4. Land use database generation

The understanding of urban dynamics is basic for planning the sustainable development of urban areas and the conservation of natural resources. Still, it represents one of the most complex tasks planners have to deal with. The complexity and variety of the different urban components and functions, and of the interactions amongst them, are even more pronounced when available mapping is outdated or very poor, and where there is a general lack of standard and comparable information on cities. The current situation demands new technologies, tools and expertise to better monitor and understand those composite realities. In this framework, the uniform monitoring of the distribution, changing patterns and growth of human settlements plays a very important role, and much research is currently focused on the development of new methodologies based on high-technology tools.

Earth observation (EO) is a modern science that intensively studies the Earth's changing environment, using remote sensing tools such as satellite imagery and aerial photography. The Earth's physical components, such as the atmosphere, oceans and land, are therefore studied from a viewpoint other than those of classical approaches. This viewpoint helps in better understanding various natural processes, and the effects of our actions on the environment.

Under the European Commission's fourth framework programme (1995–98) for research and technological development and demonstration (RTD), the Centre for Earth Observation (CEO) of the Directorate General Joint Research Centre was responsible for promoting the overall use of EO, particularly by demonstrating its potential applications and by favouring the exploration and expansion of the EO market.

In 1998, under the umbrella of activities carried out by CEO, a pilot study named Murbandy (Monitoring urban dynamics) was launched. It initially aimed at providing a measure of the extent of urban areas, as well as of their progress towards sustainability, through the creation of land use databases

for various cities. The project progressed quickly, and raised unexpected interest from both its initial potential customers and an 'external audience'. As a consequence, the number of study areas was extended to 25, and the project overview broadened, together with its objectives. In fact, in order to extend the field of research outside urban areas, the project Murbandy has been enlarged, and is continuing under the 5th framework programme of RTD with the modified name of moland (Monitoring Land Use Changes). The aim of the moland project is to define and validate a methodology in support of sectoral policies with territorial and environmental impacts. Its main objective is to study areas experiencing fast land use dynamics within and outside the EU.

Murbandy itself suggested the need for launching Moland: 'The results of the Murbandy-Munich project show that further urban growth will not be within the limits defined by the central polygon approach but along the major traffic lines (motorways and public transport networks). It seems to be advisable to extend the analysis to the 'Region of Munich' (e.g. in the framework of a Moland project) or — as a minimum solution — to analyse the urban growth along the development axis stretching towards the new Munich airport north of the city' (Murbandy-Munich final report).

The study analyses different layers of information, combined with land use changes, for urban areas. The methodology is based on the creation of an accurate land use database specifically designed for urban areas. To date, such a database has been created for 25 European cities and six extended areas (regions, transport corridors, etc.) that have been classified with a single land use classification scheme in order to obtain homogeneous data. The study has also been extended to cover seven 'mega-cities' outside Europe, and other areas are under consideration. The data were derived from satellite imagery and aerial photography, using remote sensing and GIS technologies. The database is the basis for combining environmental, economic and social data, in order better to understand dynamics and

characteristics of urban growth and related structural changes, commuting issues, and status of transport infrastructures.

One of the advantages of this approach is the multi-temporal dimension of the resulting databases, which are produced for four dates over the past 50 years, thereby enabling time-series analyses. The information is collected and elaborated with precisely the same methodology in the different cities, so as to allow comparative analyses. Thus, the approach enables the analysis of each single city as a complex urban system, and facilitates comparisons among cities, by providing comprehensive, standard and homogeneous information about the areas assessed.

Areas investigated by Murbandy/Moland for which the data sets are completed in Europe (blue colour), including a new set of areas (green colour), that are currently being studied.	Figure 4.1

Other advantages include cost efficiency, timely updating and, particularly, the possibility of combining different layers of information under a same parameter: the territorial dimension.

For this reason the methodology fits well for addressing sustainability. Moreover, the possibility of incorporating existing databases into the Murbandy/Moland one facilitates information collection and interpretation. The user can, for instance, fix the geographic limits of the system, and adapt to the system socio-economic variables collected with different methods.

Cooperation was established with several organisations. The list of partners and targeted users includes the European Environment Agency, Eurostat, DG Regional Policy, DG Environment, and local and regional administrations. Furthermore an attempt to establish an international network of agencies working in the field is currently under way. Practical results include joint work and the publication of reports, and the exchange of experiences on issues of common interest. Meetings and workshops are being organised, and the participants also include representatives from the United Nations Environment Programme (UNEP), the United Nations Research Institute for Social Development (UNRISD), the United Nations Centre for Human Settlement (Habitat) the Organisation for Economic Co-operation and Development (OECD) and the World Bank. Particularly relevant and somewhat unexpected was the interest demonstrated by local and regional administrations.

First results of the project were published in two pillars of the new European environmental policy and information literature: *the European Spatial Development Perspective — ESDP* (DG Regional Policy, 1999) and *Environment in Europe at the turn of the century* (EEA, 1999).

4.1. The Murbandy/Moland methodology

The methodology established by Murbandy/
Moland to monitor the dynamics of Europe's
settlements is implemented in three
interrelated parts:

Change detection (*Change*). Measuring
changes in the spatial extent of urban areas
and in urban structure in selected urban
areas in Europe. A period of approximately
40–50 years is considered.

Understanding (*Understand*). Identifying and
testing a number of indicators to be used to
measure the 'sustainability of urban and peri-
urban areas' in the investigated areas.

Developing scenarios (*Forecast*). Develop
'urban growth' scenarios for the investigated
areas, using state-of-the-art urban dynamics
models.

Figure 4.2	Structure of the Murbandy/Moland project
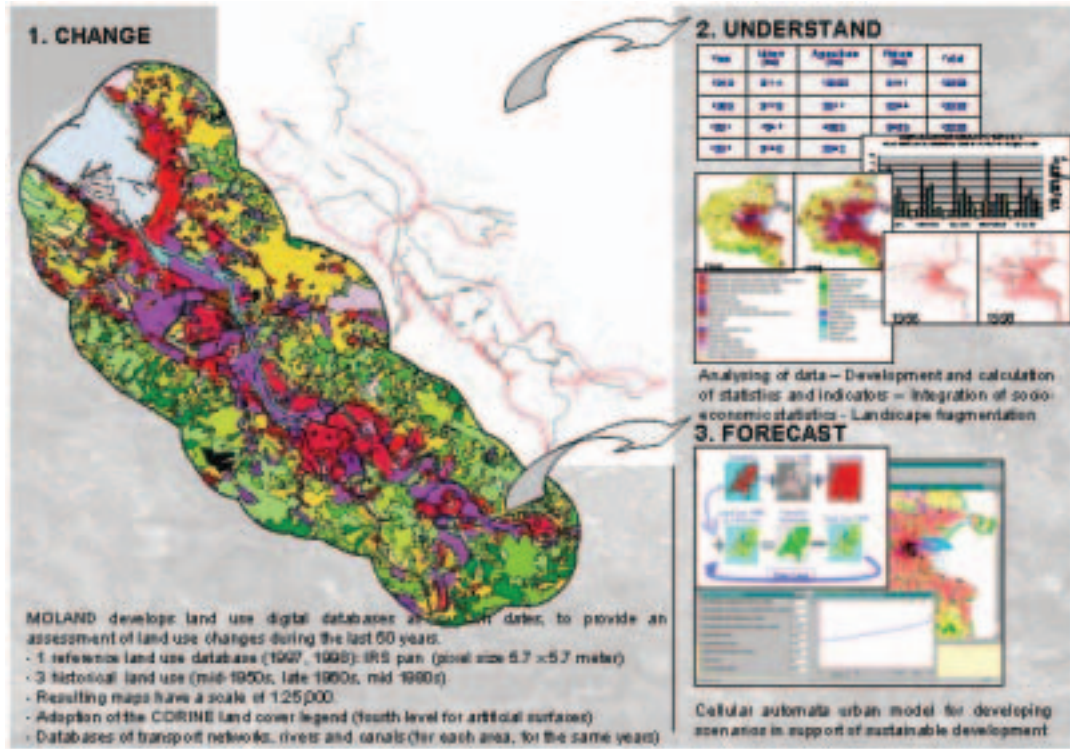
4.1.1. Murbandy/Moland — Change

CHANGE produces a reference ([1]) land use
database, typically for year 1997 or 1998, and
three historical land use databases for
selected European urban areas. Historical
databases are produced for three time
periods, ranging from 1948 to 1990. In
addition to the main built-up sector — the
core area — a part of its surrounding domain
— the buffer zone — is also assessed.

'The reference database provides the geo-
referenced framework for all the databases.
The analysis of the reference data generated
an accurate database, which could then be
easily edited for the previous datasets. This
way the interpreter could relate changes
between the historical databases by observing
on-screen the changes across the respective
data' (Murbandy-Sunderland final report).

The accuracy of the coverage refers to a map
scale of 1:25 000. The minimum mapping
unit is 1 hectare (ha) (100 x 100 m) for the
artificial surfaces and 3 ha for non-artificial
surfaces (approximately 170 x 170 m).

As the interpretation was performed within
the ArcInfo ([2]) environment, the resulting
four vector and four polygon databases are
ArcInfo vector coverages. 'Linear features
(roads, railways, canals and rivers) were
handled as separate databases. Four polygon
databases including class labels, and four

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(1)   The reference land use database is derived from very high-resolution satellite imagery (IRS1-C panchromatic,
      5.7 metre/pixel). At presentthe highest resolution data commercially available are obtained using the Indian
      IRS-1C sensor (MURBANDY-Sunderland Final Report).
(2)   GIS software.

vector databases including a class attribute, were produced. 'Historical' linear features digitised from the aerial photographs only included those features visible in the reference year satellite scene. However, changes in the road network due to larger road or rail construction have been included' (Murbandy-Copenhagen final report). Vectors representing linear features and polygons representing land use were attributed indicating the land use class they represent ([3]).

| City of Vienna. Samples of IRS-1C image | Figure 4.3 |

The historical database is computed with data from time windows in the mid-1950s, the end of the 1960s and the 1980s. Aerial photographs and other ancillary data sources are used for the computation of the historical database.

| City of Helsinki. Example of historical database (aerial photography — left) and reference database (IRS image — right) | Figure 4.4 |
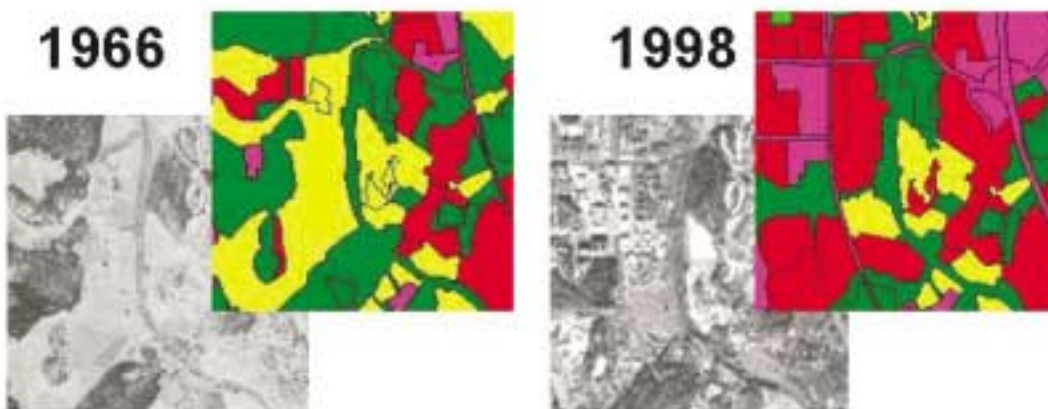
Note: The figure shows an image of the same area taken at different times and the land use classes at full detail derived from them. The increment of the urban fabric (red colour) category and the decrement of agricultural land (yellow colour) can be observed.

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(3)   Major roads, railways, canals and rivers, as far as they are visible in the image, were digitised as linear features. If their width exceeded 25 metres they were digitised as both linear features and polygons.

In order to conform to EC land cover classification standards, the nomenclature for the land cover types is based on an extended version of the Corine land cover legend, whose description is contained in the *Corine land cover technical guide*.

Table 4.1	Corine land cover legend (*Corine land cover technical guide*)

1 Artificial surfaces	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
		1.2.3 Port areas
		1.2.4 Airports
	1.3 Mine, dump and construction sites	1.3.1 Mineral extraction sites
		1.3.2 Dump sites
		1.3.3 Construction sites
	1.4 Artificial, non agricultural vegetated areas	1.4.1 Green urban areas
		1.4.2 Sport and leisure facilities
2 Agricultural areas	2.1 Arable land	2.1.1 Non-irrigated arable land
		2.1.2 Permanently irrigated land
		2.1.3 Rice fields
	2.2 Permanent crops	2.2.1 Vineyards
		2.2.2 Fruit trees and berry plantations
		2.2.3 Olive groves
	2.3 Pastures	2.3.1 Pastures
	2.4 Heterogeneous agricultural areas	2.4.1 Annual crops associated with permanent crops
		2.4.2 Complex cultivation patterns
		2.4.3 Land principally occupied by agriculture, with significant areas of natural vegetation
		2.4.4 Agro-forestry areas
3 Forests and semi-natural areas	3.1 Forests	3.1.1 Broad-leaved forest
		3.1.2 Coniferous forest
		3.1.3 Mixed forest
	3.2 Scrub and/or herbaceous vegetation associations	3.2.1 Natural grasslands
		3.2.2 Moors and heath land
		3.2.3 Sclerophyllous vegetation
		3.2.4 Transitional woodland scrub
	3.3 Open spaces with little or no vegetation	3.3.1 Beaches, dunes, sands
		3.3.2 Bare rocks
		3.3.3 Sparsely vegetated areas
		3.3.4 Burnt areas
		3.3.5 Glaciers and perpetual snow
4 Wetlands	4.1 Inland wetlands	4.1.1 Inland marshes
		4.1.2 Peat bogs
	4.2 Maritime wetlands	4.2.1 Salt marshes
		4.2.2 Salines
		4.2.3 Intertidal flats
5 Water bodies	5.1 Inland waters	5.1.1 Water courses
		5.1.2 Water bodies
	5.2 Marine waters	5.2.1 Coastal lagoons
		5.2.2 Estuaries
		5.2.3 Sea and ocean

Source: Corine land cover technical guide.

The scale chosen for the project Corine is 1:100 00, and the minimum mapping unit is 25 ha. The scale of Murbandy/Moland is 1:25 000, and the minimum mapping unit is 1 ha.

'When defining this unit [the minimum mapping unit], it must always be borne in mind that, in reality (in the field) land cover always occurs as a combination of surfaces which are to a greater or lesser degree homogeneous/heterogeneous, whatever the scale used. Furthermore, irrespective of how they have been processed, data acquired by spaceborne remote-sensing systems do not provide a representation of the actual land cover situation; nor can land cover be

mapped in all its complexity/diversity' (*Corine land cover technical guide*, 1996).

Therefore, the Corine nomenclature is neither always detailed enough nor compatible with the purposes of Murbandy/ Moland. For instance, Corine states that class 1.1.2 (discontinuous urban fabric) can be distinguished when 'buildings, roads and artificially surfaced areas cover between 50 % and 80 % of the total surface area of the unit'. According to both this definition and the scale 1:100 000, Corine individuates areas corresponding to class 1.1.2 and marks them out as polygons (Figure 4.5).

Unit area example: the areas (polygons) marked with a white line correspond to class 1.1.2, discontinuous urban fabric (*Landsat TM image, from the Corine land cover technical guide*)	Figure 4.5
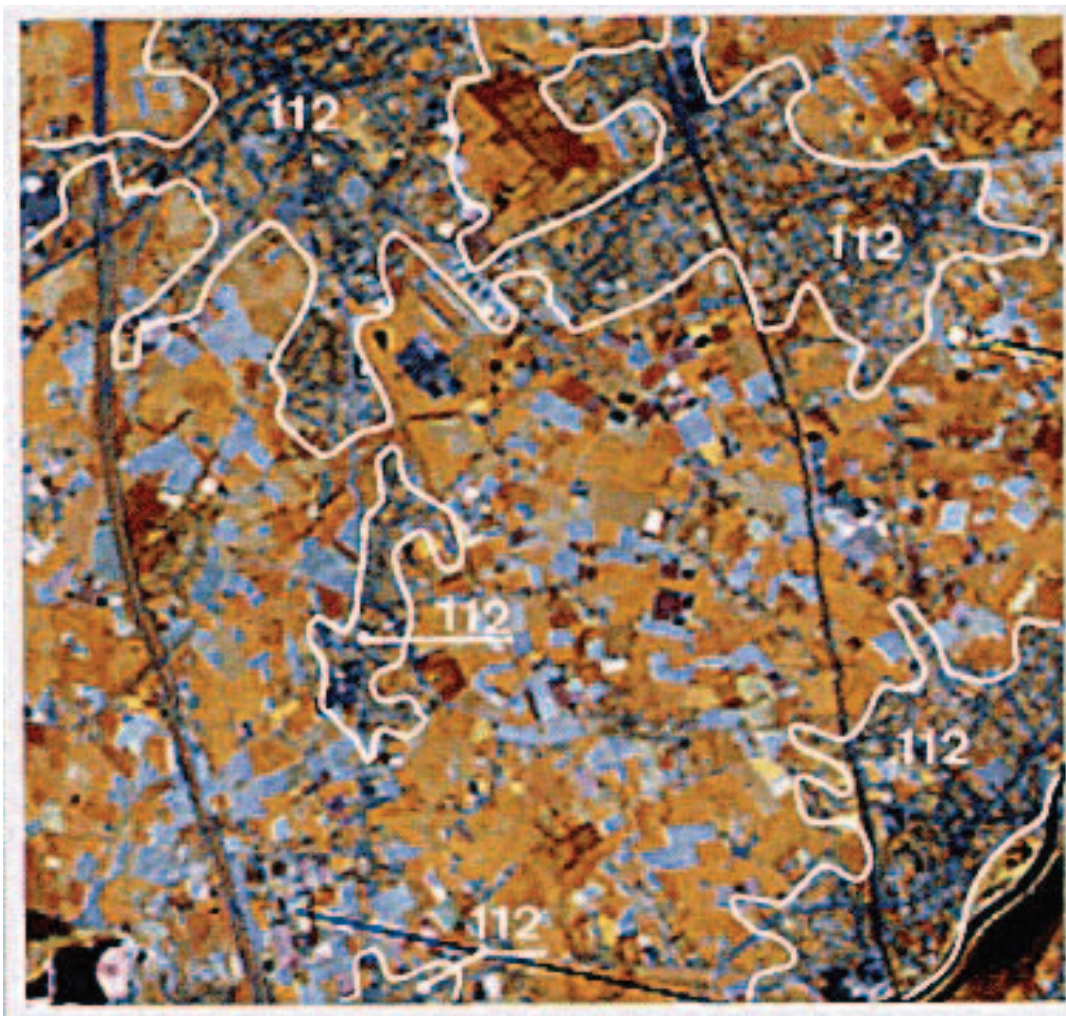
However, the same polygons investigated at the scale of Murbandy/Moland would be divided in smaller zones (Figure 4.6). As a consequence the area classified by Murbandy/Moland would most probably show parts where artificially surfaced areas

cover more than 80 % of the total surface area of the unit, and correspond to continuous urban fabric. In this case, the portion of land analysed would be classified differently according to Corine or Murbandy/Moland guidelines.

Figure 4.6	**Sample of the same area mapped by Corine land cover (left) and Murbandy/Moland (right). Inside the artificial areas in the Corine classification, and which are marked with red colour, Murbandy/Moland would individuate more features, such as green areas, public services, etc.**

2   0   2   4 kilometres

N
W   E
S

It is, therefore, of basic importance to bear in mind that a feature having a certain attribute in Corine might have a different one in Murbandy/Moland, because the unit is smaller and the scale more detailed.

Thus, one of the main differences between Murbandy/Moland and Corine is that the level of detail is different. Other important differences are:

• the presence in Murbandy/Moland of land use classes, while Corine is exclusively a land cover classification;
• the methodology adopted in the Understand and Forecast-parts of Murbandy/Moland).

Also, for this reason a much more detailed level was introduced for 'artificial surfaces' and 'water bodies', corresponding to the numeric codes and headings of the third and fourth level of the Murbandy/Moland legend. The third level almost perfectly coincides with that of the Corine land cover legend.

The fourth level introduced by Murbandy/Moland was derived taking into account Clusters(legend produced by Eurostat for statistical purposes) and the FAO land cover legend.

Nevertheless with a major effort it would have also been possible to obtain a more detailed classification, as remarked in at least one of

the final reports prepared by the Murbandy partners: 'Due to the high resolution of the aerial photography, a finely detailed set of land use polygons could have been created. However, the specification for the project gives guideline minimum sizes for polygons, which are larger than those possibly attainable. There are some situations, therefore, where a mixed classification has been obtained from the data sources, yet a singular code is required. This is most common in the commercial centre area where shopping, residential and public/private services are all represented within one, small, city block. In these cases, a 'majority' category has been applied.

'A common contemporary feature within the study area are business parks or retail parks. Commonly they have one activity only: i.e. office provision or shopping centre. Occasionally, however, the use is mixed and, again, a 'majority usage' was determined' (Murbandy-Sunderland final report).

However, for a more detailed classification the satellite imagery would not have been of any advantage 'since the spatial and spectral resolutions of the IRS-1C do not allow the identification of all land uses specified in the legend and the delimitation of artificial classes with 1 ha' (Murbandy-Algarve final report). However, the recent successful launch of a new private satellite with 1 metre resolution panchromatic images and 4 metre resolution multispectral images has offered

new perspectives, and the new areas under study by Murbandy/Moland are testing the adoption of new classes.

After data processing, a validity of each dataset is carried out in order to guarantee a high quality of land use classification products.

Numeric codes and headings of the third and fourth level of the Murbandy/Moland legend. The fourth level almost perfectly coincides with — that of the Corine land cover legend		Table 4.2

1.1.1	Continuous urban fabric. Most of the land is covered by structures and the transport network. Buildings, roads and artificially surfaced areas cover more than 80 % of the total surface. Non-linear areas of vegetation and bare soil are exceptional. When roads and structures along roads are only 25 m wide, as long as they are more than 1 ha in size will be classified as continuous dense urban fabric.	
1.1.1.1	Residential continuous dense urban fabric. Residential structures cover more than 80 % of the total surface. More than 50 % of the buildings have 3 or more stories.	
1.1.1.2	Residential continuous medium dense urban fabric. Residential structures cover more than 80 % of the total surface. Less than 50 % of the buildings have 3 or more stories.	
1.1.2	Discontinuous urban fabric. Most of the land is covered by structures. Buildings, roads and artificially surfaced areas are associated with vegetated areas and bare soil, which occupy discontinuous but significant surfaces. This type of land cover can be distinguished from continuous urban fabric by the presence of non-impervious surfaces: gardens, parks, planted areas and non-surfaced public areas. (Buildings, roads and artificially surfaced areas cover between 50 % and 80 % of the total surface area of the unit). *Between 10 % and 80 % of the land is covered by residential structures.*	
1.1.2.1	*Residential discontinuous urban fabric. Buildings, roads and other artificially surfaced areas cover between 50 % and 80 % of the total surface.*	
1.1.2.2	Residential discontinuous sparse urban fabric. Buildings, roads and other artificially surfaced areas cover between 10 % and 50 % of the total surface. The vegetated areas are predominant but is not land dedicated to forestry of agriculture.	
1.2.1	Industrial *(and)*, commercial, *public and private* units. Artificially surfaced areas (with concrete, asphalt, tarmacadam, or stabilised, e.g. beaten earth) devoid of vegetation, occupy *(most)* more than 50 % of the area in question, which also contains buildings and/or vegetated areas.	
1.2.1.1	Industrial areas. Surfaces occupied by industrial activities, including their related areas.	
1.2.1.2	Commercial areas. Surfaces basically occupied by commercial activities, including their related areas.	
1.2.1.3	Public and private services not related to the transport system. Surfaces occupied by general government, semi-public or private administrations including their related areas (access ways, lawns, parking areas).	
1.2.2	Road and rail networks and associated land. Motorways, railways, including associated installations (stations, platforms, embankments). Minimum width to include: *(100 m)* 25 m.	
1.2.2.1	Fast transit roads and associated land. Motorways, by-pass roads, toll-ways, etc.	
1.2.2.1	Other roads and associated land.	
1.2.2.3	Railways and associated land.	
1.2.3	Port areas. Infrastructure of port areas, including quays, dockyards and marinas.	
1.2.4	Airports. Airport installations: runways, buildings and associated land.	
1.3.1	Mineral extraction sites. Areas with open-pit extraction of industrial minerals (sandpits, quarries) or other minerals (opencast mines). Includes flooded gravel pits, except for river-bed extraction.	
1.3.2	Dump sites. Landfill or mine dump sites, industrial or public.	
1.3.3	Construction sites. Spaces under construction development, soil or bedrock excavations, earthworks.	
1.3.4	Abandoned land. Land within urban areas, where no particular use can be seen.	
1.4.1	Green urban areas. Areas with vegetation within urban fabric. Includes parks *(and cemeteries with vegetation)*.	
1.4.2	Sport and leisure facilities. Camping grounds, sports grounds, leisure parks, golf courses, racecourses, etc. Includes formal parks not surrounded by urban zones.	
5.1.1	Water courses Natural or artificial water courses serving as water drainage channels. Includes canals. Minimum width to include: *(100)* 25m.	
5.1.1.1	Canals. Including man made watercourses.	
5.1.1.2	Rivers.	

Note: The above is a description of the third Corine land cover level as reported in the technical guide. In italic are the changes introduced by Murbandy/Moland The — fourth level has been introduced by Murbandy/Moland.

Figure 4.7	Colour codes of the legend adopted by Murbandy/Moland. A more complete legend is currently being used for new study areas.

Residential continuous dense urban fabric
Residential discontinuous urban fabric
Residential discontinuous sparse urban fabric
Industrial areas
Commercial areas
Public and private services
Toll ways
Other roads
Rail ways
Port areas
Airports
Mineral extraction sites
Dump sites
Construction sites
Abandoned land
Green urban areas
Sport and leisure facilities
Non–irrigated arable land
Vineyards
Fruit trees and berry plantations
Complex cultivation patterns
Land principally occupied by agriculture, with significant areas of natural vegetation
Agro–forestry areas
Broad–leaved forest
Coniferous forest
Natural grassland
Transitional woodland shrub
Sparsely vegetated areas
Canals
Rivers
Water bodies

A major aim of this project is to demonstrate the advantages of the use of satellite remote sensing data to develop land use databases. However, the spectral, spatial and radiometric resolutions of IRS-1C imagery are not adequate to identify some classes of the legend, especially in artificial areas. A significant amount of ancillary data was required to ensure the completeness and accuracy of the reference database.
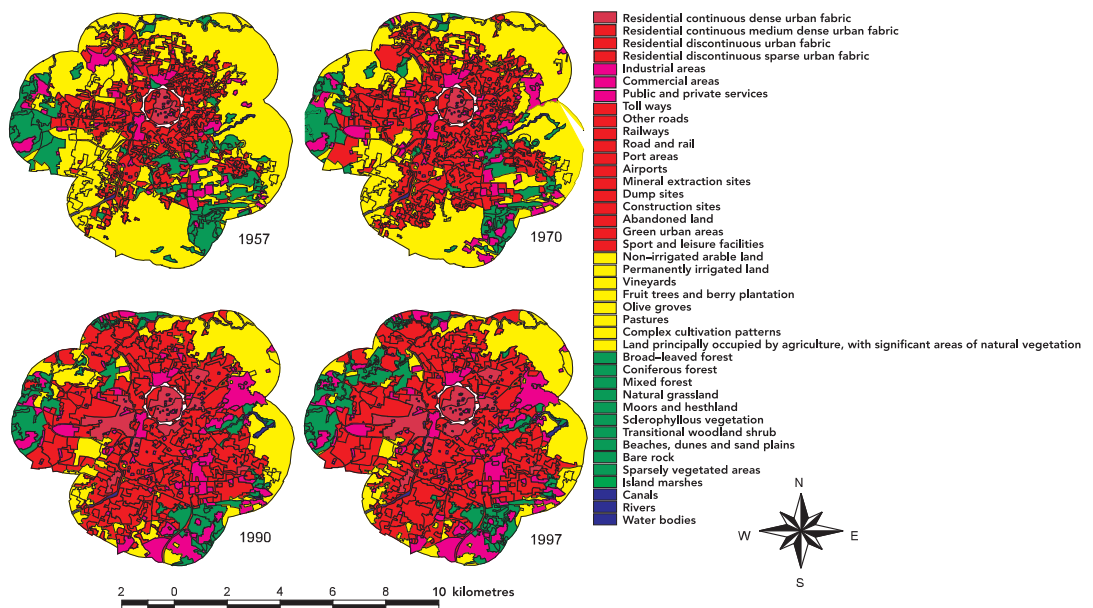
Several considerations about the potential improvement of both the legend and the methodology have been made by the project managers involved in the study. Most of the ideas and suggestions collected during about three years of intensive cooperation with teams of experts from all around Europe are currently being used for an updating of the technical guidelines. A few corrections were also made while the work was carried out.

The legend is being perfected and extended together with the technical guidelines, in order to better fit with the purposes of Murbandy/Moland.

Figure 4.8	City of Nicosia (Cyprus). Simplified land use maps (limited number of classes)

Residential continuous dense urban fabric
Residential continuous medium dense urban fabric
Residential discontinuous urban fabric
Residential discontinuous sparse urban fabric
Industrial areas
Commercial areas
Public and private services
Toll ways
Other roads
Railways
Road and rail
Port areas
Airports
Mineral extraction sites
Dump sites
Construction sites
Abandoned land
Green urban areas
Sport and leisure facilities
Non–irrigated arable land
Permanently irrigated land
Vineyards
Fruit trees and berry plantation
Olive groves
Pastures
Complex cultivation patterns
Land principally occupied by agriculture, with significant areas of natural vegetation
Broad–leaved forest
Coniferous forest
Mixed forest
Natural grassland
Moors and hesthland
Sclerophyllous vegetation
Transitional woodland shrub
Beaches, dunes and sand plains
Bare rock
Sparsely vegetated areas
Island marshes
Canals
Rivers
Water bodies

1957   1970
1990   1997

2 0 2 4 6 8 10 kilometres

| City of Copenhagen, Denmark. Example of complete polygon data set, showing the land use evolution of the study area during four different time periods. Each colour corresponds to a different land use. | Figure 4.9 |
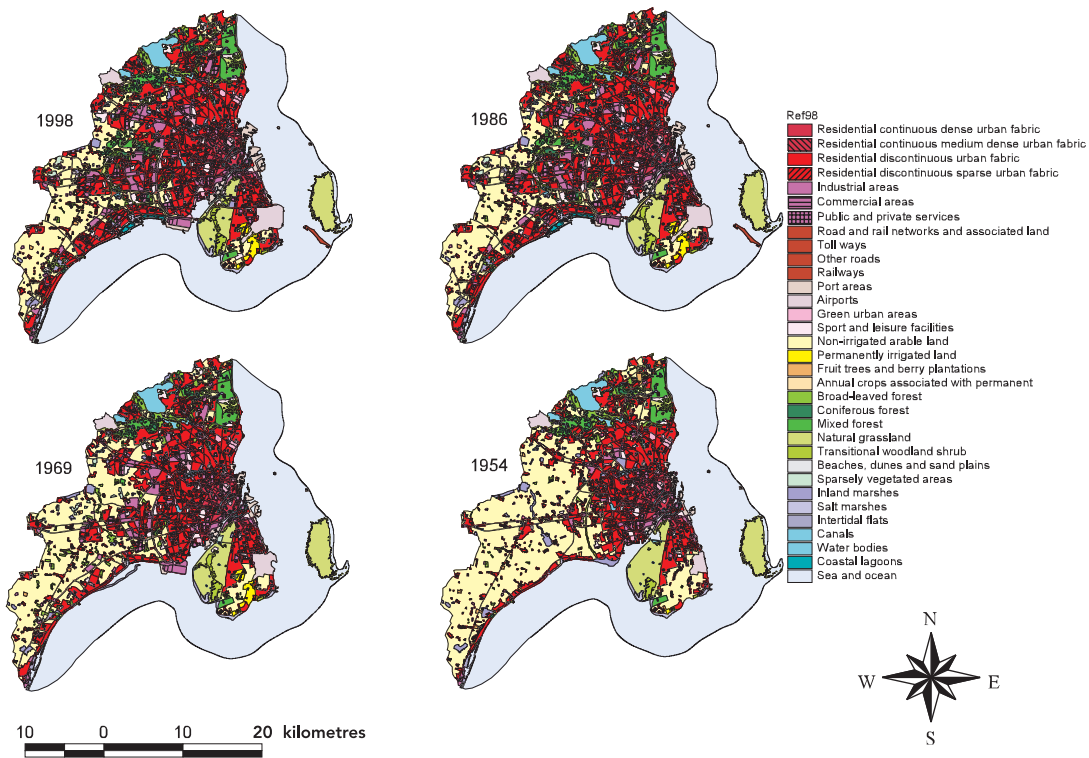
Limits of the study areas

The area of investigation was selected on the basis of the contiguous artificial surface — core area — of the city centres , plus a peri-urban buffer zone. The former usually corresponds to the 'artificial surface' class of the Corine land cover map and equals an area (A). The buffer zone was calculated as follows:

Buffer zone width = 0.25 x √A

This extends the area by approximately the double of the basic core area.

| City of Munich. Example of core area and buffer zone | Figure 4.10 |
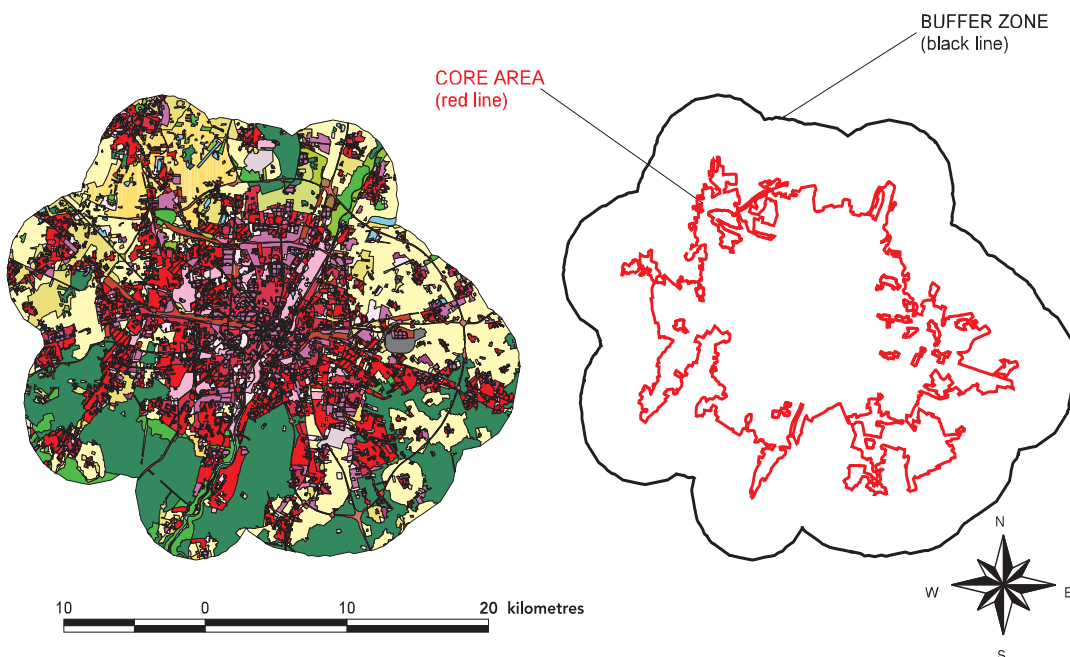
In some cases, such as Algarve, Ruhrgebiet and Padua-Venice (Veneto), the buffer zone was further extended to study larger areas, where a complete part of an administrative region — and not just a city — was considered. In this set of areas, which brings to the study a regional dimension, the formula has not been strictly applied. However, every time it is needed, it can be applied to the settlements included in the regional areas under examination for carrying out specific case studies. The flexibility of the GIS software, in fact, easily allows for the re-calculation of the buffer zone around any urban centre according to the formula given above. This process allows a constant proportion between core and buffer to be maintained in specific areas within the broader region investigated, and therefore enables comparative analyses among specific zones.

In specific cases the calculated buffer was also modified and adapted to the neighbouring structures in order to avoid excluding or cutting zones of primary significance such as an airport, a village or, simply, the administrative boundaries.

| Figure 4.11 | **Urban area of Sunderland and Washington New Town (United Kingdom)** |
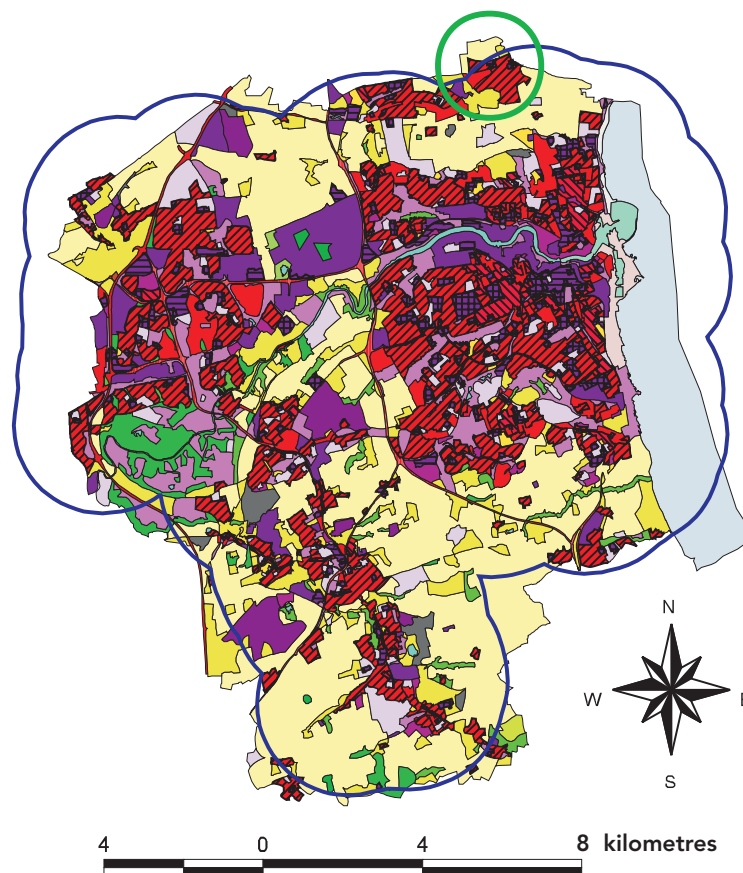
Note: The calculated buffer (blue line) was modified to exclude areas of minor importance (e.g. the sea) and include other areas. For instance, part of the settlement indicated with a green circle — top of the picture — would have been cut off if the buffer calculated with the formula were used.

The area of investigation was hence selected for the reference year. It was then adopted for the other periods, so to have exactly the same area (in position, size and shape) during the overall time frame.

Most of Murbandy/Moland — Change is developed in cooperation with European partners selected through an invitation to tender. Amongst others, an important selection criterion was the position 'in loco' of the enterprise, research centre, university, etc. that would be in charge of the assignment for a certain area (see Annex 4).

4.1.2. Murbandy/Moland — Understand
Understand attempts to explain features and trends comprised in the products of Change, and contribute to the basis for Forecast. Since Murbandy/Moland involves the analysis of many different European urban environments, and aims to undertake comparisons amongst them, the complexity represented by analysing each single urban system is enhanced. In order to better achieve comprehensive, standard and comparable information about the areas assessed, most of Understand is tackled through the development of sets of statistics.

The extensive data sets created a series of unique land-referenced data. These data are used to build and, particularly, to test specific spatial-referenced indicators, that are expected to be useful for several purposes:

- to provide more complete information for the most common approaches to urban issues;
- to help better understanding of the complexity of urban problems;
- to help city managers and decision-makers in defining local policies;
- to provide regional/national authorities and international institutions (such as Eurostat and the EEA) with detailed local territorial-referenced information relevant at local and European levels.

The indicators produced allow a better understanding of the dynamics of the urban areas, and of the impact of the cities on the global environment. For instance, for all the Murbandy/Moland cities and regions, basic spatial indicators are calculated which show the land use changes of the three main classes (i.e. artificial surfaces, agriculture, nature) over a 50-year period. In particular, the changes from agricultural and natural areas to artificial surfaces are investigated, documented and their statistics calculated. In addition, for several cities, changes in the structure (i.e. fragmentation) of the area considered are being measured and analysed, using a landscape structural analysis software (Fragstats) that has been specially modified for the Murbandy/Moland database.

The trends over time of the various fragmentation metrics (e.g. edge metrics, core area metrics, nearest neighbour metrics, diversity metrics) that are computed by Fragstats are being interpreted in the light of known environmental and demographic factors for the different urban areas.

The indicators developed aim to report on the sustainability of Europe's cities and urban areas. They are, therefore, defined to be robust in space and time, as well as flexible to accommodate different urban structures. At the same time such indicators have a degree of standardisation allowing for comparisons within Europe. A further key feature of these indicators is the historical perspective for assessing past and future trends.

Socio-economic data are also collected in a spatially disaggregated format, and combined with the territorial database. More

complex indicators can consequently be developed as well as concepts such as the carrying capacity of cities (e.g. the ecological footprint), and general urban sustainability issues at both local and European level can be better addressed.

4.1.3. Murbandy/Moland — Forecast

The main objective of Forecast is to develop scenarios of growth for urban and peri-urban areas using the information derived from the combination of EO and other data. The scenarios serve as major input for the formulation and evaluation of long-term strategies for sustainable urban development.

This package is based on the implementation of an integrated model of regional spatial dynamics consisting of a cellular automaton-based model of land use linked both to geographical information system (GIS) tools and to regional economics and demographics. The model allows for the modification of input parameters (e.g. the transportation network) so as to quantitatively and qualitatively simulate the temporal evolution of land use. The model is based on input variables such as:

- current and planned infrastructure;
- current and planned transportation network;
- past land cover changes (from Change);
- trends in population growth and income;
- legislation;
- indicators (from Understand).

The model is based on 24 cell states, each representing a land use class. Six of the classes (road and rail networks, airports, mineral extraction sites, dump sites, artificial non-agricultural vegetated areas and water bodies) represent fixed features in the model. Eight (arable land, permanent crops, pastures, heterogeneous agricultural areas, forests, shrub, sparsely vegetated areas and wetlands) are passive functions — that is, their dynamics are not directly driven by an exogenous demand for land but they appear or disappear in response to land being taken or abandoned by the active functions. These latter, the urban land uses (residential dense, medium dense, continuous and discontinuous sparse; industrial areas; commercial areas; public and private services; port areas; and abandoned land) are forced by demands for land generated exogenously to the cellular automaton, in response to the growth of the urban area. Construction site represents a transitional

state between one function and another. The transition potential (one potential for each function) is calculated for each cell according to the suitability, accessibility, zoning and neighbourhood effects.

Box. 4.1: The Moland urban and regional growth model

As part of Moland, a model has been developed for simulating urban and regional growth (White et al., 1999). This model, which is based on spatial dynamics systems called 'cellular automata', takes as input the Moland land use and transport databases, maps of land use suitability and zoning (i.e. legal constraints), and socio-economic data. The model then simulates future land use development under the input spatial planning and policy scenarios. The output from the model is maps of predicted land use development over 20 years. The aim of the model is to forecast future land use development under existing spatial plans and policies, and to compare alternative spatial planning and policy scenarios, in terms of their effects on future land use development.

The underlying spatial dynamics of the Moland urban and regional growth model are determined by so-called 'transition rules', which specify the interaction between neighbouring land use types. Examples of two transition rules are shown in Figure 1. The upper part of Figure 1 shows the effect of 'Residential discontinuous sparse urban fabric' on itself, while the lower part shows the effect of 'Industrial areas' on 'Residential discontinuous sparse urban fabric'. In both graphs, the x-axis indicates the distance (in pixels) from the central pixel in a neighbourhood of radius 8 pixels, while the y-axis quantifies the attraction (above x-axis) or repulsion (below x-axis) effect between the two land use types in question. As can be seen, close to the centre of the neighbourhood, 'Residential discontinuous sparse urban fabric' has an attraction effect on itself, while 'Industrial areas' have a repulsion effect on 'Residential discontinuous sparse urban fabric'. In other words, 'Residential discontinuous sparse urban fabric' will tend to occur beside cells of the same type, and not beside 'Industrial areas'.
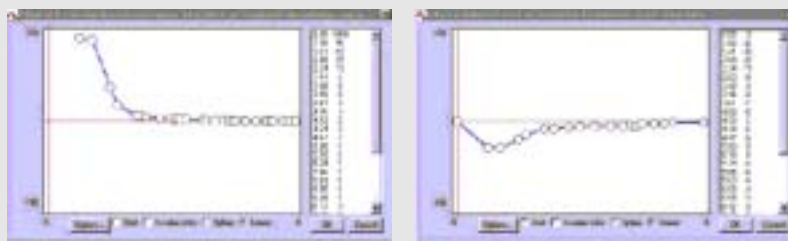
Two transition rules used in the Moland urban and regional growth model

By modifying the input data, the Moland urban and regional growth model can be used to explore, in a realistic way, alternative future scenarios of land use development. The following types of spatial planning and policy 'interventions' — with sample 'real' applications — can be easily simulated with the model:

- Addition / removal of transport links: This can be used, for example, for a strategic environment assessment of the trans-European network for transport (TEN).
- Modification of land use zoning: This can be used, for example, to assess the effects on land use development of prohibiting the development of artificial surfaces in natural areas.
- Modification of land use suitability: This can be used, for example, to assess the effects on land use development of decreasing the flooding risk, due to infrastructural improvements.
- Modification of socio-economic data: This can be used, for example, to assess the effects on land use development of a changing economic climate (e.g. decreased industrial production).
- Modification of model's transition rules: This can be used, for example, to capture the particular cultural characteristics of an area (e.g. in certain areas, nearness to water might be considered attractive for residential areas).

Alternative spatial planning and policy scenarios to the Moland urban and regional growth model are presented in the form of digital data sets of the transport networks, socio-economic data, land use zoning status and land use suitability. Based on these scenarios, and on the actual land use types at the start of the forecasting period, the model then predicts the likely future pattern of land use development for each year over the next 20 years. In order to compare the alternative predicted land use maps produced by the model, in terms of the long-term sustainability of the input land use planning and management parameters, various indicators — including those describing landscape fragmentation — are computed and analysed.

Currently, the Moland urban and regional growth model is being calibrated for Moland's extensive Europe-wide network of cities and regions, using the Moland land use and transport databases, as well as the ancillary data sets acquired from local authorities. The latest version of the model also incorporates data describing the socio-economic properties of the area, and will be used to simulate the interactions between the cities and their surrounding regions. This so-called 'macro model' is being tested on four new extended Moland European study areas, where extensive regional changes in land use are likely to occur as a result of major economic and infrastructural developments (e.g. the Dresden-Prague transport corridor).

Source: White et al., 1999 ([1])

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(1) White, R., G. Engelen, I. Uljee, C. Lavalle, and D. Ehrlich. 1999. Developing an Urban Land Use Simulator for European Cities. Conference on 'GIS for Tomorrow'. Stresa, Italy, June 1999.

4.2. Technical issues

As mentioned, several difficulties became apparent during the development of the project. As soon as a query was posed by one of the partners, it was discussed and solved. Most of these cases turned out to be extremely useful for improving methodology and technical specifications. Both Murbandy legend and technical guidelines are currently being revised to be adopted during the development of Moland. A few examples of the difficulties encountered during the interpretation are shown below.

Residential continuous dense urban fabric (class 1.1.1.1) in city centres is usually composed of buildings having small shops on the ground floor and offices on upper floors. Commercial use is taking over the residential functions. Only local knowledge and sometimes aerial photos allow the correct class to be assigned. Maps can only help when special use is marked.

'Large parts of the inner city area of Munich have been classified as 1.1.1.1. The basements of the 3–5 storey apartment houses are occupied by restaurants and stores. But also the suburban residential areas with up to 20 stories and with far less than 80 % land coverage belong to this class' (Murbandy-Munich final report).

A similar problem arose for the areas of Bratislava and Prague. During the communist era, one of the major development aspects for the former socialist cities was the building up of new residential areas: the so-called panel-house (housing estate) or Plattenbau. A high number of inhabitants live in these buildings, even if it might appear that the population density is lower. In fact, due to the particular structure of the panel-houses, the use of ground is not very high, and there are many green urban areas between the housing blocks. In addition, these 'sub-cities' have their own infrastructure like small supermarkets, schools and kindergartens. Buildings are usually single blocks with an area smaller than 1 ha with many green areas around. Even if they cover less than 80 % of the land, the buildings themselves have a large number of floors (between 5 and 10) and a high population density. Therefore that kind of land cover was classified as residential continuous dense urban fabric (class 1.1.1.1).

| **Bratislava — example of panel houses** | Figure 4.12 |

A new class has now been introduced for panel-houses and/or residential buildings with a high number of stories.

For industrial areas (class 1.2.1.1), often new 'industry parks' consist of indifferent building structures and contain a mixture of industry, commercial areas and services, which makes a classification to one of the given classes according to the deduced or assumed main activity extremely difficult if not impossible' (Murbandy-Munich final report).

The abandoned land class (1.3.4) is difficult to interpret, as no-use is an excluding definition. In a temporal context it would include areas, where a certain land use existed at one point of time, but had disappeared at the following point of time. However, there are other classes in the nomenclature that might be appropriate for abandoned land such as sparsely vegetated areas. Here we face the ambiguity of land cover and land use. An area that had been of industrial use or/and where previously existing buildings have been destroyed might match the land use definition of abandoned land. However, the actual land cover of the abandoned land might be sparse vegetation. This problem generally occurs in this kind of nomenclature. Despite ongoing discussions in the geo-science community no generally applicable solution to this problem has been found so far and only locally gathered information can help assign a correct class.

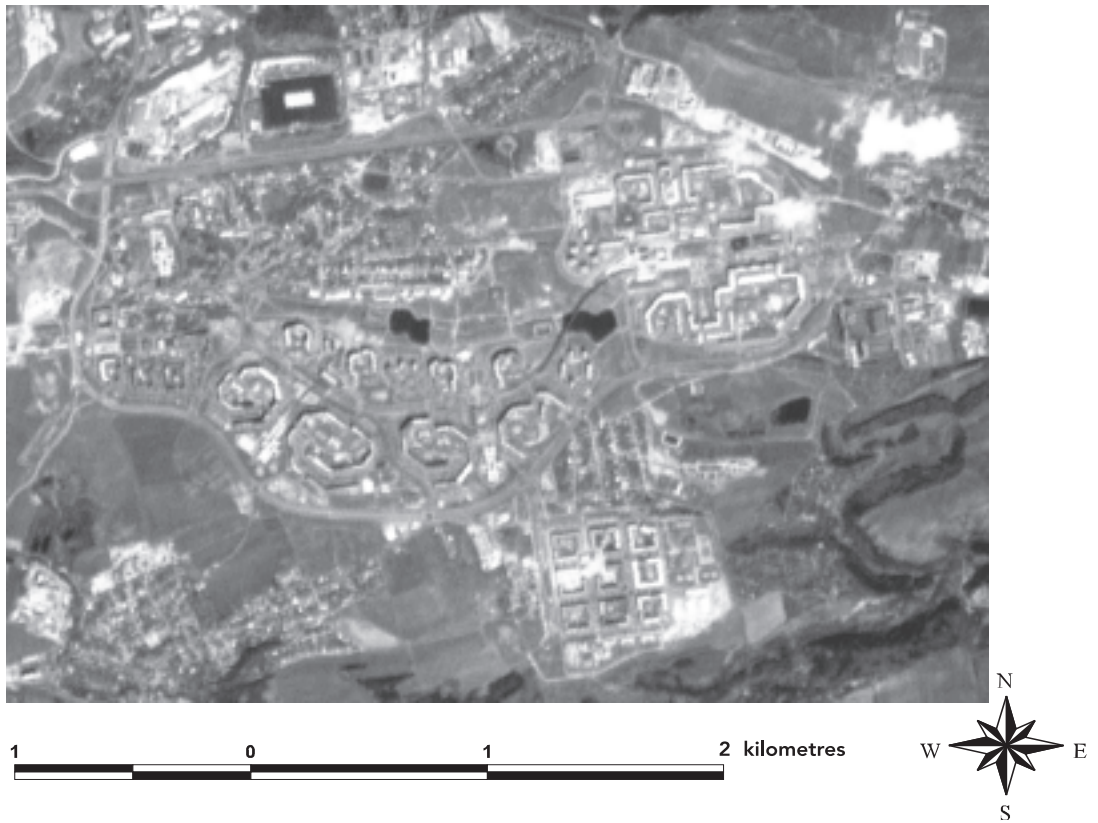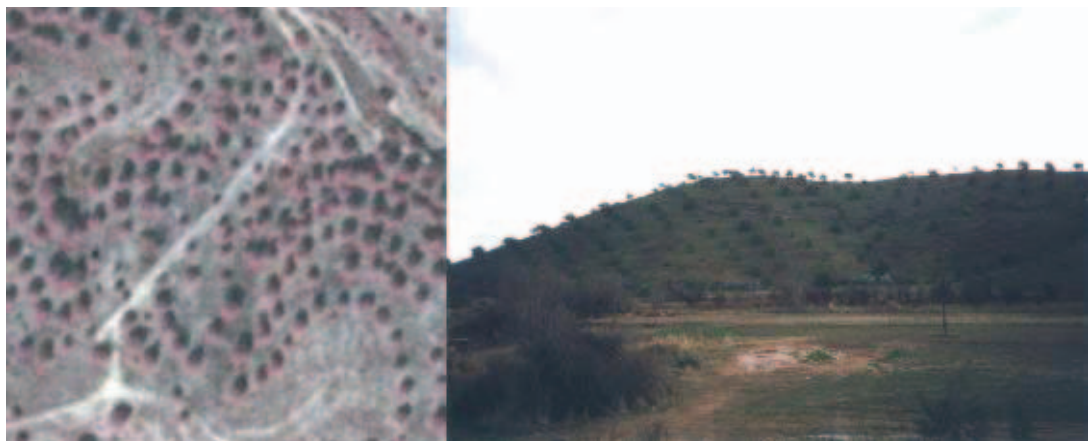| Figure 4.13 | Prague — the IRS image shows the structure of the panel houses |

| Figure 4.14 | Algarve — assigning classes to abandoned land |

Note: Areas where the land use in the imagery appears to be similar to olive groves, yet with a larger space between trees. By fieldwork it was detected that these areas are covered by Ceratonia siliqua. Although this fruit tree plantation does not follow the classic pattern of an orchard these areas were classified as 'fruit trees' (class 2.2.2).
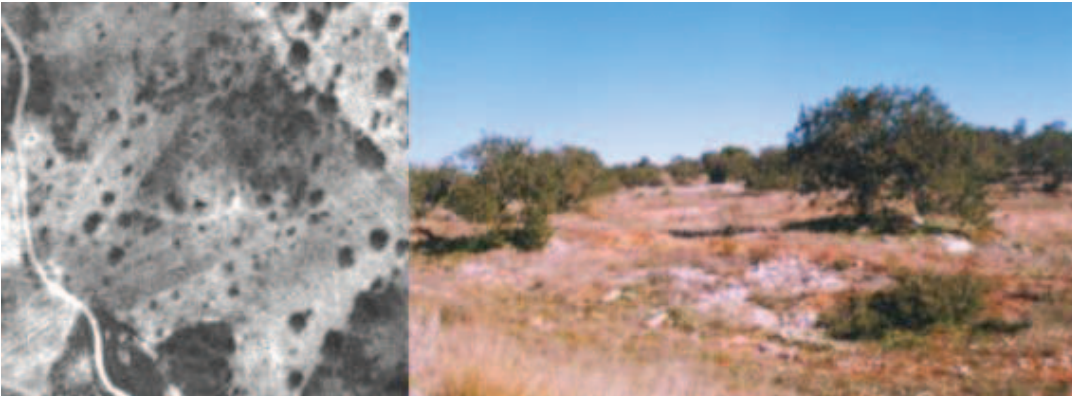
Note: Areas where Ceratonia siliqua is the dominant species and with large abundance of shrubs. Although Ceratonia siliqua is a fruit tree, these areas do not have an agricultural purpose. Because this species is autochthonous in Algarve, these areas were classified as sclerophyllous vegetation (class 3.2.3).

4.2.1. Development process

Some European local authorities have shown a genuine interest in Murbandy/Moland, proposing to co-fund the project itself, in order to include in the study areas, cities and regions belonging to their administrative jurisdiction. Also, workshops were organised with representatives from various international and European agencies, including UNEP, the World Health Organization (WHO), UNRISD, OECD and the European Environment Agency (EEA).

Before answering the question. 'How can a single project be of interest to so many diverse organisations?' it should be pointed out that the methodology adopted by Murbandy/Moland requires a very limited number of highly skilled developers in order to be implemented. The Murbandy/Moland team operates as a 'remote' coordinator, so that the project methodology can be — and usually is — implemented directly 'in loco' by a local partner. Different targeted customers can then carry out the assessment of the products at any level of analysis. Such an approach greatly reduces the costs. Additionally, local authorities usually already own the basic material — satellite data, aerial photographs, master plans, statistical information, etc. — for applying the methodology. When this material is not available, it can nowadays be easily acquired at a moderate cost.

The initial costs therefore are limited, since it is manpower that ultimately determines the expenses. This means that the cost of studying a certain area in Sweden or in Greece will be proportional to the different cost of living in the two countries. Once the database has been prepared, a minimum effort is required for successive updating. The approach has shown itself, on balance, to be quite cost-efficient. For example, the average cost of the Change part of the project was about EUR 90 per square kilometre for the European areas. As mentioned above, such a cost varied considerably from one study domain to another. The land use fabric also affects the costs. The denser the urban fabric, for example, the more accurate the analysis it requires in order to be disaggregated into detailed land use classes. On the other hand, if the investigated region contains, for instance, several water bodies or large almost uniform vegetated areas, the classification exercise is relatively simple.

The project is now in the phase of investigating likely difficulties in exporting the methodology to non-European and developing countries. It is also worth noting that the level of detail required to carry out assessments in Europe is probably too high for developing countries, which have different priorities. Due to the much lower cost of manpower, transferring the methodology to southern countries is expected to be proportionally less costly. However, the larger the area is, the higher the cost will be: studying a mega-city is expensive. Moreover, European areas tend to be compact, while in other continents the phenomenon of 'sprawl' is more evident. For example, the core urban area of Munich is 300 km^2 while the core urban area of Bangkok is 1 000 km^2. Clearly, even if the level of detail of the Bangkok database is reduced, the size of the study domain is so large that costs cannot be reduced very much.