Chapter 13
ArcGIS Processing Models for Regional Environmental Planning in Bavaria

Jörg Schaller, Thomas Gehrke and Nathan Strout

13.1 Introduction

Over the past five years, the Geographical Information Systems (GIS) laboratory headed by Jörg Schaller at the University of Technology Munich (TUM) has worked on the development of new GIS software processing tools and models for environmental planning and management. The research cooperation between the University of Technology in Munich, ESRI Germany and ESRI Inc. in Redlands and the University of California in Redlands involved the development of new applications of ESRI's *ModelBuilde*r software for planning support, and is based on the existing experience of the four institutions. The cooperation focused on the development of GIS environmental modelling technology to provide new applications in the field of regional environmental planning and assessment, and the applied model and software tools were tested using existing regional databases from Bavarian and Californian sources, and applying them in actual regional planning projects.

The chapter will therefore describe the methodology of the related Geo-Database generation, the *ModelBuilder* technology and the geoprocessing applications for regional planning. The result of the successful research cooperation between the four institutions has been the development of general GIS processing model structures for the regional Landscape Development Concept (LDC) in the Munich planning region and an urban growth model for the Munich and Redlands regions. The graphical interface that is used for creating models allows an entire processing package to be run over and over again with the click of a mouse, which means that a GIS analyst can change a parameter quickly and easily. This optical interface structure makes GIS planning processes simple to understand, and allows more efficient teamwork, even via the Internet.

The Environmental Model applications themselves were carried out to deliver results for political planning decisions. The presentations of the results to regional governmental bodies and to the involved public were very successful, since the

J. Schaller (✉)
ESRI Geoinformatik GmbH
Ringstrasse 7, 85402 Kranzberg, Germany
E-mail: j.schaller@esri-germany.de

S. Geertman, J. Stillwell (eds.), *Planning Support Systems Best Practice and New Methods,*
DOI 10.1007/978-1-4020-8952-7_13, © Springer Science+Business Media B.V. 2009

workflow diagrams were excellent for easy explanation of the complex planning and assessment steps that had been carried out. The new GIS-based planning and modelling technology therefore strongly supports the acceptance of modelling and planning results by decision makers and the public. The two selected planning examples will illustrate the advantages for optimising and speeding up planning procedures from data collection to support for decision making, and for the new possibilities for documenting planning and decision procedures for the public.

13.2 Background

In order to support actual regional planning projects, the ESRI *ModelBuilder* technology was used to support complex planning issues. During 'normal' GIS work in a planning process, GIS analysts use one tool after another to complete their task(s) and must always be aware which working step they are completing at any one time. If the data changes (e.g., new protection areas have been established), most of the work has to be repeated. It is also not really feasible to work with a team on a project unless detailed data documentation has been written in a final form. In contrast, the *ModelBuilder* technology opens up a workspace in which the user can 'plan' the GIS jobs to be carried out, and ultimately run them. Parameters and input data can be changed again at any time, and the model can be run again with these new settings with a click of the mouse. Therefore, it is not necessary to open the whole GIS data processing model before running the model. Since all tasks are documented graphically, the work can therefore be planned by a team, since all working steps are traceable.

Actual regional planning activities requirements necessitate intensive geo-data processing in which many existing geo-datasets must be processed to create output datasets using geoprocessing tools, scripts or models. Accordingly, the *ModelBuilder* innovation allows complex actions to be displayed in the form of flux diagrams in a graphical user interface. Thanks to the diagram, every step of the whole process can be traced and documented on the fly. Planners themselves are able to run the necessary operations because they are very simple and intuitive, since datasets or tools can be selected by drag and drop into the model window and connected graphically with arrows according to the planning and processing workflow. Together with the model, other planners, decision makers, and, not least, the public, can follow the planning process. The result can be stored and used as tool for future applications, or for providing the application to other planners for similar planning requirements with different Geo-Databases, e.g., as a template for necessary modifications (McCoy 2003).

13.2.1 ModelBuilder Window

The *ModelBuilder* window (Fig. 13.1) consists of a display window in which users build a diagram of the processing model, a main menu and a toolbar that they can

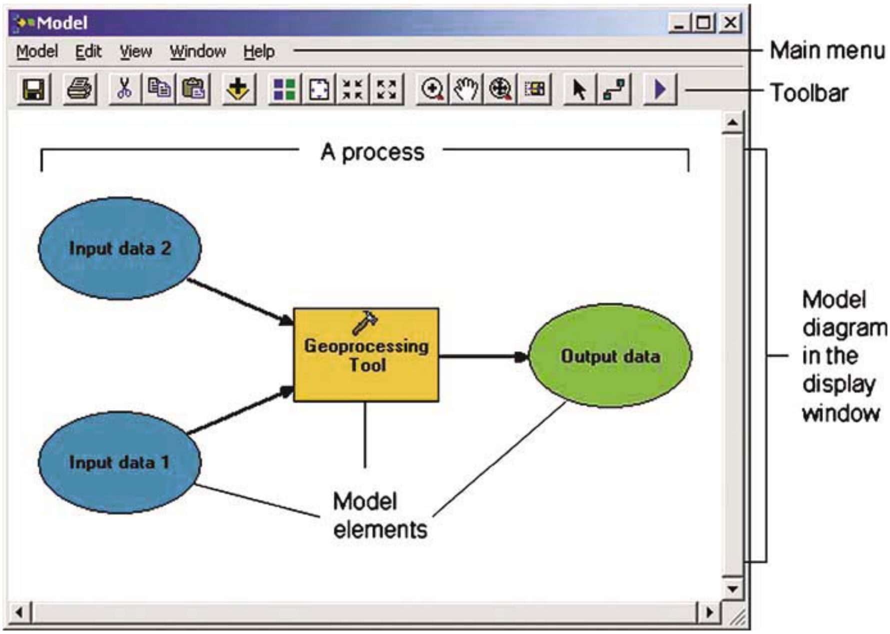

Fig. 13.1 ModelBuilder window

use to interact with elements in the model diagram. They can run a model from within the *ModelBuilder* window or from its dialogue box.

One of the easiest ways to author and automate a workflow and keep track of a geoprocessing task is to create a model. A model consists of one *process*, or, more commonly, multiple processes strung together. A process consists of a *tool* – a system tool or a custom tool – and its *parameter* values. Examples of parameter values include input and output data, a cluster tolerance and a re-classification table. The model presented here allows the user to perform a workflow, modify it and repeat it over and over again with a single click of the mouse. ArcGIS 9.x presents a comprehensive set of geoprocessing tools that work with all the supported data formats, including Geo-Database features. It also offers a completely new framework for working with these tools that enables the user to open them individually, combine them in a visual modelling environment, write scripts in standard scripting languages, and run the tools as commands in a command line window.

13.2.2 Personal Geo-Database and ArcToolbox

The new ArcGIS Personal Geo-Database format (Fig. 13.2) has been used to store all geographical information. Unlike the older shapefile and grid data formats, in which all data are stored in separate files, the Geo-Database stores all relevant information in one single database. As based on the MS Access format, some information (tables) can also be read but not written with Access. As shown in Fig. 13.2, a

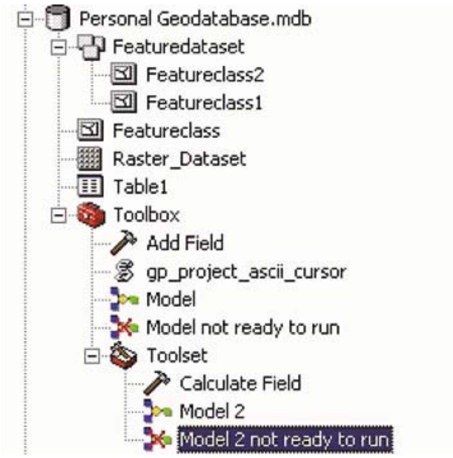

Fig. 13.2 Structure of a personal Geo-Database

Geo-Database can store geographical information directly as feature classes (vectors), raster datasets and tables. Information with the same spatial extent and geographical features can also be combined into feature datasets.

Additionally, toolboxes can be integrated into the Geo-Database. A toolbox can contain tools, scripts, toolsets and models. Normally, only a handful of tools are used within a model. For quicker accessibility, it is advisable to copy these tools into one central toolbox. This is even more convenient if self-compiled scripts are being used in one model. In ArcGIS, the Toolbox is a dockable window that is integrated into all the ArcGIS Desktop applications. For example, when users run tools from the ArcToolbox window in ArcMap, they can use the layers of the current map as inputs, and the outputs can be directly added to the map as new layers. In ArcGIS *ModelBuilder*, these tools can be dragged and dropped into the model and set up. If teamwork is required, only one database has to be spread within the team, and all data, tools and models are contained within it. Models that are not ready to run are crossed out (e.g., if some data or a tool is missing).

13.2.3 Model Elements

As described in the previous section, an ArcGIS model consists of model elements. These can be divided into three categories: input; processes; and output.The model elements are represented in the user interface in form of graphical symbols such as ovals and boxes in different colour.

13.2.3.1 Input Data

Input data are represented by a dark blue oval. They can be raster and vector data, as well as single input values such as numbers. By default, the oval shows the name of the input data, but can be renamed afterwards. Input data can also be specified as a parameter (oval shows the letter P next to it). Input data specified as a parameter appears in the model parameter dialogue box, and can be changed/replaced there before running the model.

13.2.3.2 Input Expression

Instead of input data, a SQL expression can be used. Such an expression is represented by a light blue oval. A dialogue box can be used to generate the expression. If a tool property is set as a parameter, the P symbol does not appear next to the tool icon, but instead a new input parameter oval will be visible in the model.

13.2.3.3 Tools

The input data is normally processed by a tool. The GIS software offers a huge amount of predefined tools that can be dragged and dropped into the model and connected to the input data. The tools settings can be altered in the properties dialogue.

13.2.3.4 Scripts

A script can be used as a tool. The scripting language can be Python, VBScript, Jscript or Pearl, whereby Python is used for most of the predefined scripts. The settings for a script can be altered the same way as for a tool, while the source code can be modified directly from within the model.

13.2.3.5 Embedded Models

Sometimes, a calculation needs several processes to be completed (e.g., a specialised tool is missing and must therefore be done by two or more tools). In order to keep a model clearly arranged, it is wise to put these processes into a separate model and to embed this into the main model. This is extremely useful if the calculation has to be executed several times in a model. The whole model appears as only one tool, with a small model symbol on top. For modifications, the embedded model can be opened and modified within the main model. The selected tools, scripts or embedded models are represented as yellow boxes in the user interface.

13.2.3.6 Output Data

Output data are represented by a green oval. The type of output data is dependent on the tool producing this output. Only the name and path of the output can be changed. Sometimes, a tool produces several outputs (e.g., the distance tool that derives a distance grid and a direction grid). If this remains unused, it is symbolised by a white oval.

13.2.3.7 Model Parameter Dialogue Box

Before running a model, the dialogue box with all model parameters opens (Fig. 13.3). All properties set as a parameter can be changed here (e.g., data path, re-classification table, SQL expression).

13.2.4 Sub-models

In order to keep a model clearly arranged, it is most important to keep it 'readable' for other persons (e.g., clients, planning partners in the team). A model for urban growth, for example, cannot be done with a handful of processes. It is therefore useful to arrange the processes into sub-models with specific topics. The following application examples will show the issue-based selection of sub-model topics and their integration to final planning results (Schaller *et al.* 2006).

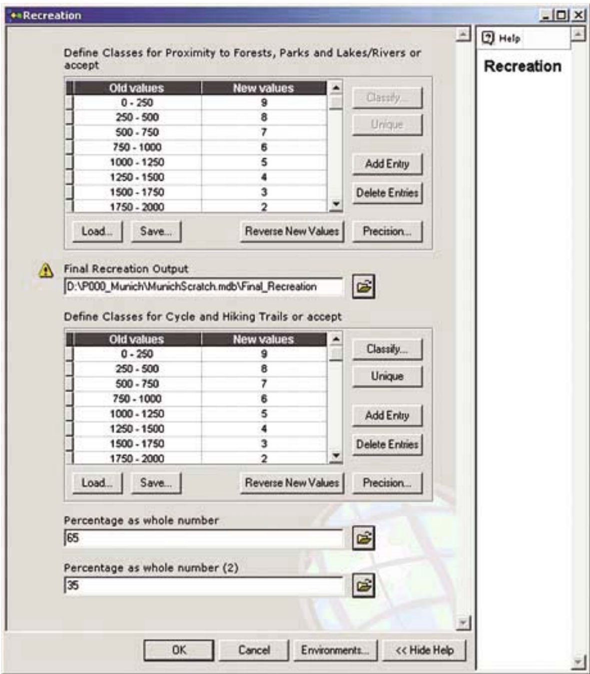

Fig. 13.3 Model parameter dialogue box

13.3 Application Examples

13.3.1 Munich Planning Region

The planning region of Munich, the capital city of Bavaria in southern Germany, is an economically strong and dynamically growing region. The Munich region has a population of 2.5 million distributed over 5,504 km^2 in 199 municipalities (*Gemeinden*) contained within nine districts (*Landkreise*). Munich city has a population of 1.2 million spread over 310 km^2. The continuing growth requires additional land development for infrastructure, commercial and housing requirements.

13.3.2 The Landscape Development Concept (LDC)

The dynamic growth of the region is having an increasing impact on natural resources such as soils and water and air quality, and is associated with land development, intensification of land use and increasing pressures on nature and the landscape. The result is a decline of living quality and loss of natural landscape quality. Sustainable development of this regional growth is not yet guaranteed, while the inhabitants of the region place high demands on maintaining their existing outstanding quality of rural landscapes and the open spaces of the city and region for recreation. The regional government, therefore, decided to create a planning concept for sustainable development based on GIS and environmental planning methods and advanced modelling technologies for further application, with permanent updating to follow up the impacts of growth and the results of planning measures for sustainable development. The LDC therefore makes an important contribution to the sustainable protection and development of the natural resources of the region. It also supports decisions for the

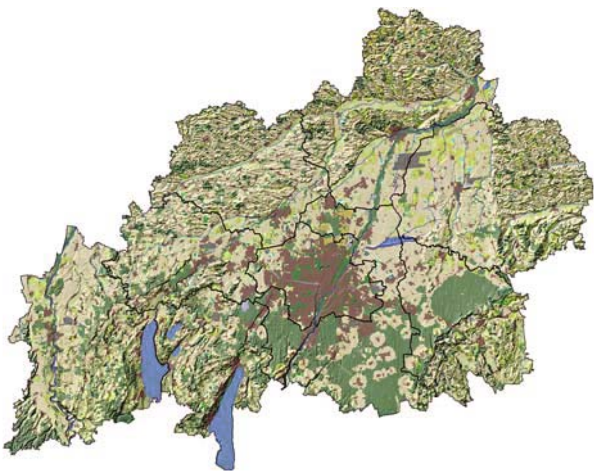

Fig. 13.4 Land use map and digital terrain model (DTM) of the Munich planning region (Schaller and Schober 2007) (See also Plate 30 in the Colour Plate Section)

regional plan in the field of environmental protection, as well as for the maintenance of nature reserves and visual landscape quality (Schaller and Schober 2004).

13.3.2.1 The Goals of LDP

The main general goals of this regional planning concept are:

- maintenance, protection and development of nature and landscape as compensation for intensively used urban areas;
- protection and sustainable development, and utilisation of the natural resources;
- development of open-space and green-belt concepts for the city and region as a foundation for the maintenance of living quality in the region; and
- proposals for sustainable land use and land use development, especially for commercial, housing, transportation and water management, and also agriculture, forestry and recreation demands.

To support this LDC, complex spatial issues need to be solved for the planning workflow and the display of results for effective decision support: What quality and sensitivity do the natural resources have in the region? What are the actual environmental impacts on population, nature and visual landscape values? What are the actual planning and development scenarios for the next 20 years? What qualitative and quantitative changes are caused by these developments, and how can these be compensated by planning measures? How can these complex inter-relationships be communicated to decision-makers and the public? (Schaller and Schober 2004).

13.3.2.2 The LDC Geo-Database

The first step was the creation of an issue-based Geo-Database structure containing all necessary spatial information to solve these planning issues, such as abiotic resources, biotic resources, land use changes and planning data (Arthur and Zeiter 2004; Booth *et al.* 2004). These data include the following: topographical data – digital terrain model (DTM); nature protection and biotic resources; geology, soils and soil quality; surface water and groundwater resources; local climate, air quality and ventilation; noise, eutrophication and other impacts; administrational boundaries; statistical data related to municipalities; actual land use data from aerial photographs; and municipality and infrastructure master plans. The data structure is related to the main issues of the project, documented in the personal Geo-Database and can be visualised with VISIO. Figure 13.5 depicts an example of this documentation for the soil database and related thematical maps.

13.3.2.3 Assessment of Natural Resources and Land Use Impacts

The natural resources of the planning region are assessed on the basis of function, quality and development potential. Actual and planned land use types are assessed

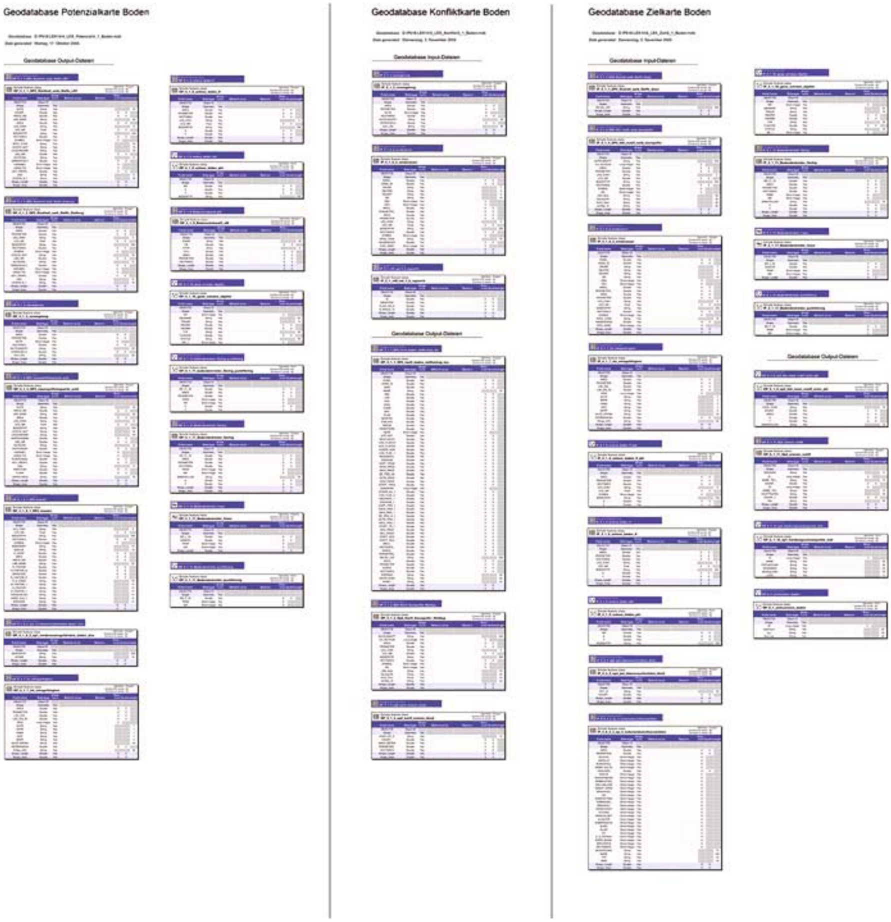

Fig. 13.5 Example of a VISIO documentation of part of the LDC Geo-Database

by intensity and impacts on natural resources. The derived conflicts were modelled and general and specialist goals for sustainable land use and development formulated from the results of the conflict analysis for each abiotic or biotic resource, as well as impacts on human requirements. Typical examples of abiotic resource functions or environmental risks that can be either reduced or exacerbated by land use impacts are described in Table 13.1.

13.3.2.4 Creation of Resource Assessment Maps

The first step of the model application was therefore the creation of resource assessment maps that provided the basic information for the conflict and impact analysis. As an example, Fig. 13.6 depicts a sectional map of the soil potential and yield classes for agricultural land use (Schaller 2004).

Table 13.1 Examples of abiotic functions or risks impacted by land use

Soils	• Buffer capacity for absorbable substances • Erosion hazard
Water	• Groundwater recharge • Floodplain functions (retention) • Flooding risk
Air quality, local climate, noise	• Energy exchange functions • Ventilation functions • Noise impact
Biotic resources	• Wildlife preservation functions • Species diversity and biotope network functions
Recreation	• Recreational functions of the landscape

13.3.3 Processing Model Applications for LDC

In order to estimate possible impacts of actual land use or land use changes, very simple relationships between resource potentials and sensitivity of impacts were initially described in conceptual relationship models. Figure 13.7 depicts examples of these conceptual models and a table of the assessment criteria used, in this case in relation to soil resource functions. For each conceptual base model, a detailed

Fig. 13.6 Soil potential and yield classes for agricultural land use (See also Plate 31 in the Colour Plate Section)

model was developed in a second design phase with a direct relationship to the existing Geo-Database and scientific assessment criteria from literature and expert ratings. In some cases, based on the issues to be solved and the additional input of expert know-how, the primary Geo-Database had to be expanded. Figure 13.7 depicts the related detailed model structure for calculation purposes, e.g., the soil erosion hazard using the Geo-Database.

13.3.4 Sustainable Development Goal Maps

In order to develop general and detailed goals for sustainable land use and resource protection, the resource function maps were overlaid with land use maps in a processing model to illustrate the actual conflicts between land use and resource functions. Based on the intensity of conflicts in relation to the protection and sustainable development goals, general goal maps have been calculated and displayed as the model output in the form of thematic maps. Figure 13.8 depicts such an example of a result map for the protection and development goals for groundwater and surface water resources in the region.

13.3.5 Urban Growth Model

In order to estimate possible impacts on natural resources and visual landscape quality in the future, an urban growth model framework was developed. The model for urban growth in regions is divided into three parts: six sub-models, each handling one specific topic; the main model called 'settlement suitability'; and a model adding the time dimension.

Although the input data for the models are available as vector data, most of the calculations are done in raster format. For performance reasons and for storage space efficiency, a raster resolution of 100 × 100 m has been chosen that can easily be rendered more precisely at a higher spatial resolution if required. The raster format allows some mathematical operations to be carried out more quickly and easily, e.g., a weighted overlay or distance calculations. Suitability classes used in the following models comprise ten classes with a range from 0 to 9: 0 is unsuitable, 1 very low suitability, 5 medium suitability, and 9 is very high suitability (Schaller *et al.* 2006).

13.3.5.1 Sub-models

In order to keep the growth model clearly arranged, the following sub-models were defined: exclusion of 'taboo' areas, restrictions for urban development, landscape suitability, land use, proximity to existing infrastructures, and recreation potentials. These sub-models each deliver a final result for the specific topic. They are

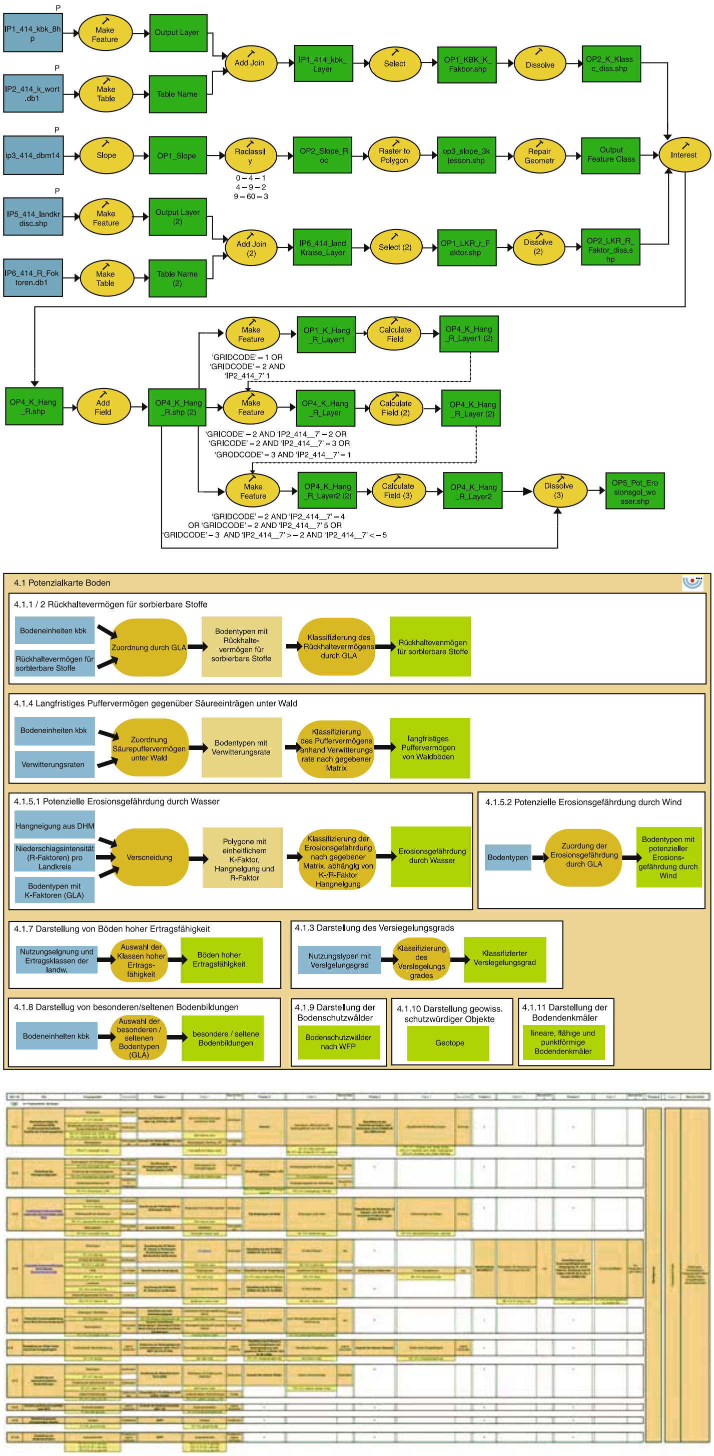

Fig. 13.7 Conceptual and detailed processing models for resource assessment

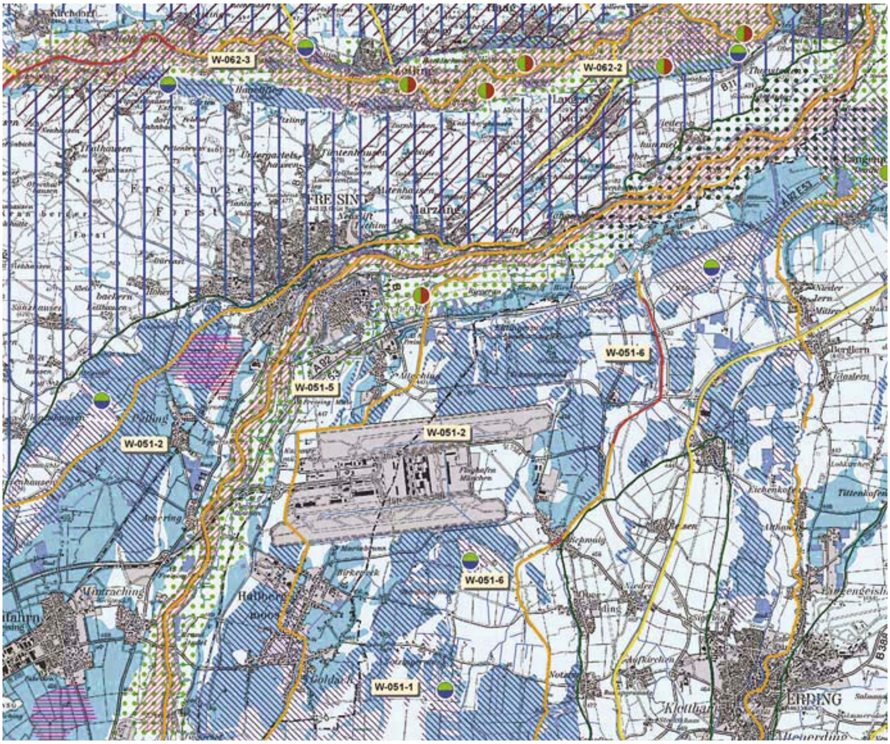

Fig. 13.8 Protection and sustainable development goals of groundwater and surface water resources in the region (Schaller and Schober 2007)

implemented into the main model as embedded models. Areas that are unsuitable for settlement are handled in the 'exclusions sub-model' and include: water surfaces, water protection areas, flood areas, biotopes, flora fauna habitat (FFH) areas, special protected areas (SPA) for birds, Ramsar bird protection habitats, and nature protection areas (NSGs). These are treated as taboo areas, and are excluded from any further examination.

13.3.5.2 Restrictions for Urban Development

The restriction model is more complex than the exclusion model. All restrictions are given a suitability value in the range from 0 to 9 that the planner can change before running the model. By assigning a value of '0', it is also possible to regard a category as exclusion. In the second step, the planner can weight the restrictions against one another. A tool checks whether the entered values add up to 100 per cent, or otherwise reports an error. This mechanism has also been used in some of the following models. In the restriction model, the following categories are examined: forest reservations, greenbelts, dividing green corridors, landscape retention

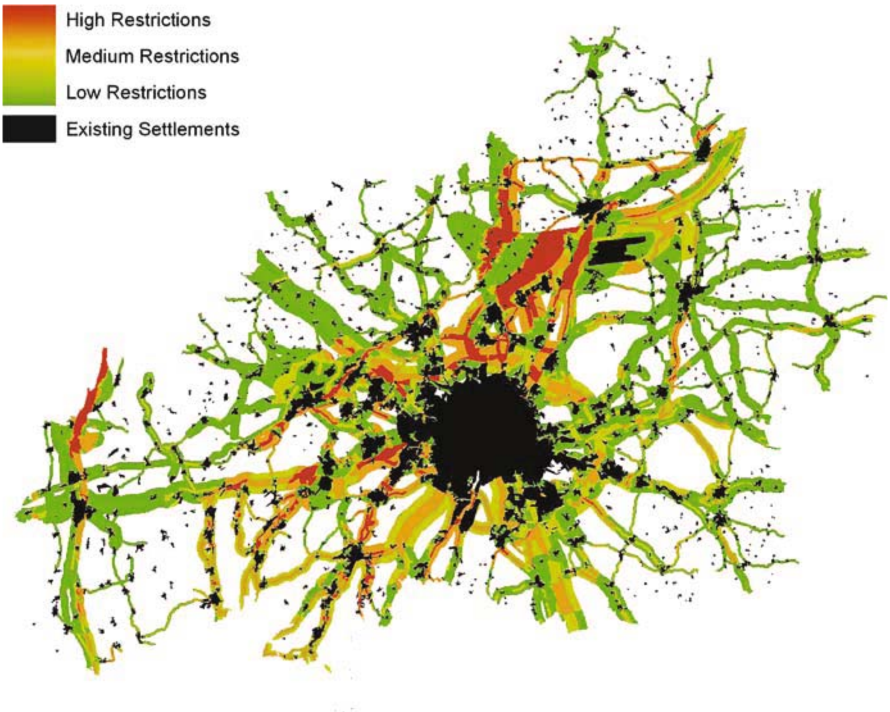

Fig. 13.9 The final restrictions raster (white spaces = no restriction) (See also Plate 32 in the Colour Plate Section)

areas, landscape protection areas (LSGs), and noise impacts from transportation and traffic. After the model has verified that the weighting adds up to a hundred per cent, the suitability is calculated for all six categories. In the following steps, these are added up to one geometry showing the settlement suitability for all restriction categories. The result map of the restriction model (Fig. 13.9) shows the number of restrictions per raster cell, as all six categories have been weighted almost equally. In this example, low represents only one restriction, whereas high stands for up to five restrictions.

13.3.5.3 Landscape Suitability

This sub-model covers two topics that are very much related to one another. Firstly, it evaluates the suitability of the soil potential where new settlements should not be built, for example: gley and mixed forms of groundwater-influenced soils, cultivated soils with high yield classes for agriculture, existing settlements, water bodies, wet terrestrial soils, very dry terrestrial soils, and wetlands and swamps. Secondly, it analyses the slope of the relief and reclassifies it to the ten suitability classes. With the weighting factors, it is possible to balance slope and soil suitability.

13.3.5.4 Land Use

The land use sub-model is a simple model that assigns a suitability value to each of the land use categories. Thus, it is more likely that agricultural areas are used for new settlements than, for example, forests. The land use data has been derived from aerial photograph mapping and generalised to the following 11 categories: unused areas; forests; agricultural; military; recreation; mines; transportation, traffic; settlements; industrial, commercial; lakes, rivers, and other land uses.

13.3.5.5 Proximity to Existing Infrastructure

The idea behind this sub-model is that people indeed want to live in ‘green surroundings’. Because, however, most people have to work in the city or a bigger town, and the children have to go to school, the proximity to existing settlements and public transportation as well as a good road connection are important factors for future settlements. Therefore, the proximity model deals with the following categories: proximity to Munich, proximity to other settlements, proximity to railroads, proximity to roads, and proximity to the airport. Cities and towns offer many jobs to the population, which means it is not very advisable to live very far away from these places. Big cities normally offer far more jobs than smaller towns do, and so they are handled separately, and the weighting can be set independently.

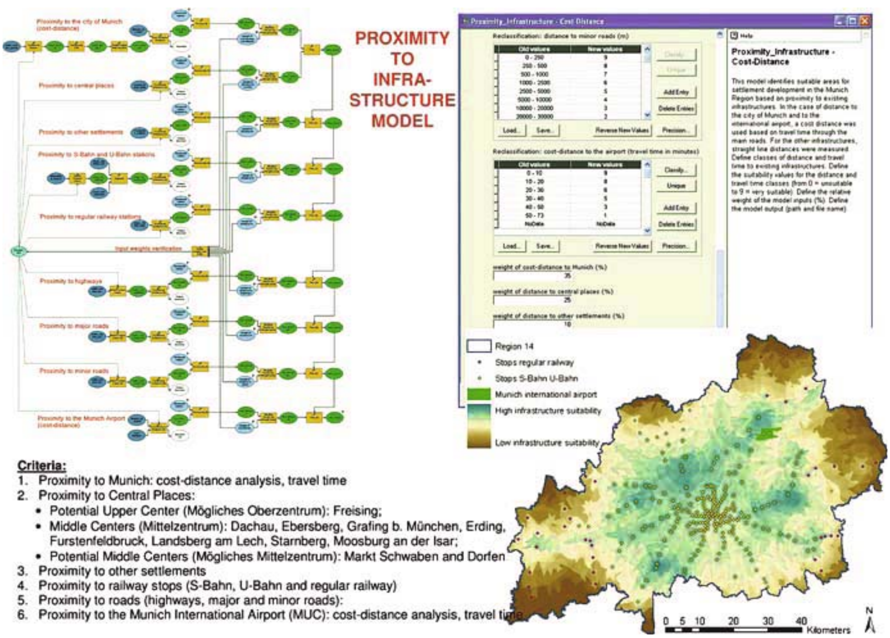

Fig. 13.10 The final proximity model and map result (Mattos 2007) (See also Plate 33 in the Colour Plate Section)

For all people in the region, transportation is a very important factor, as hardly anyone lives within walking distance from their workplace. The proximity to roads for individual traffic and to railways for public transportation are handled separately in this model. Finally, the distance from an international airport and its connections is important for the population, and for business. The model calculates the Euclidean distance to the five categories separately, and reclassifies the distances into the ten suitability classes. Finally, the partial results are added to the final result. In the proximity model, the suitability classes can be defined individually, and a weighting among the five categories can be set. Figure 13.10 depicts the proximity model and its result. The resulting raster dataset clearly shows the massive influence of the city of Munich and the relatively minor influence of the airport owing to the weighting values chosen. However, the medium-weighted categories such as roads also are clearly visible.

13.3.5.6 Recreation

The idea behind the recreation sub-model is that people prefer to live close to places that are suitable for recreation. This can be a forest, park, river or lake, or also cycle or hiking trails that are used for sport. In this sub-model, the categories cycle trails, hiking trails, lakes, forests, and parks are appended and the Euclidean distance is calculated and reclassified into nine classes for suitability. Figure 13.11 depicts the structure of the recreation sub-model.

In the model properties, the user can modify the class ranges and suitability values, and also alter the weighting of nature-oriented over more sports-oriented recreation. Figure 13.12 depicts the resulting map of the recreation suitability of the

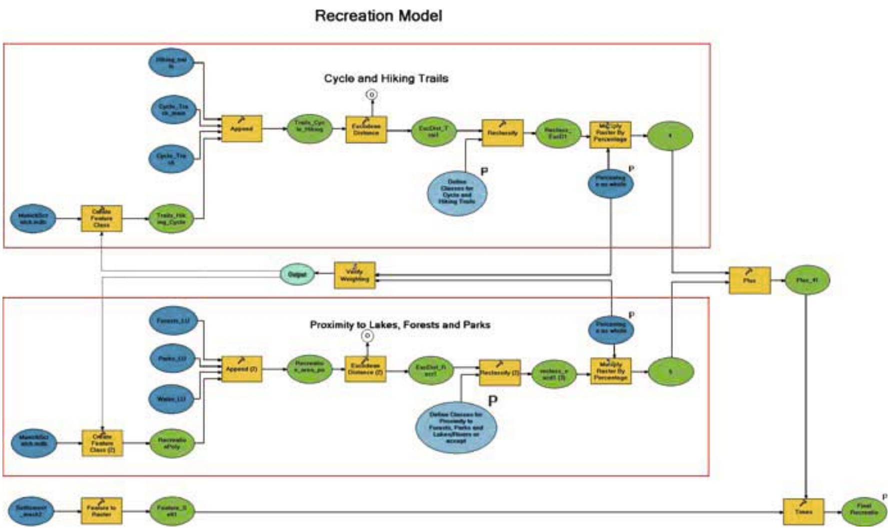

Fig. 13.11 The structure of the recreation sub-model

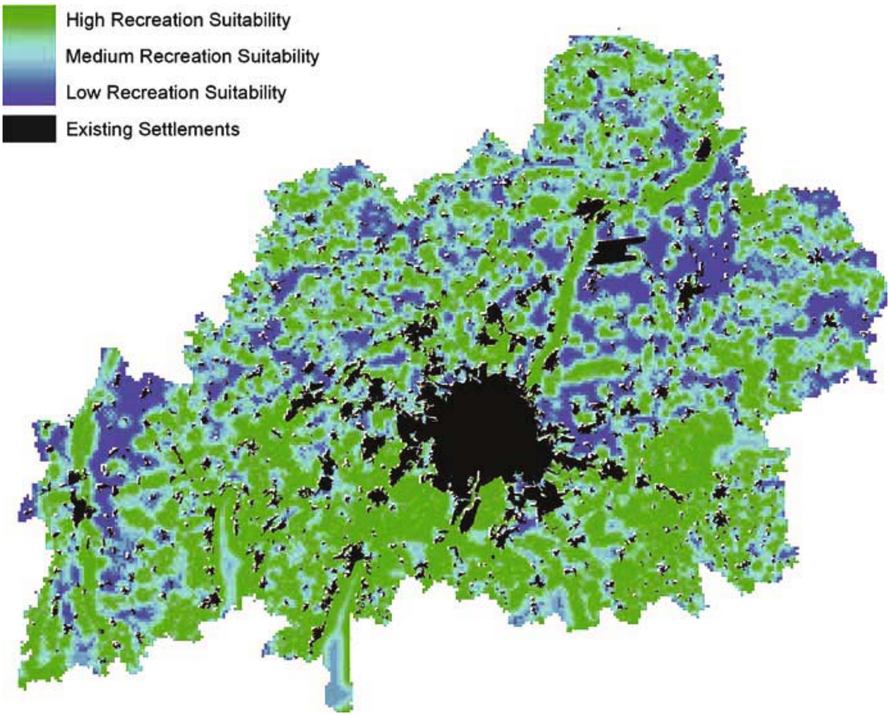

Fig. 13.12 The final recreation raster map (See also Plate 34 in the Colour Plate Section)

region. The resulting raster dataset gives an impression of where people would most like to live (green) from a recreation point of view.

13.3.5.7 The Main Model

The main model is called 'Settlement Suitability', because it finally calculates the suitability for new settlements (the higher the value, the more likely it is that the urban area will grow here first). In the model dialogue box, the user can again specify a weighting of all the sub-models (apart from the exclusions that are taboo zones) that are implemented here. The model first verifies whether or not the values add up to 100 per cent. The model processes the sub-models itself. It contains, or, if already executed, takes their results and weights them as specified in the dialogue box. Apart from the exclusions, all other models can be weighted. The final result of the main model is a raster dataset showing values from 0 (white = not suitable for settlements/excluded areas) up to 9 (red = very suitable for settlements) (Fig. 13.13). The higher the number, the more likely it is that the city will 'grow' into these areas first during the next decades. This growth rate will be analysed in the following model.

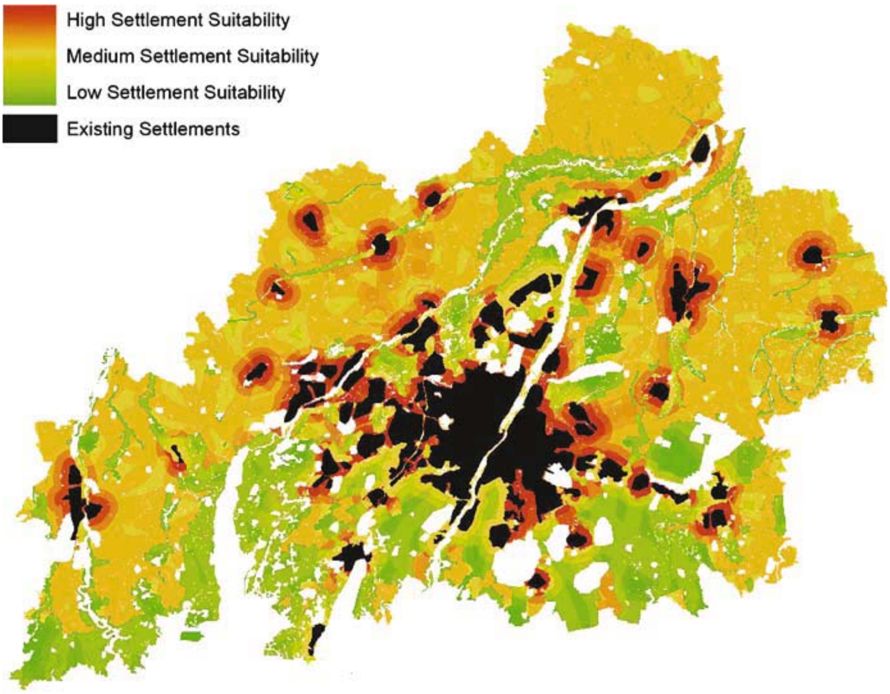

Fig. 13.13 The resulting map for settlement suitability (white spaces = exclusions) (See also Plate 35 in the Colour Plate Section)

13.3.5.8 Time Scale

In the preceding model, the general feasibility for urban growth into the surrounding region has been determined, whereby not only the growth of the city of Munich, but also that of the surrounding towns and villages have been taken into account. With this model, a time dimension will be added (Fig. 13.14). Therefore, the currently existing settlement area will be excluded from the examination.

In the model parameter dialogue box, the user can specify the number of years for which the urban growth will be calculated. The idea of the model is to 'fill up' the region year by year, taking the most likely places for new settlements first and the least likely ones last. The assumed growth rate has been determined from historical maps of the city of Munich. The area of these 'footprints' from the years

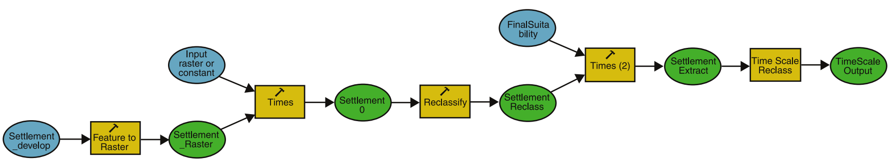

Fig. 13.14 Time model

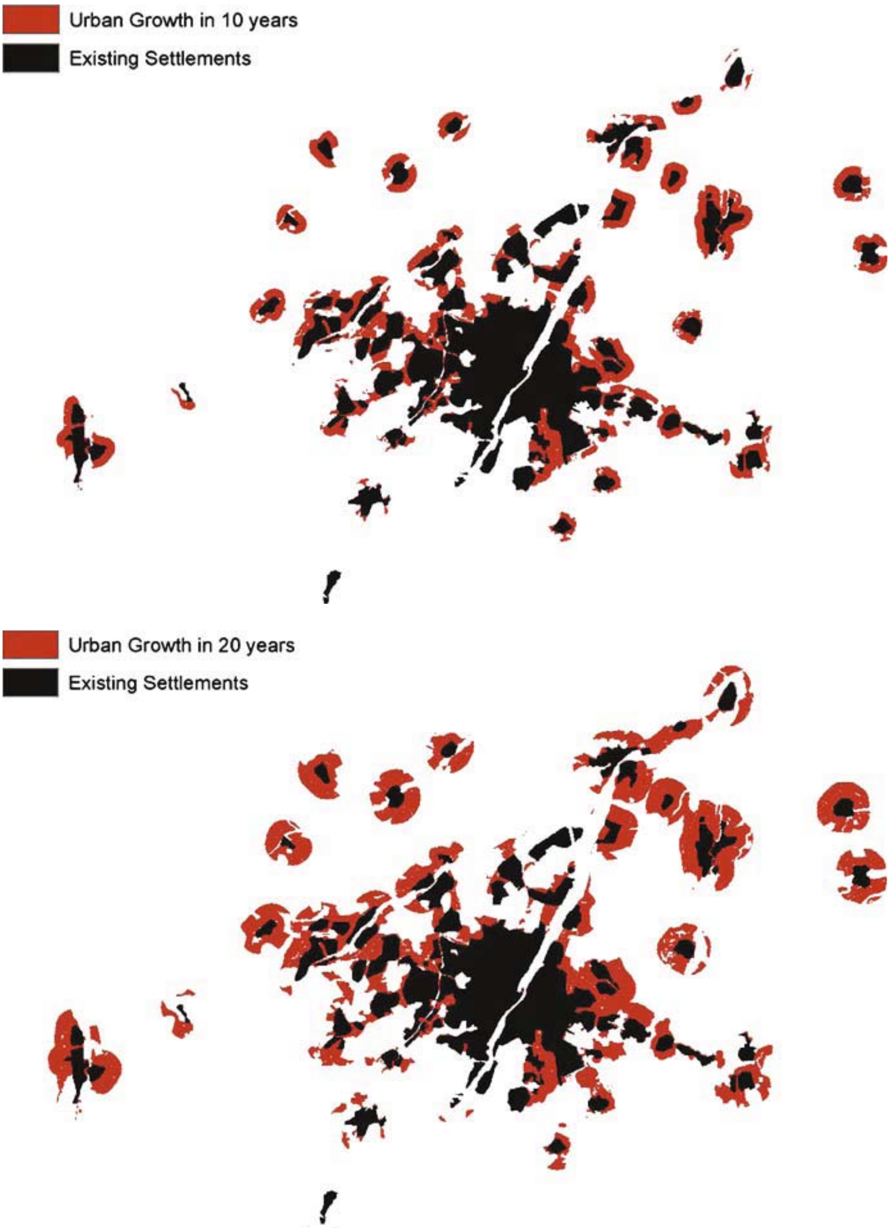

Fig. 13.15 Assumed growth in the Munich region in the next 10 and 20 years

1958–2000 has therefore been calculated and statistically analysed. In the time scale model, the assumed growth for the next decades can be calculated. The resulting maps (Fig. 13.15) show the assumed extent of settlements after 10 and 20 years (Schaller *et al.* 2007).

13.4 Conclusions and Future Research

On the whole, the application of the GIS *ModelBuilder* geoprocessing technology in a actual and large regional environmental planning project for the region of Munich has proved very successful. Nevertheless, the model application for the planning support showed some limitations: *ModelBuilder* processing models can be created only for processes that can be fully automated in relation to the content of the existing Geo-Database; there are certain planning processes that cannot be fully automated, such as data collection and selection, expert rating or expert selections with different data aggregation and weighting types, *et cetera*; and some calculations can be carried out with models, but must be finalised by manual interactions such as the creation of spatial units of visual landscape quality.

On the other hand, it has been shown that the application of this technology has many advantages in the form of an effective and convincing planning support system: better data and process documentation; easy modifications of workflows, updates, GIS processes; simple re-calculation after data and model parameter updates; simple modification of assessment criteria or changes in methodology; better documentation of workflows; models and GIS tools and scripts can be integrated in the personal Geo-Database; the method provides an easily understandable common language between the planners involved; and there is high acceptance by decision-makers and the public, since all planning steps and decisions are highly transparent.

The region of Munich, the districts and municipalities, the public and non-profit organisations, and also commercial and industrial decision makers can use the complex information for their assessments and decisions for the future development of the region. In future, the Internet will be the discussion panel for the different regional players.

Therefore, the following steps need to be taken. Firstly, the delivery of the Geo-Database and the developed models to the regional government, city and regional planners, and also to the municipalities for decision support and own model applications. Secondly, the implementation of the Geo-Database and the models on the Internet for public access. Thirdly, the creation of a monitoring procedure for land use changes and related database updates. Fourthly, the implementation of an Internet-based discussion forum for planners, municipalities and the public to improve the models and the scenario applications. Finally, the provision of models for public use via 'model on the web' technology.

The developed model applications can be improved by future teaching and research activities for planning support systems in the following fields: development of a general Geo-Database design instrument to support the generation of standard planning data descriptions according to INSPIRE and the local planning legislation; development of a 3D GIS model design for real-time simulation of a region and virtual 3D; visualisation of time-related model output or display of planning variants or decisions; development of standard schemes and structures of models and sub-models to be applied to the standard Geo-Databases 2D and 3D visualisation as planning support tools; integration of dynamic modelling technologies for more sophisticated modelling of developments over time (replacement of the time model); and development of a training model package for regional environmental and urban planning designed for planner workshops and university-level curricula.

References

Arthur, D. and Zeiler, M. (2004) *Designing Geo-Databases Case Studies in GIS Data Modeling*, ESRI Press, Redlands, CA.

Booth, B., Shaner, J., MacDonald, A., Sanchez, P. and Pfaff, R. (2004) *ArcGIS9 Geo-Database Workbook*, ESRI Press, Redlands, CA.

Mattos, C.O. (2007) *GIS-Based Modeling of Settlement Development Scenarios in the Munich Region*, Master of Science thesis submitted to the School of Forest Science and Resource Management, Sustainable Resource Management Program, University of Technology (TUM) Munich-Weihenstephan.

McCoy, J. (2003) *ArcGIS 9—Geoprocessing in ArcGIS*, ESRI Press, Redlands, CA.

Schaller, J. (2004) *GIS for Resource Management and Environmental Planning in the Region of Munich,* Redlands Institute, ESRI Colloquium Series, University of Redlands, Redlands, CA.

Schaller, J. and Schober, H.M. (2004) Das Landschaftsentwicklungskonzept (LEK) für die Region München, In Zehlius-Eckert, W., Gnädinger, J. and Tobias, K. (eds.) Landschaftsökologie in Forschung, Planung und Anwendung. Friedrich Duhme zum Gedenken, Freising, Weihenstephan.

Schaller, J. and Schober, H.M. (2007) *Landschaftsentwicklungskonzept Region München (LEK14),* Schlussbericht im Auftrag der Regierung von Oberbayern, unpublished final report, Freising, Kranzberg.

Schaller, J., Gehrke, T., Kemp, K. and Strout, N. (2006) *GIS-Processing Model Development for Environmental Planning and Management*, Research Report, Bavaria California Technology Center (BaCaTec), Erlangen.

Powerpoint Presentations of the Topic at Scientific Conferences

Schaller, J. (2006) *ArcGIS processing models for regional environmental planning in Bavaria*, Presentation at the 21st ESRI EUC, Athens, Greece, 6–8 November.

Schaller, J. (2006) *GIS Processing models for regional urban environmental planning and management*, Presentation at the 44th Annual Conference of the Urban and Regional Information Systems Association, Vancouver, British Columbia, 26–29 September.

Schaller, J. (2007) *ArcGIS—ModelBuilder Applications for Regional and Development Planning in the Region of Munich (Bavaria)*, Presentation at the 16th Czech ESRI GIS User Conference 7–8 November 2007 Praha, Czech Republic.

Schaller, J. (2007) *Sustainable development of the region of Munich using advanced GIS Geo-Database and environmental modelling technologies*, Presentation at the 7th International Workshop on Geographical Information System (IWGIS'07), Peking, 14–15 September.

Additional Readings

Ahern, J. (1999) Spatial concepts, planning strategies and future scenarios: a framework method for integrating landscape ecology and landscape planning, In Klopatek, J.M. and Gardner, R.H. (ed.) *Landscape Ecological Analysis: Issues and Applications,* Springer-Verlag, New York. pp. 175–201.

Batty, M. and Xie, Y. (2005) Urban growth using cellular automata models, In Maguire, D., Batty, M. and Goodchild M.F. (eds.) *GIS, Spatial Analysis and Modeling,* ESRI Press, Redlands, CA, pp. 151–172.

Burrough, P.A. (1986) *Principles of Geographical Information Systems for Land Resources Assessment,* Clarendon, Oxford.

By, R.A. de, Knippers, R.A., Weir, M.J.C., Georgiadou, Y., Kraak, M-J., Westen, C.J. van and Sun, Y. (2001) *Principles of Geographical Information Systems: An Introductory Textbook,* Institute for Geo-Information Science and Earth Observation, Entschede.

ESRI (2000) *ModelBuilder* for ArcView Spatial Analyst 2, ESRI, Redlands, CA. (ESRI White Paper – May 2000). http://downloads.esri.com/support/whitepapers/other_/model_bldravsa2.pdf.#.

ESRI (2003) *ArcGIS 9: Geoprocessing in ArcGIS,* ESRI, Redlands, CA.

ESRI (2005) *ArcGIS 9: Getting Started with ArcGIS,* ESRI, Redlands, CA.

ESRI (2006) *ArcGIS 9: Building Geodatabases Tutorial,* ESRI, Redlands, CA.

ESRI (2007) *Spatial Analyst – Data Analysis Tutorial,* ESRI, Redlands, CA.

Fabos, J.G. (1985) *Land-use Planning: From Global to Local Challenges,* Chapman & Hall, New York.

Goodchild, M.F. (2005) GIS, spatial analysis and modeling overview, In Maguire, D., Batty, M. and Goodchild, M.F. (eds.) *GIS, Spatial Analysis and Modeling,* ESRI Press, Redlands, CA, pp. 1–18.

Krivoruchko, K. and Crawford, C.A.G. (2005) Assessing the uncertainty resulting from geoprocessing operations, In Maguire, D., Batty, M. and Goodchild, M.F. (eds.) *GIS, Spatial Analysis and Modeling,* ESRI Press, Redlands, CA, pp. 67–92.

Maguire, D.J. (2005) Towards a GIS platform for spatial analysis and modelling, In Maguire, D., Batty, M. and Goodchild, M.F. (eds.) *GIS, Spatial Analysis and Modeling,* ESRI Press, Redlands, CA, pp. 19–40.

Maguire, D.J., Batty, M. and Goodchild, M.F. (eds.) (2005) *GIS, Spatial Analysis and Modeling,* ESRI Press, Redlands, CA.

Maxwell, T. and Voinov, A. (2005) Dynamic, geospatial landscape modeling and simulation, In Maguire, D., Batty, M. and Goodchild, M.F. (eds.) *GIS, Spatial Analysis and Modeling,* ESRI Press, Redlands, CA.

Parker, D.C. (2005) Integration of geographic information systems and agent-based models of land use: prospects and challenges, In Maguire, D., Batty, M. and Goodchild, M.F. (eds.) *GIS, Spatial Analysis and Modeling,* ESRI Press, Redlands, CA, pp. 403–422.

Steinitz, C. and Rogers, P. (1970) *A Systems Analysis Model of Urban Change: An Experiment in Interdisciplinary Education,* MIT Report 20, Massachusetts Institute of Education Press, Cambridge.