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A GIS APPLICATION AS DECISION SUPPORT FOR AIR MONITORING NETWORK

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ABSTRACT

The results of a GIS application in designing an air monitoring network in Northern Italy are presented. In order to understand the distribution of pollutants (NO_x, NO_2, O_3 and VOCs), four specific campaigns (October to August 2004) were carried out using diffusive samplers. Maps showing spatial distribution of each pollutant were created, and a land cover map was obtained using a mosaic of orthophotos. By overlaying pollutant distribution maps and land cover map, it was possible to determine the suitable location of monitoring stations.

Key Words: Air Pollution, Monitoring Network, GIS, Land Cover/Use Map, Digital Ortophotos

1. INTRODUCTION

Air pollution and its impact has become one of the most important problem throughout the world, and the quantification of emissions as well as their spatial distribution are essential for any air quality program (Aleksandropoulou and Lazaridis, 2004; Sengupta et al., 1996).
One of the most difficult tasks in designing an air monitoring network is the choice of the location of the monitoring station, taking into account the harmful effects of pollution on both human health and environment (Allegrini et al., 2004). The European and Italian Directives provide the criteria to select areas suitable to install monitoring stations; these directives indicate the minimum distance that should exist between the pollutant source and the monitoring station, the minimum number of sample points and the reference measurement and sampling techniques to be used on a macro and micro scale. In the past, the Italian legislation indicated areas with higher concentration of pollutants as the most suitable measuring sites. Recently the European Directive (EEA, 1999) on atmospheric pollution required a detailed evaluation of the environment on a local and regional scale, by means of field data and thematic maps, particularly if industrial sites are located close to urban areas.
A GIS technology can be adopted to fulfil this Directive: a Geographic Information System (GIS) is a computer-based information system that enables storing, modelling, manipulation, retrieval, analysis and presentation of geographically referenced data (Burrough, 2001). The organization of all this information by means of geographic coordinates allows data from a variety of sources to be easily combined in a uniform framework. GIS mainly involves overlaying different data sets such as environmental, chemical, population and meteorological data, thus allowing to perform arithmetical and relational operations. In addition, the

integration of multitemporal data allows the monitoring of environmental parameters related to an area or to a particular process, highlighting the dynamic process that develops over a long time period.
Every environmental analysis should be based on the land cover/use maps (Weirs et al., 2004). By means of an automatic classification method applied to satellite images or digital aerial photographs (Foody, 2000), it is possible to obtain an accurate map to be integrated with atmospheric data.
Maps indicating the concentration of air pollutants such as NOx, NO_2 or ozone can be used to assess the possible impact of pollutants on human health (Stedman et al., 1997). By overlaying the land cover/use map with pollutant concentration maps, urban and vegetated areas subject to long periods of high level of pollution can be identified, and consequently the monitoring station in according to current directives can be located.

This paper presents the results of a GIS application in designing an air monitoring network, according to the European Criteria; the test site is a complex area in Northern Italy characterized by urban and rural agglomerates surrounded by industrial plant and agricultural areas.

2. MAIN TEXT

The study area is located in Northern Italy, close to the city of Mantova, in Po Valley. It is a large alluvial and fertile plain, characterised by open agricultural land, intermingled with scattered rural dwellings and farmhouses. The agricultural areas are associated with permanent crops under a continuous rotation system, flooded crops such as rice fields and other inundated croplands, and complex cultivation patterns. Natural vegetation systems are represented by two small regional reserves, named “Marsh of Ostiglia” and “Isola di Boschina”, and also include hedge and trees rows along croplands.
The marshes of Ostiglia are international wetlands according to the Ramsar Convention and are connected with Natura 2000 network in line with the Birds directive (79/409/CEE) and the Habitats directive (92/43/CEE). The principal vegetation is large reed beds and sedge communities, and covers an area of 123 ha. The “Isola Boschina” reserve is close to the Po river. The vegetation is composed of broadleaved woodlands with *Quercus pedunculata* and *Populus* sp. pl., associated with *Ulmus minor, Acer campestre*, *Prunus avium* and *Fraxinus oxycarpa.* The reserve covers a small surface area (about 38 ha) and represents the last residual plain forest that once constituted the landscape of the Po Valley.
In the study area an hydroelectric station is located at about 40 km from Mantova, surrounding Sermide countryside. Toxic emissions of NO_x and CO are controlled by a monitoring emission system (SME).

In order to understand the distribution of air pollution throughout the study area, four specific assessment campaigns (October 2003 to August 2004) were carried out using a diffusive sampling method. The diffusive samplers were developed at the Institute for Atmospheric Pollution of CNR; the samplers are particularly suitable for preliminary assessment since they may be exposed for several months in an specific

location, providing average concentrations over the entire exposure period (De Santis et al., 1997 and 2004). The sampler is a modification of the open-tube design obtained by using a filter treated with appropriate reagents to trap the pollutant. The body of the sampler is a cylindrical vial with a threaded cap at one end. The pollutant is collected on an impregnated disc placed at the bottom of the vial and held in position by a stainless steel ring. To avoid turbulent diffusion inside the vessel, the open end is protected using a fine stainless steel screen.
More than hundred diffusive samplers were used and an exposure time of 30 days was selected. Nitrogen Oxides, Nitrogen Dioxide, Ozone and Volatile Organic Compounds (VOCs) were monitored during the campaigns.
The samplers were distributed in a regularly spaced 3 km x 3 km grid in the study area. Concentration values of the measured pollutants and the geographic co-ordinates of the samplers were organized in a database.
Using GIS routines, concentration maps for each pollutant were created for each campaign and used as layers in the Geographic Information System.
To perform pollutant concentration maps, Inverse Distance squared Weighted (IDW) interpolation technique was applied. IDW estimates cell values by averaging the value of sample data points in the vicinity of each cell. This method assumes that each measured point has a local influence that decreases with distance. To classify the concentration maps, the range of pollutant values was divided into eight equal-size intervals.

In order to perform landscape assessment, as required by the European criteria, a preliminary analysis was performed using a mosaic of orthophotos of the Po River Plain. Because of high spatial resolution, orthophotos represent excellent base maps for recognising territorial features and for determining the precise location of the sites where the monitoring system should be installed. The nominal scale of the orthophoto is 1:5000, satisfying the requirements of the European Community.
Using the orthophoto mosaic, a land cover classification was performed using photointerpretation techniques and nearest neighbourhood interpolation algorithm. The land cover/use classes were selected and analysed according to CORINE Land Cover Classification as reported in Table 1. Twelve land cover/use classes were recognized and particular attention was paid to urban areas.

Table 1. CORINE land cover/use classes

Level 2	Level 3
1.1 **Urban fabric**	1.1.1 Continuous urban fabric
	1.1.2 Discontinuous urban fabric
1.2 **Industrial, commercial and transport units**	1.2.1 Industrial or commercial units
	1.2.2 Road and rail networks and associated land
2.1 **Arable land**	2.1.1 Non-irrigated arable land
	2.1.3 Rice fields
2.4 **Heterogeneous agricultural areas**	2.4.1 Annual crops associated with permanent crops
	2.4.2 Complex cultivation patternes
3.1 **Forest**	3.1.1 Broad-leaved forest
3.2 **Scrub and/or herbaceous vegetation associations**	3.2.4 Transitional woodland-scrub
4.1 **Inland wetlands**	4.1.1 Inland marshes
5.1 **Inland waters**	5.1.2 Water bodies

Since the orthophotos were taken in different periods, the spectral response varied in several parts of the mosaic consistent with phenological phases of vegetation and water colour of the Po River.
Therefore the following processing steps were carried out to obtain the land cover map:

- a regular grid of 250 m^2 was overlaid on the photo mosaic;
- each grid cell was associated to a land cover/use class listed in Table 1;
- Nearest Neighbour algorithm was applied to the grid to obtain the land cover map (Figure 1);
- the orthophoto mosaic was georeferred to an cartographic base map on a 1:100.000 scale.

The use of a regular grid and the photointerpretation of each cell grid were suitable tools to represent all landscape features and, in particular, they were very useful to characterize the scattered rural buildings that are peculiar elements of the Po Valley. Since this study was focused on preventing the effects of pollutants on human health, coding of each cell was carried out overestimating the urban fabric. The cell was classified as discontinuous urban fabric even if a single farmhouse was identified; the same procedure was applied to road and rail networks and industrial or commercial units (Table 1). The land cover map was afterwards obtained using Nearest Neighbour interpolation technique. The Nearest Neighbour is a point interpolation which requires a point map as input and returns a raster map as output. Each pixel in the output map is assigned to the class of the nearest point, based on the shortest distance according to the Euclidean distance.

The concentration maps of each pollutant, carried out using the IDW method, were analysed in order to understand the temporal distribution of each pollutant in the study area. In Figure 2 concentration maps of ozone achieved during the monitoring campaigns are shown. For all campaigns, the areas with concentration values above average were selected and the results were resumed in four different summery maps, one for each pollutant (NO_x, NO_2, O_3 and VOC respectively). Afterwards, from each summery map, areas with values above average for three or four campaigns were extracted and plotted together in a new map. This map, called multiple occurrence map (Figure 3), shows all the areas with high concentration values of each pollutant over a long period. In the north-east part of the map, an area where all pollutants have high concentration values is shown, while in the central part of the map, a large area with a high concentration of ozone is present.

Suitable areas for monitoring station were determined by integrating the land cover map and the multiple occurrence map (Figure 4). Areas related to urban fabric and road network classes were extracted from the land cover map and were crossed with the occurrence map in order to identify suitable areas for each type of monitoring station (traffic, exposition and background station), according to EUROAIRNET criteria (EEA, 1999). In the traffic stations, the emissions from motor vehicles are considered as a major source of pollution while in the industrial stations only the emission from industrial zones are considered. The background stations are located where the pollutants come from all windward sources.

GIS techniques using pollutants distribution maps and land cover maps together with supplementary territorial analyses data was therefore used to retrieve information needed to determine the potential location of measuring stations.
In Figure 4a, the most suitable locations for traffic monitoring stations are recognized in the northern portion of the study area, while exposition stations should be located close to the small town where in three different seasons a maximum concentrations of ozone was measured. During the monitoring period, in the other small town present in the study area, the pollutant concentrations were always lower than the maximum value for that period. For this reason, monitoring stations close to this area are not necessary. In Figure 4b, the sites for background stations were indicated by large areas where the concentration of NO_x and Ozone was above the mean values for that period.
The final resulting maps obtained can be used for developing air pollution management strategies, such as the delineation of control areas and the selection of monitoring sites. Site that matches best fitting criteria were located on the maps and

their location was indicated to local authorities to establish a permanent measuring network.

3. CONCLUSION

A decision support system was developed for air quality management in the Po River Valley. Concentration of NO_x, NO_2, O_3 and VOCs have been measured using diffusive samplers during four campaigns. Pollutant concentrations and ortophoto mosaic were used to created a GIS project to perform spatial analysis.
Pollutant concentration maps were computed with IDW method. To obtain a land cover map of the study area (scale 1:5000) a multi-stage approach which includes photointepretation and spatial interpolation was performed. Overlaying pollutant distribution maps, multiple occurrence map and land cover map, areas suitable as monitoring station were detected.

In this study, GIS techniques have been used as an efficient tool for planning the monitoring network and for assessing the exposure level of population.. The final maps obtained from GIS analysis can be used for developing different air pollution management strategies, such as the delineation of control areas or the position of monitoring stations, taking into account the European directives.

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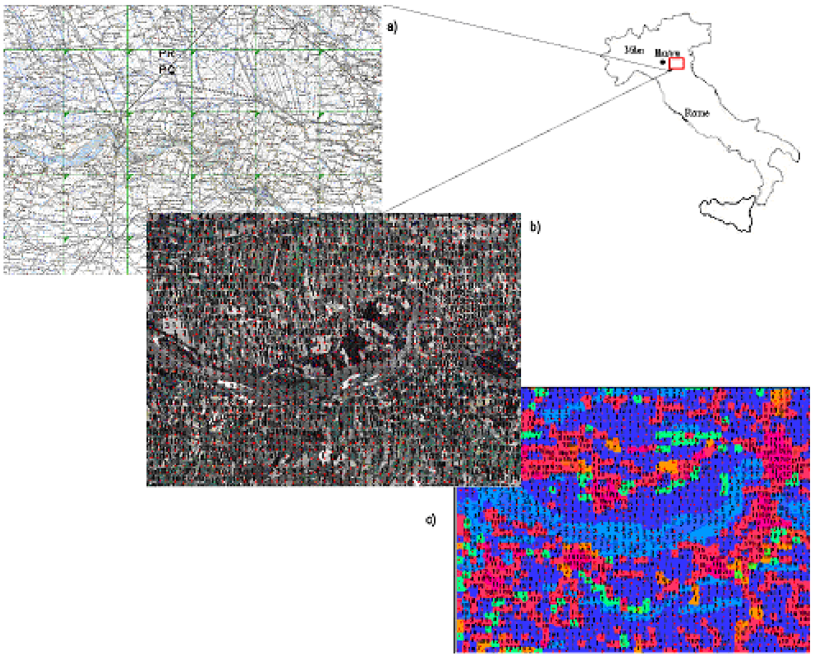

Figure 1. Location map (a), ortophoto detail with land cover codes overlaid (b), and land cover map obtained with nearest neighbour interpolation (c).

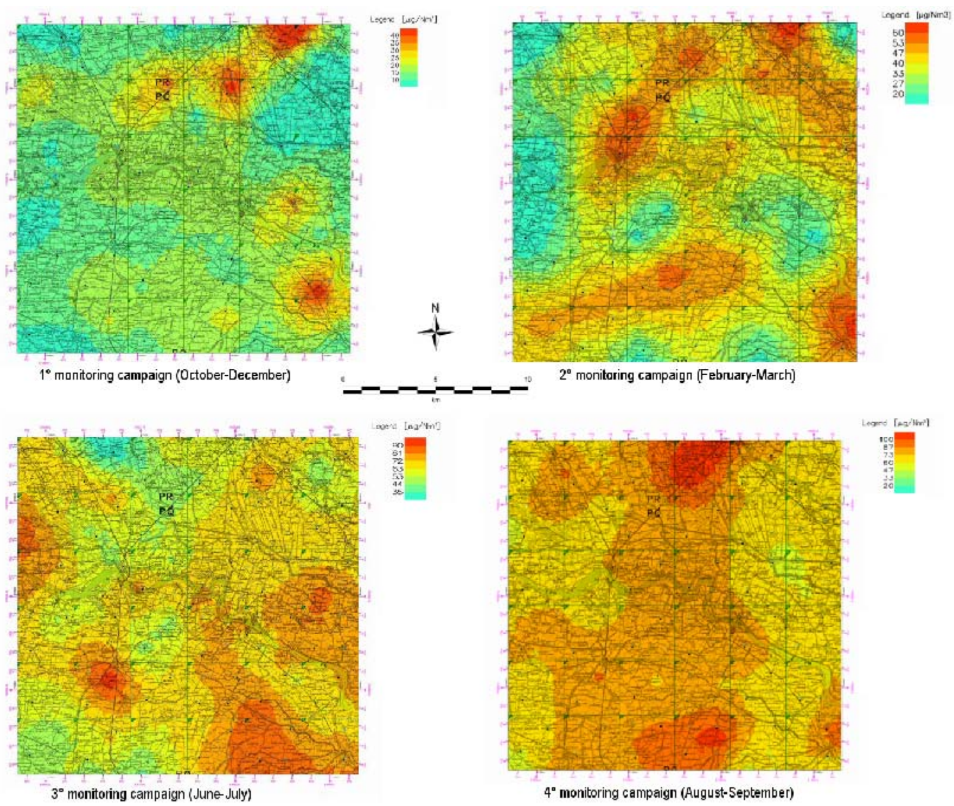

Figure 2. Concentration maps of Ozone during the different monitoring campaigns.

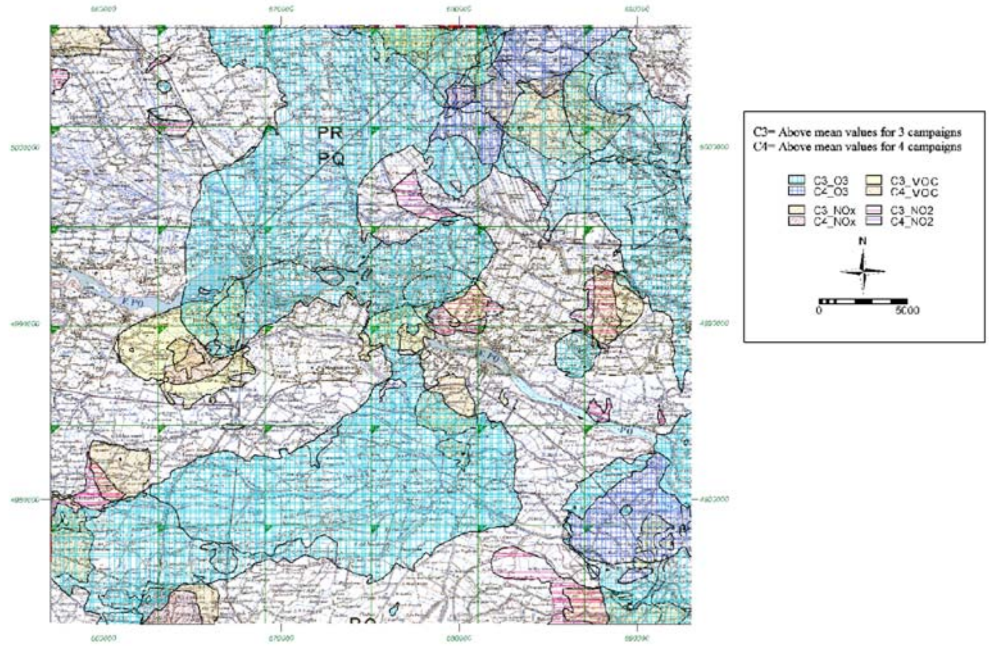

Figure 3. Multiple occurrence map.

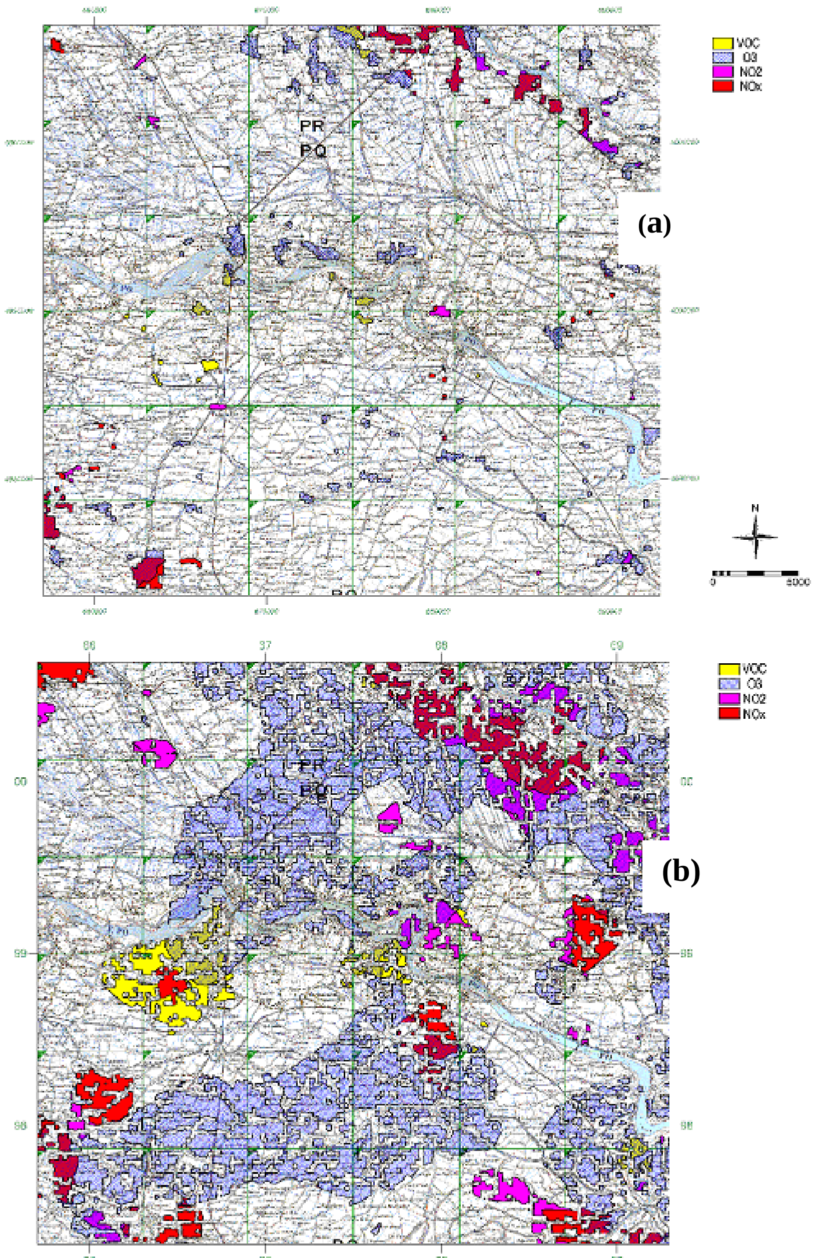

Figure 4. Areas suitable for monitoring stations: (a) traffic station, (b) background station.