartoWeb	Chamaleon	ka-Map	Mapbuilder	p.mapper
Version	3.3.0	2.4.1	1.0	1.0.1	3.1.0
License	GNU GPL	X11	MIT	GNU LGPL	GNU GPL
Overview map	✓	✓	✓	-	✓
Layer overview	✓	✓	✓	✓	✓
Legend	✓	✓	✓	-	✓
Scale Bar	✓	-	✓	✓	✓
Zoom Bar	-	-	-	-	✓
Pan Navigation on map edge	✓	✓	-	-	-
Zooming with mouse wheel	-	-	✓	-	✓
zoomBox	✓	✓	✓	✓	✓
Panning with overview map	✓	✓	✓	-	✓
Zooming - Panning with keyboard	-	-	-	-	✓

Out of the comparison and considering the particular needs for a Soil Web mapping application (Dobos et al., 2006) p.mapper (3.1) was selected. The p.mapper framework is intended to offer broad functionality and multiple configurations in order to facilitate the setup of a MapServer application based on PHP/MapScript. Functions included are:

- DHTML (DOM) zoom/pan interface (no use of frames)
- Zoom/pan also via keyboard keys, mouse wheel, reference map, slider
- Query functions (identify, select, search)
- Fully featured attribute search, including suggest, select boxes, etc.
- Query results display with database joins and hyperlinks
- Pop-up identify when moving with mouse over map
- Flexible layout of query results via JavaScript
- Support for point layers with data in a database supported by PEAR framework
- Print functions: HTML and PDF
- Distance and area measurement function
- HTML legends and various display styles of legend and layers/TOC
- Very flexible configuration of functions, behaviour and layout
- Multilingual user interface
- Adding points of interest with labels on map
- Pop-up windows as DHTML elements
- Fully XHTML 1.0 Strict compliant
- Plugin API to add custom functionality
- Various plugins: layer transparency, query result export, and more

Configuration

p.mapper can be customised through a set of options that can be changed in the available files. The most important are:

a) `config.ini` in this file all general aspects are defined, e.g. layers to be visualised, grouping of layers, etc;
b) `php_config.php` in this file the options related to php calls can be customised;
c) `js_config.php` in this file to javascript can be fine-tuned, as well as the options for the personalisation of the GUI.

2.4.4 XAMPP

In order to make the developed application portable and usable from a USB device, the XAMPP tool was used to set up the web server and database environments. The UMN mapserver was added to the traditional XAMPP package in order to get a full working web mapping application that can work also locally in different operative systems. The behaviour of PHP was customised to better integrate with mapserver and p.mapper requests.
XAMPP is a free, cross-platform web server, consisting mainly of the Apache HTTP Server, MySQL database, and interpreters for scripts written in the PHP and Perl programming languages. XAMPP's name is an acronym for:

- X (meaning cross-platform)
- Apache
- MySQL
- PHP
- Perl

The program is released under the GNU General Public License and acts as a free, easy-to-use web server capable of serving dynamic pages. XAMPP is available for Microsoft Windows, Linux, Sun Solaris, and Mac OS X, and is mainly used for web development projects. Officially, XAMPP's designers only intended it for use as a development tool, to allow website designers and programmers to test their work on their own computers without any access to the Internet. To make this as easy as possible, many important security features are disabled by default. In practice, however, XAMPP is sometimes used to actually serve web pages on the World Wide Web. A special tool is provided to password-protect the most important parts of the package. XAMPP also provides support for creating and manipulating databases in MySQL and SQLite among others.

Chapter 3

Results and Discussion

The framework of the proposed tool is presented in Figure 1. Its structure is described in more details in the following paragraphs dealing in particular with the two fundamental part of a Soil Information System (Bartsch et al., 1997; Dobos et al., 2006):

a) database;

b) mapping application.

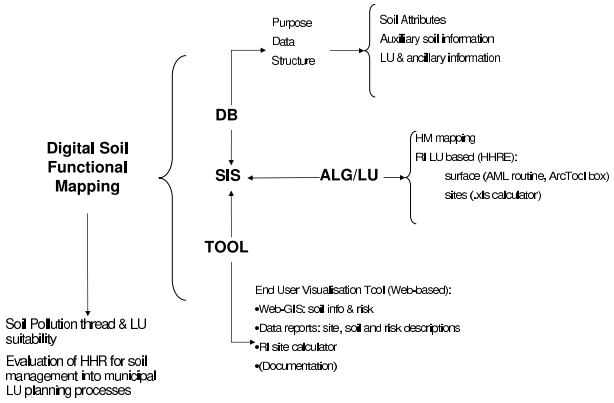


Figure 3.1: Structure of the designed tool.

3.1 Database

Simple, easy manageable databases for storing soil related data. The Database part of the developed Soil Information System was composed by two databases with commons keys to establish the needed relationships:

1) soil and site information
   - Soil attributes
   - Auxiliary soil information
   - Land use and ancillary soil information
2) health risk information

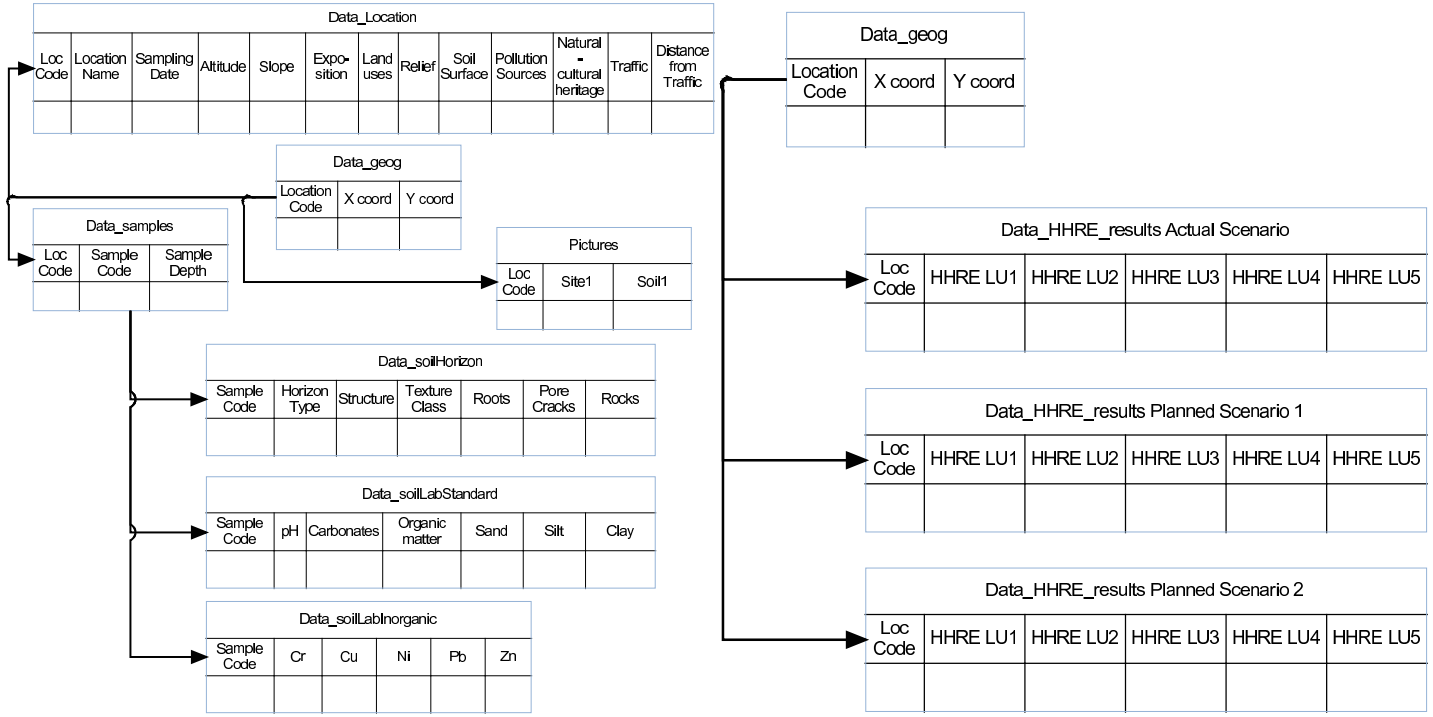
3.1.1 Soil and Site

The first database was designed and developed in order to store all the information related to sampled sites, soil profiles and the ancillary data provided by secondary sources. The structure of this database is presented in figure 3.2a. The coordinates of each site are stored in a separated table together with the label of each suite. The label is a unique code used as primary key in all tables with soil information. This table is linked to a sample table where the labels of the different samples are linked to the site key. Each site can have more samples. each sample label is a unique code and a sample can belong to only a site. These minimum required structure is recommended by Finke et al. (2001) when dealing with soil databases. Various tables related to site or samples were created.

A table storing pictures of the sites was prepared. The table stores only the relative link to the files that are archived locally in order to avoid database file with huge size. All information collected during sampling campaign are stored in two tables: (i) for soil profile description, and (ii) for site description As in most cases the information collected are coded Look Up Tables (LUT) are created in order to provide more detailed explanation to the different options. The information derived from the laboratory analysis of the collected soil samples are stored in separated tables and are linked to sites through previously established relations and keys.

3.1.2 Health risk information

The second database was designed in order to store the results of the HHRE method for all the considered sites (figure 3.2b). The keys of the sites are the same as in the previous database. These information could be stored in a table of the first database. however a second database was generated in order to provide a more flexible approach to the application and to data protection, allowing the possibility to use the two database separately for different purposes. The design database consist of two tables: (i) storing site geographical information and (ii) storing human health risk evaluation results for the considered sites for different land uses.



(a) Soil and sites

(b) HHRE

Figure 3.2: Developed Databases

Figure 3.3: Web Planning tool.

3.2 Web Planning tool

An End User Visualisation Tool (Web-based) was developed (figure 3.3) and it included:
a) Web-GIS: soil information and risk estimation;
b) Data reports: site, soil and risk descriptions with direct access to the developed database;
c) Short Documentation about the algorithms used and instructions for the tool;
d) Risk Index (RI) site calculator as stand alone downloadable tool.

The tool was developed in order to make easier access to complex scientific soil information for a more informed decision making in the planning process. The typical end-user for this application is a municipal planner or an expert of an environmental agency with none or little experience or knowledge about soil, soil pollution and soil quality problems. Particular attention was paid to data accessibility, usability and visualisation. All problems related to data quality, uncertainty and (geo)statistical elaboration are not discussed in details in this study. However data quality estimation is behind the data used as example for the development of this application and was exhaustively discussed in other studies (e.g. Poggio et al., 2006; Vrščaj et al., 2006).

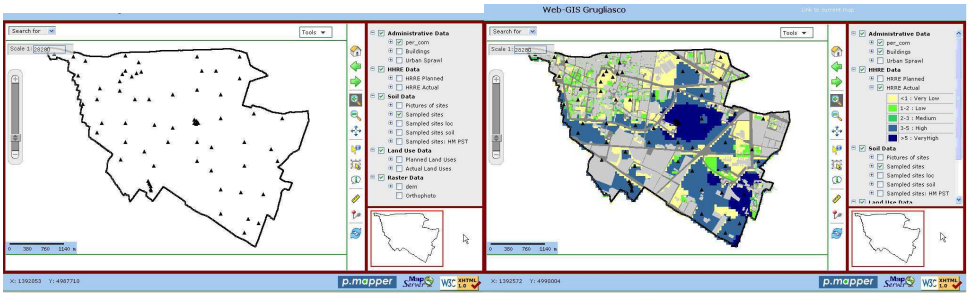
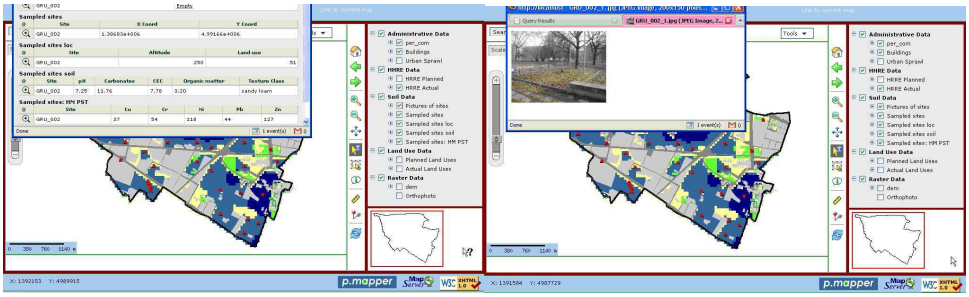


Figure 3.4: GUI of developed Web planning tool.



(a) a (b) b

Figure 3.5: Details of GUI for developed Web planning tool.

3.2.1 WEB-GIS

The developed Soil Web GIS presented an end user map interface (figure 3.4) for navigation, such as pan, zoom and themes controls. The interface can be initialised in various languages (en, it, fr, de). The tool has extensive query possibilities (figure 3.5a) in order to get the soil and site information stored in the database. Results are presented as pop up windows with hyperlinks (figure 3.5b) to picture of the site, detailed topographic maps and data reports.
All layers are queryable, including the raster grids created with ArcGIS routine. The layers shown were selected in order to provide a general description of the test area and to provide information on soils and human health risk levels.
The selected layers were grouped in five categories:

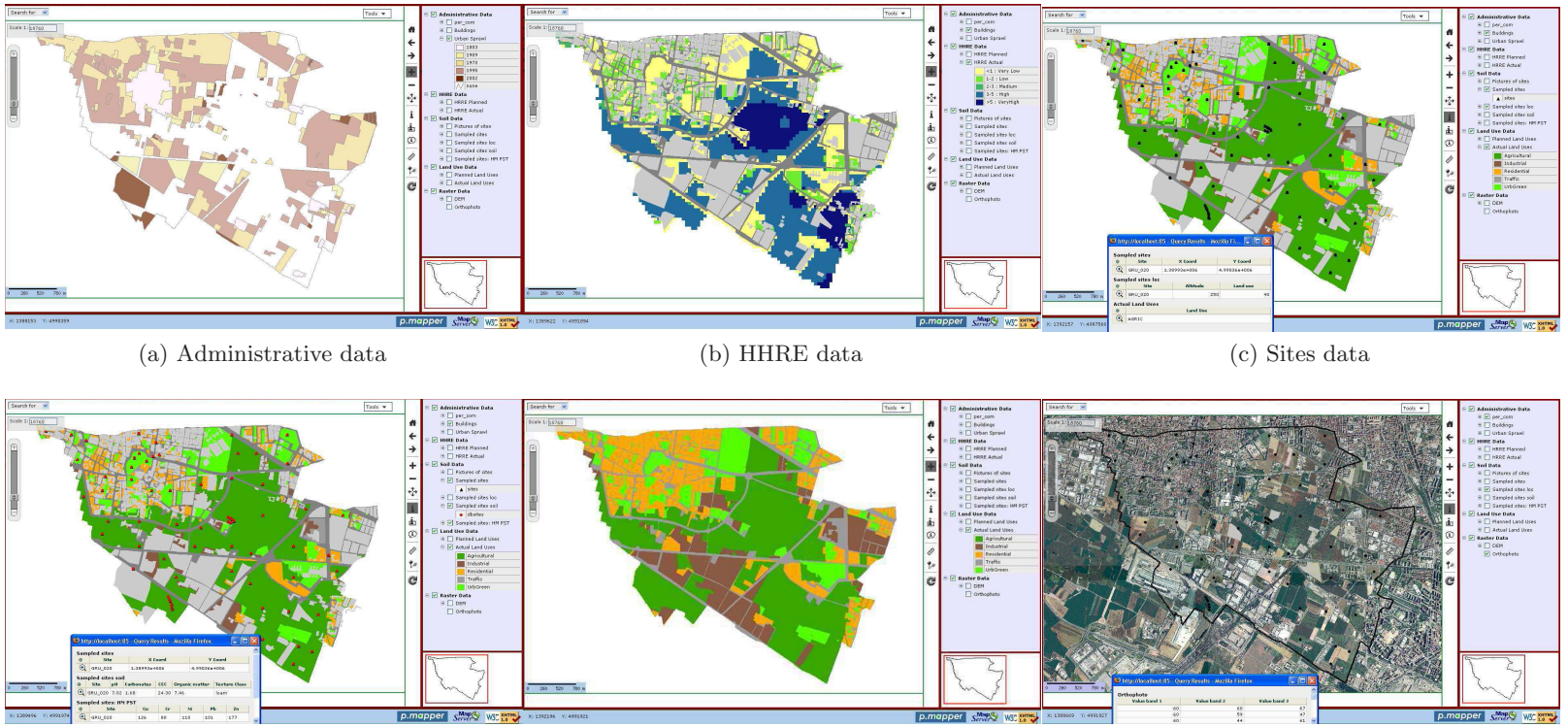
1) *Administrative data* with vector layers describing the borders of the municipality, the built areas and the spatial sprawl on the municipality in the last 150 years (3.6a)

2) *HHRE data* with raster layers representing the results of the HHRE method applied on interpolated concentrations of heavy metals (Poggio, 2007) for the actual land use scenario and for other planned scenarios (3.6b).

3) *Soil data* with point layers of data and information for the sampled sites and with query facilities in order to retrieve data (3.6c, 3.6d)

4) *Land use data* with raster data of land uses scenarios corresponding to the HHRE results (3.6e).

5) *Raster data* with digital elevation models and aerial orthophoto of the test region (3.6f). These layers are separated because of the long time needed for display.



(a) Administrative data (b) HHRE data (c) Sites data

(d) Soil data (e) Land use data (f) Raster data

Figure 3.6: Displayed layers in the web mapping application.

3.2.2 RI site calculator

A tool to easily calculate the risk index for single sites was developed as deliverable of TUSEC-IP project (Poggio et al., 2006). In this study the tool was further modified and integrated in the developed application as stand alone downloadable tool. The method was implemented in an Excel® tool, to facilitate and to expedite the calculations for a possible inclusion in planning and management procedures (figure 3.7). Iterated calculations are possible due to a macro routine in Visual Basic for Application®. The Excel tool enabled site-by-site calculations, giving point information on the risk. With the calculation tool it is possible to get the results of complex algorithm for a bench of locations in a easy way. The tool allows the personalisation of parameters of the algorithm in order to be adapted to the local situation. The results are related to sites, point information where data are collected. It is not possible yet to create a tool that automatically interpolate the point locations in order to get maps of the variable over a certain region. The interpolation is a process that require careful analysis of the results, of the uncertainty and of the quality of the model (Frangi and Richard, 1997; Webster and Oliver, 2001). Automatic wizards and methods are not suitable especially in urban areas where the soil is highly fragmented. therefore the proposed tool is dealing only with site information. The mapping application was set up in order to show interpolated results when available.

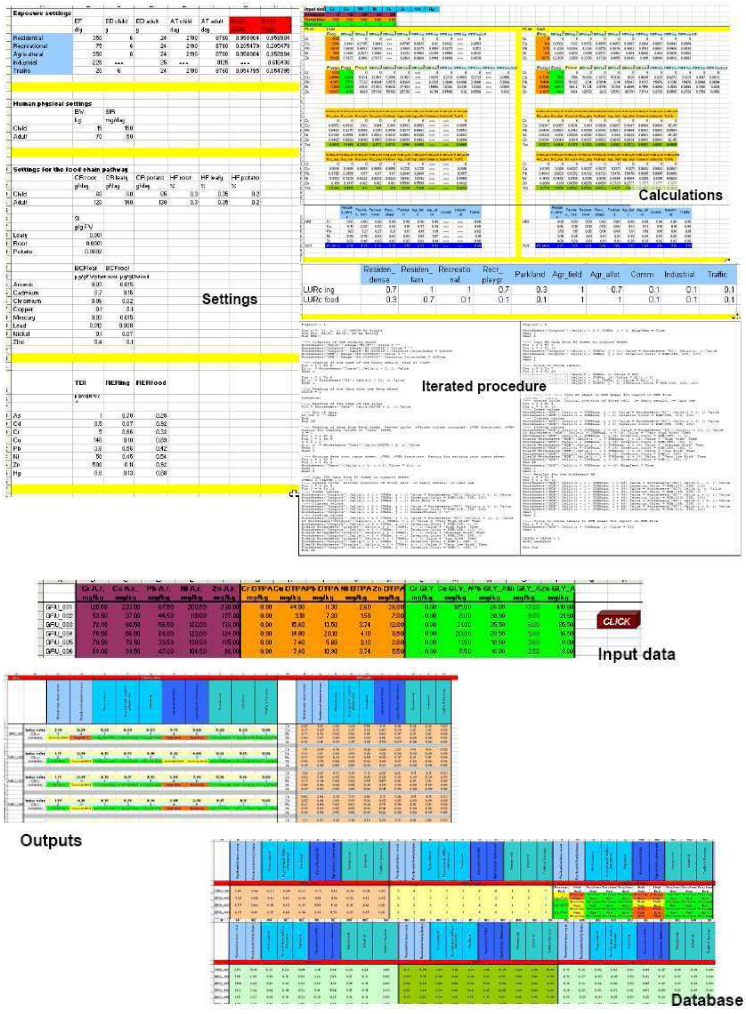
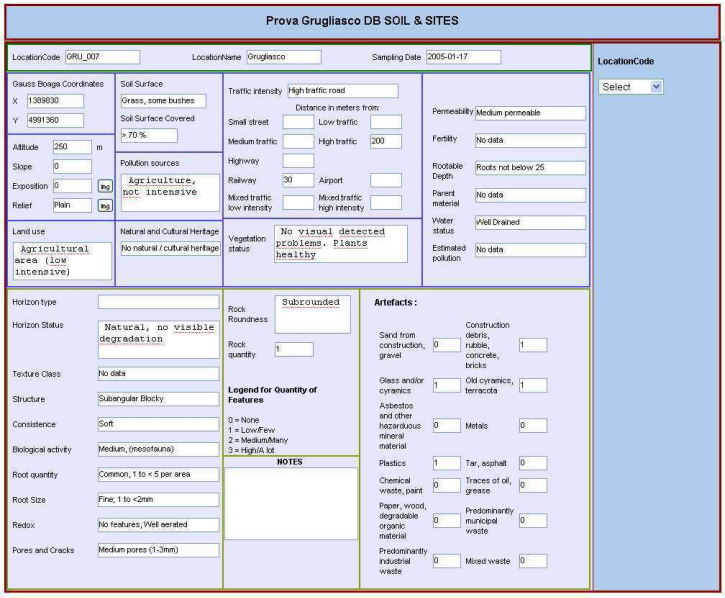


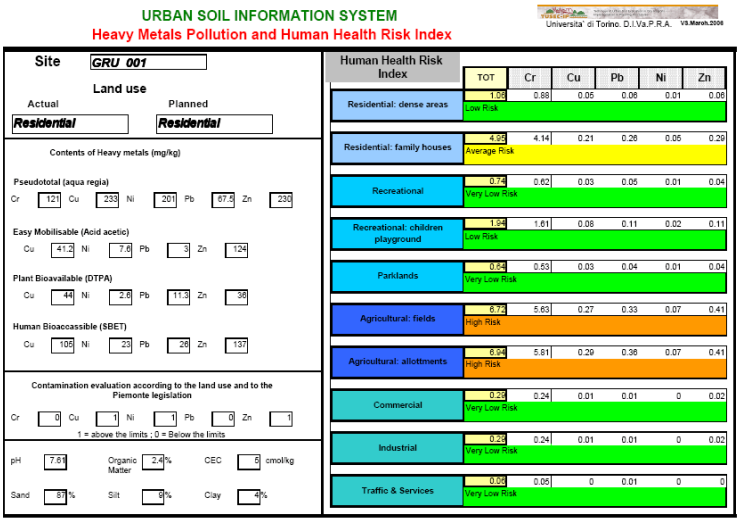
Figure 3.7: Risk index calculation tool.

3.2.3 Data reports

Various information and data were stored in the database. A web interface for each of the designed database was developed in order to query the database outside of the web mapping application (figure 3.8). The interface (figure 3.8a) recalled the layout of a sampling form (Poggio et al., 2006) and reports the collected information. The results of the calculation of HHRE method were linked to the database of the study area for an easier interpretation on the territory with the support of a GIS environment. The results were also organised in reports for an easier interpretation (figure 3.8a). In both cases a PHP script connected the interface with the underlying database. These data reports allowed an immediate visualisation of all the information and data of the considered site, as support for more informed decision making process.



(a) Soil & Sites



(b) HHR

Figure 3.8: Data reports in the developed SIS.

3.3 Applicability in planning procedures

A major objective of land use planning is to evaluate the advantages and disadvantages of one use of soil as compared to another, to reach the most advantageous soil use and the conservation of fundamental natural resources (Dai et al., 2001). The request for tools supporting decisions-making has increased over the last few years. Tools to apply in an effective way ecological data in daily planning cases are viewed as essential in order to conserve a sustainable development in highly pressured areas (Adriassens et al., 2004). The tool accompanying the HHRE method was designed to be used also by planners not expert in soil science and soil contamination issues. The calculated values should provide more information to decision-makers, helping them to answer questions like: (i) is the considered area suitable for the actual/planned land use, e.g. a kindergarten? or (ii) Which is the less risky land use for the considered area (avoiding sealing)?

The advantages of quantitative environmental risk assessment techniques over the more commonly used qualitative approach is widely accepted. Yet, correct implementation of quantitative risk assessment is a difficult task, given the present state of understanding of the environmental processes. One important parameter related to the level of risk is the extent and spatial spread of pollutants. Geographic information systems provide a powerful and flexible tool that increases the applicability of the risk assessment methodology. Through spatial representation, the estimated risk becomes more comprehensive, thus facilitating the decision making process. In addition, valuable qualitative information can be incorporated into the risk assessment procedure with the help of GIS. The geographic database held in GIS served as the host environment for additional spatial operations such as spatial referencing between quantitative and qualitative information (geology, topographic relief, human activities) and for the graphical representation of the results (Hooker and Nathanail, 2006; Korre, 1999; Korre et al., 2002).
The use of a web mapping application is important in order to increase the sharing of the information among experts of different fields. In the future the use of such tools could be extended to public users in order to increase the participation of citizens into planning and environmental decision-making processes.

Chapter 4

Concluding remarks

In planning processes it is common to address questions such as (i) which is the most suitable land use for the considered area, or (ii) which is the most suitable area for a certain land use in the considered region. Rarely soil, soil pollution, soil quality and management of soil as natural resource are considered. Most often this is due to the lack of relevant information and to the costs to get the data. However an other reason is the lack of tools to manage and present already available information. A web-based application to store and visualise soil-sites information and human health risk levels due to soil pollution was developed and applied for the test area of Grugliasco, a municipality near Torino, large industrial town of North West of Italy. The application can be used through a network, locally and it is portable, i.e. does not need any installation on a specific machine. All the software and tools used are freely available under GPL (General Public License) license. The tool developed can be used by a not experienced end-user after a short period of training, but it needs an expert in order to be set-up. The developed application should provide a support tool in the decision making process of planning procedures. It is not yet intended to be for public use from citizens. A lot of careful information and education would be needed in order to introduce such a *delicate* topic to the public opinion. Therefore it was designed to be used by planners of municipalities or technicians of environmental agencies. The SIS was developed in order to make soil and health risk assessment information available for planning and soil management in an end-user oriented manner, providing an immediate spatial visualisation of risks likely to arise from current and planned land uses. By identifying areas of concern for human health, it provides a basis for a more informed decision making on land uses and for setting soil protection guidelines. It has to be pointed out that the consideration of risk is only a part of a multi-objective problem, such land use planning in urban areas. However, the possibility to get an immediate visualisation of risk location on the territory, with respect to current and planned land uses, can improve the information available to planners, easily identifying areas of concern for human health. It can provide indication for more informed decision making, setting soil protection guidelines and suitability for particular land uses.

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Servizio Progetti Formativi

DICHIARAZIONE DI CONSULTABILITA' O NON CONSULTABILITA' DELLA TESI
AUTORIZZAZIONE ALLA PUBBLICAZIONE DELLA TESI/PRESENTAZIONE TESI

(da inserire come ultima pagina della tesi)

Il/la sottoscritto/a..LAURA.....POGGIO.....
nato/a a..TORINO.....il..01.../..03..../.1978...

ammesso all'esame finale del master..in...SISTEMI...INFORMATIVI.....
.TERRITORIALI&..TELERILEVAMENTO.-.SECONDO..LIVELLO.-.A DISTANZA

sessione .LUGLIO...2008..... dell'a.a. 2006/.2007.....

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1. che la sua tesi dal titolo:
WEB...MUNICIPAL...SIS...FOR...EVALUATION...OF..HUMAN..HEALTH..RISK
.DUE...TO....SOIL....POLLUTION...AND..URBAN..SOIL..MANAGEMENT....

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data TORINO,..19/06/08 firma Laura Poggio