TEACHING EXPERIENCES IN COMPUTER CARTOGRAPHY AND GIS FOR A LAND-USE, CITY AND ENVIRONMENTAL PLANNING COURSE

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ABSTRACT

The teaching experience which we present here started in the academic year 1996-1997 at the Faculty of Architecture of the Milan (Italy) Politecnico University. The one semester, 50 hours course in cartography was designed to give a body of basic but comprehensive knowledge to students in the disciplines of urban and environmental management and planning.

A basic course in statistics was assumed as a prerequisite. Theoretical and practical lessons were planned to complement each other. Of course, special attention was paid in order to highlight the official Italian cartography (both from IGMI - Italian Military Geographic Institute and from the Italian Cadastre) and Italian applications in the field.

1. General part: an introduction to cartography

First of all, the basic concepts of cartography had to be pointed out.

We started with a short review of the history of cartography, highlighting the main achievements in the field.

Then the basic characteristics of maps (common to all kinds of maps) were described:

- all maps are concerned with two elements of reality:
  - locations (positions in (e.g) X, Y coordinates);
  - attributes;
- all maps are abstractions of reality;
- all maps are reductions (concept of scale);
- all maps involve geometrical transformations (choice of map projection);
- all maps use signs (symbolism of cartography).

Despite the fact that a univocal classification of maps cannot be given, we decided to present classifications of maps based on:

- scale (small, medium, large, very large scale maps);
- function:
  - general reference maps;
  - thematic maps;
  - cadastral maps;
  - charts.

The impact of changing technology and technical advances on cartography was also explored, to come to present-day information age mapping: this also served as a preliminary introduction to geographical information systems (GIS).

Subsequently, a number of lessons was devoted to what we considered the main problem of cartography: the determination of point positions on the earth surface (definition of reference surface) and the projection of these positions on the map reference frame (transformation reference surface – plane).

We presented the following subjects in basic geodesy:

- definition of a reference surface:
  - sphere;
  - ellipsoid (official ellipsoids, e.g. international, WGS84);
  - geoid (fundamental equations, cartographic use);
- coordinate systems, reference systems:
  - cartesian geocentric systems:
    - CTS (Conventional Terrestrial System);
    - WGS84 system;
  - local cartesian coordinates;
  - intrinsic coordinate systems (geopotential heights);
  - geodetic coordinate systems:
    - geographic coordinates (latitude and longitude);
    - coordinates in a local datum;
- transformation reference surface – plane:
  - alteration of geometrical relationships:
  - transformations and distorsion of:
    - angles;
    - areas;
    - distances;
    - directions;
  - analytical definition of transformations;
  - geometrical definition of transformations;
- commonly used map projections:
  - conformal projections:
    - Lambert conic;
    - polar stereographic;
    - Mercator;
    - transverse Mercator (UTM);
  - equal - area projections:
    - Sanson-Flamsteed;

- other projections:
  - Cassini-Soldner.
- choice of map projection: how to decide which map projection is best suited to one's purposes.

Special attention was of course paid to the cartography coming from official Italian organizations, such as:

- cartography from the Italian Military Geographic Institute (IGMI), at the 1:50000 and 1:25000 scale;
- cartography from the Italian Cadastre;
- technical maps of the Italian administrative Regions.

2. Sources of data for cartography

We considered the following sources of (primary) data for cartography:

- ground survey:
  - principles, instruments, methods;
  - geodetic networks (Italian geodetic networks);
- electronic positioning: GPS;
- remote sensing:
  - electromagnetic waves and spectrum;
  - spectral signature;
  - sensors:
    - photographic cameras and films;
    - CCD cameras;
    - multispectral scanners;
    - radar (and SAR);
  - platforms (SPOT);
  - thematic information extraction.

Also secondary sources of data were taken into account, namely data coming from map digitizing and scanning.

3. Computer cartography and GIS

Regarding computer cartography, its main characteristics were first of all highlighted:

- basic definitions;
- typologies;
- concept of scale;
- planimetric data;
- altimetric data;
- editing problems;
- use of standard codes.

Afterwards, the geographical information systems were introduced and their main aspects were studied:

- origins and applications;
- components of a GIS:
  - scientific;
  - hardware;
  - software;
  - data;
- data models and data structures for raster and vector data:
  - external models;
  - conceptual models;
  - logic models;
  - physical models;
- data organization:
  - vector structure;
  - raster structure;
- different DBMS structures:
  - hierarchical systems;
  - network systems;
  - relational systems.

4. Practical lesson: analysis of data over a urban area in the south-west of Milan (Italy)

The students, divided into groups, performed a statistical analysis on data sets regarding the population living in the south-west area of Milan (Italy) (see Fig. 4.1).

At first every group analyzed the data sets referring to one of eleven towns of the area, collected in the years 1951-1991 (see Fig. 4.2); afterwards, two temporal models were studied: linear and exponential (see Fig. 4.3). Finally they considered the spatial distribution (in two directions: West-East, North-South) of one type of data (for example: residents, working population, employed, etc.) over the whole geographical area, obtaining a graphic representation of this analysis using a linear regression model (see Fig. 4.4 and Fig. 4.5).

5. Practical lesson: reading and validation of technical maps

This exercise consisted in reading and validating two different technical maps (1:10000 and 1:2000) of the town of San Donato Milanese (Milan, Italy).

After dividing both maps into a regular grid (corresponding to about 100m x 100m), the students identified the corresponding vertices in the two maps and highlighted the new vertices in the 1:2000 map (the vertices represented different categories of topographic elements: buildings, roads, other).

The final products were tables and graphic representations (see Fig. 5.1).

The students represented the results of the thematic variations collected by the previous analysis on the maps at different scales, for every category identified.

The map used for the representation of the territorial analysis of San Donato Milanese (Milan, Italy) was at the scale 1:2000 (see Fig. 5.2).

6. References

The references suggested to the students were the following:

A.H. Robinson, J.L. Morrison, P.C. Muehrcke, A.J. Kimerling, S.C. Guptill *"Elements of cartography"*, J. Wiley and Sons, 1995 (6^{th} edition) (Parts I, II, III, IV).

M. Fondelli *"Manuale di topografia"*, Editori Laterza, 1991 (vol. II, cap. 13, 14, 15).
G. Bezoari, A. Selvini *"Manuale di topografia moderna"*, Città Studi Edizioni, 1996 (cap. 10 e 13).
A. Selvini *"Elementi di cartografia"*, Città Studi Edizioni, 1996.
P. Richardus, R.K. Adler *"Map projections"*, North-Holland Publishing Company, 1972.
"Breve introduzione ai Sistemi Informativi Territoriali", Franco Ziviani Editore, 1995

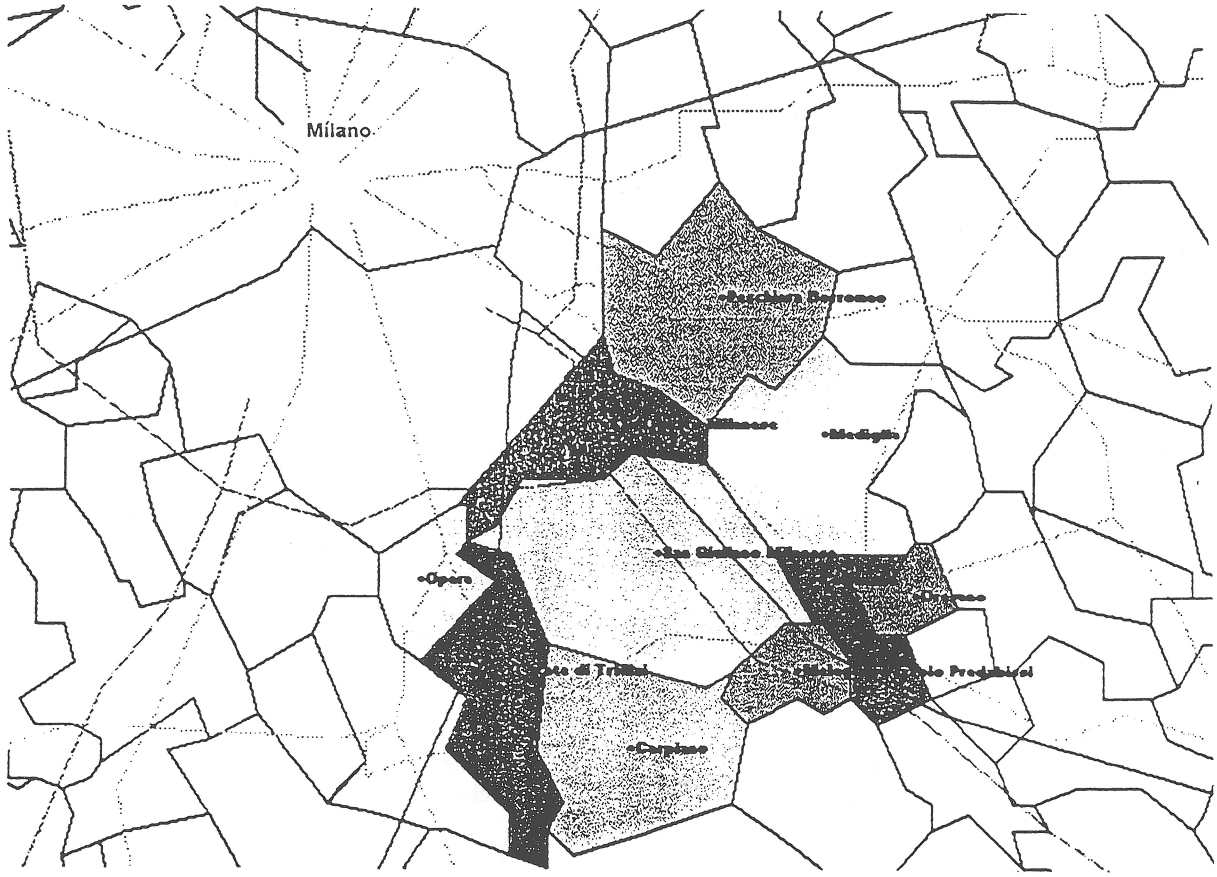


Fig. 4.1 The geographical area studied

DATA OF THE POPULATION

TOWN	Years	Residents
San Donato M.	51	2667
"	61	10296
"	71	26872
"	81	31962
"	91	31331

Linear Model $Y=AX+B$

	$\sigma_{xy}=(\Sigma(x-mx)(y-my))/N$	$A = \sigma_{xy}/\sigma^2_x$
residents / years	157988	789.94
$B = \mu_y - A\mu_x$	$\rho = \sigma_{xy}/\sigma_x\sigma_y$	Equation
-35460.14	0.936596947	Y=789.94X-35460.14

DATA DISTRIBUTION

median	71	26872
mean	71	20625.6
variance	200	142269803.4
r.m.s.	14.142	11927.69062
width	40	29295
m.a.v.		5090

Exponential Model $S=Pe^{QT}$ >>>> $\ln S = \ln P + QT$

	σ_{ST}	$P = e^{(\mu s - (\sigma ts/\sigma 2t)\, \mu t)}$
residents / years	12.12019956	2.02E+00002
$Q = \sigma_{ts}/\sigma^2_t$	$\rho = \sigma_{ts}/\sigma_t\sigma_s$	Equation
0.060600998	0.895555176	S=2.02E+00002e$^{0,060600998\,T}$

Fig. 4.2 Analysis of the data referring to one of eleven towns of the area

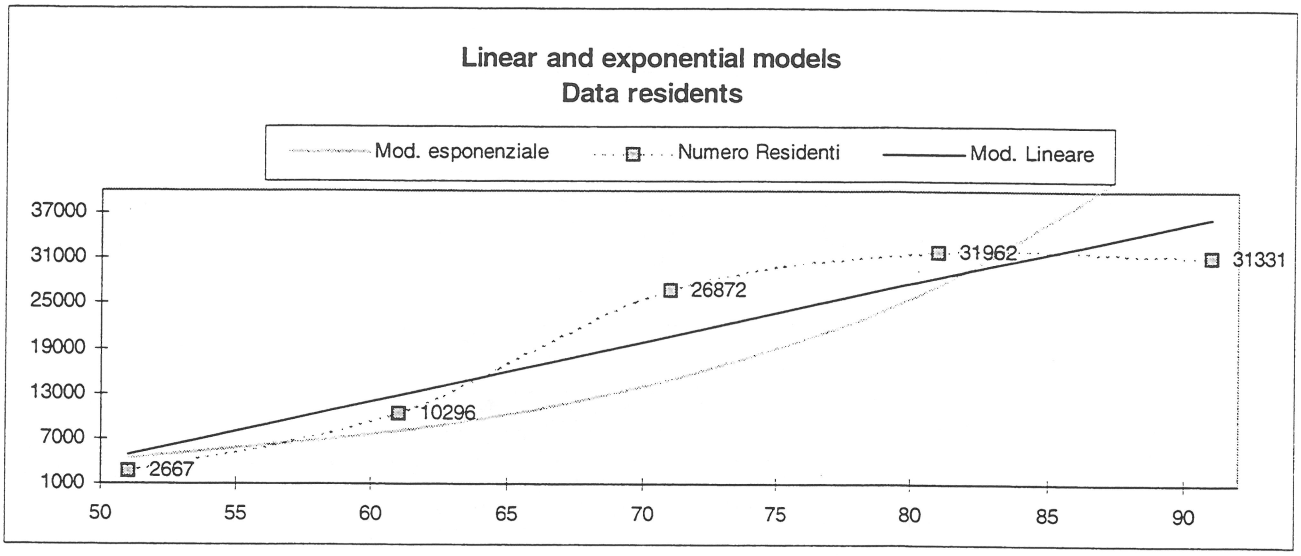


Fig. 4.3 Graphic representation of the temporal analysis

Geographical location of the towns in the area considered

x \ y				
	Milano(1/20)	Peschiera	-	-
	Milano(1/20)	S.Donato M.	Mediglia	-
	Opera	S.Giuliano M.	Colturano	Dresano
	Locate di T.	Carpiano	Melegnano	Vizzolo P.

y(1,2,3,4)= West-East direction

x(1,2,3,4)= North-South direction

Table of the distribution of the resident population

Residents 1961

	1	2	3	4	P
1	79121	4892	0	0	84013
2	79121	10296	3481	0	92898
3	3249	14999	979	961	20188
4	5996	1596	13247	1014	21853
Q	167487	31783	17707	1975	218952

Milan tot. res. 61	1582421

Table of the distribution of the frequencies

	1	2	3	4	pi
1	0.361362	0.022343	0	0	0.383705
2	0.361362	0.047024	0.015898	0	0.424285
3	0.014839	0.068504	0.004471	0.004389	0.092203
4	0.027385	0.007289	0.060502	0.004631	0.099807
qj	0.764948	0.14516	0.080872	0.00902	1

Bonferroni's indices

$\beta x = C_0/1-\Sigma pi^2$	0.335466
$\beta y = C_0/1-\Sigma qj^2$	0.566927
β_0	0.436102
β_{-1}	0.421512

variance of y

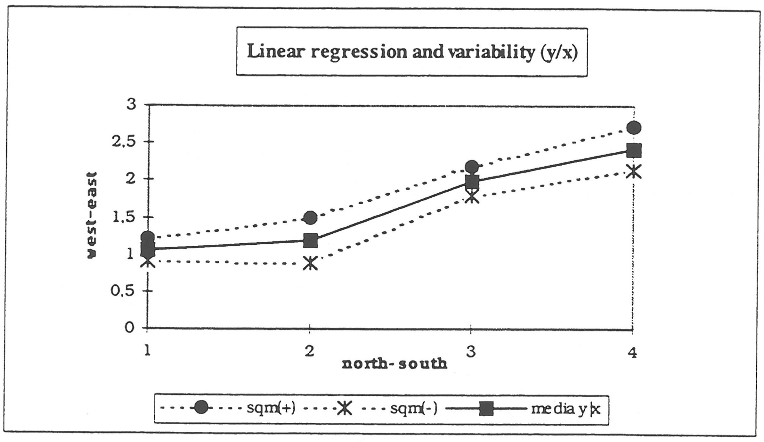
variance of x

$\sigma^2 y$	0.438297
$\sigma^2 x$	0.866694

Pearson's indices

$\eta^2 y$	0.44724
$\eta^2 x$	0.396433
η^2	0.413497

Fig. 4.4 Analysis of the data of the spatial analysis



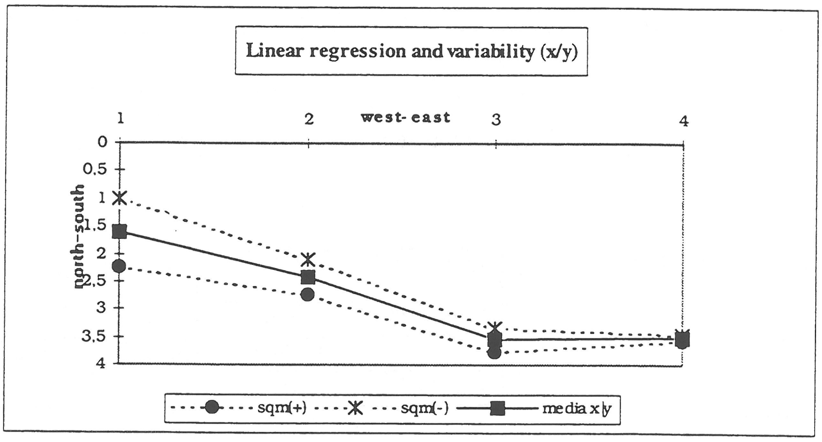
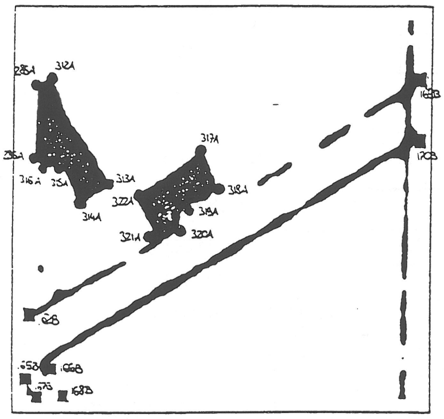
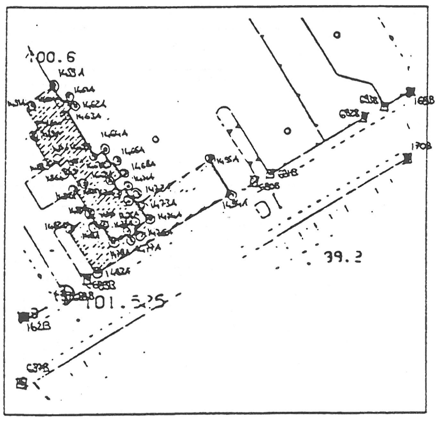


Fig. 4.5 Graphic representations of the spatial analysis

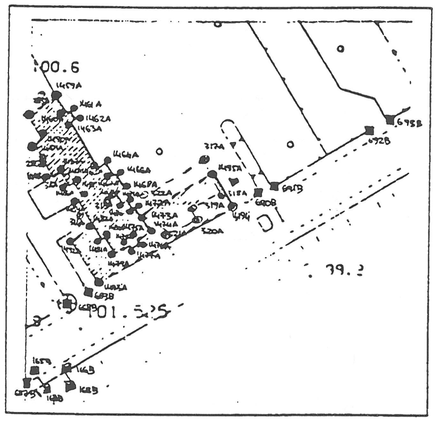
Identification of verteces on the Regional Technical Map (scale 1:10000)



Recognition and identification of new verteces on the Municipal Map (scale 1:2000)



Localization of variations (alterations or differences)



● Buildings ■ Roads ♦ Cemeteries, parks, sport grounds, et.

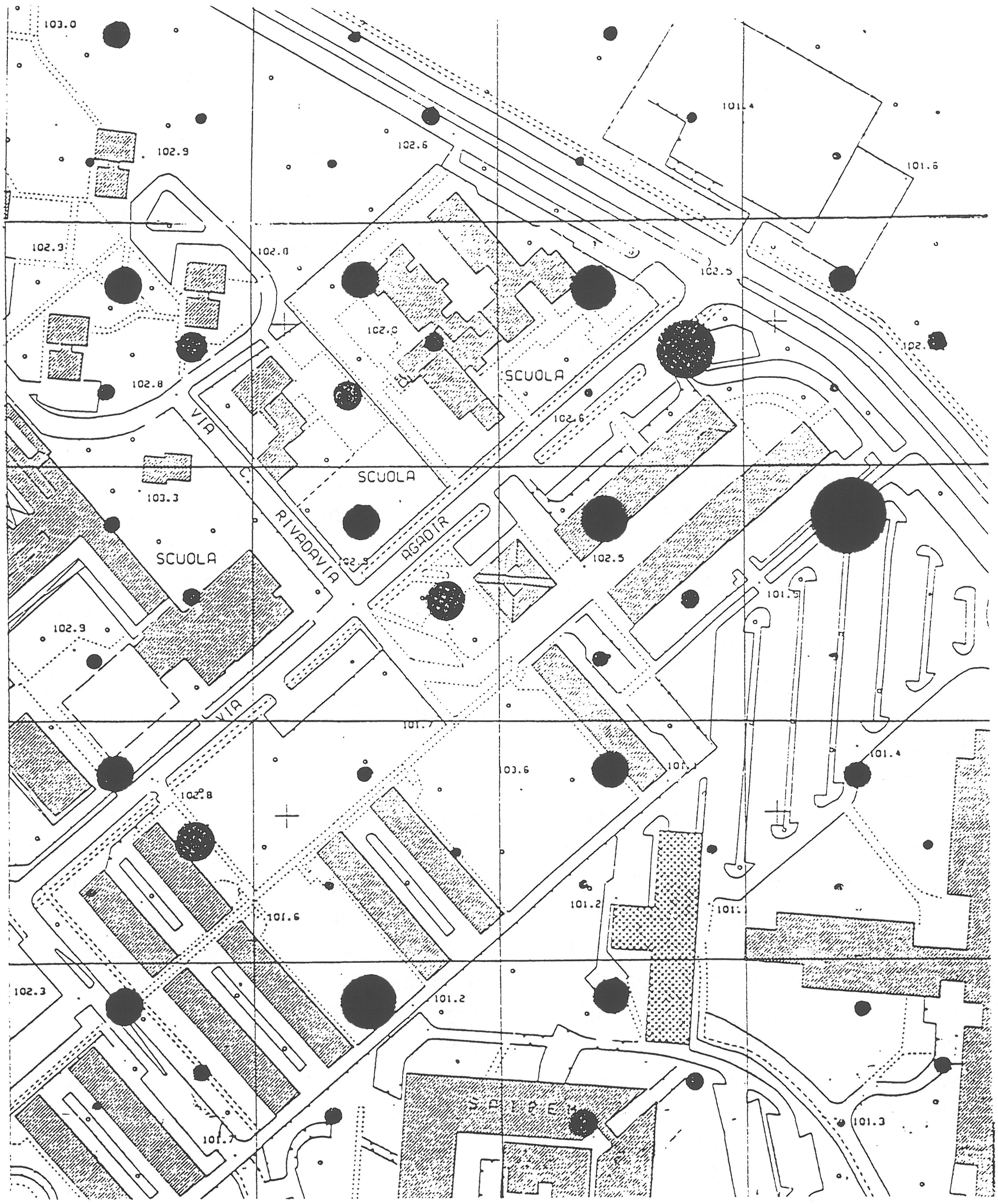
●	■	♦
285	162	
286	165	
312	166	
313	167	
314	168	
315	169	
316	170	
317		
318		
319		
320		
321		
322		

●	■	♦
1459	162	
1460	169	
1461	170	
1462	688	
1463	689	
1464	690	
1465	691	
1466	692	
1467	693	
1468	687	
1469		
1470		
1471		

●	■	♦
285	165	
286	166	
312	167	
313	168	
314	687	
315	688	
316	689	
317	690	
318	691	
319	692	
320	693	
321		
322		

Table of contents

Fig. 5.1 An example of schedule



LIST OF CONTENTS

BUILDINGS ROADS OTHER

NOTE: the diameter of the circles is proportional to the variations

Fig. 5.2 An example of thematic representation of the variations on the map at the scale 1:2000