

# Tisa Catchment Area Development

**TICAD SDSS, a dynamic and spatially explicit tool for assessing the impacts of transnational strategies in the Tisza basin**

Jointly for our common future

# TICAD

This document has been developed in the frame of the Tisa Catchment Area Development (TICAD) project. The TICAD project is co financed by the South East Europe Transnational Cooperation Programme of the European Union.

The document contains the introduction of a spatial decision support system, the TICAD SDSS, which was developed to support the development of the transnational strategy and the pilot actions of the TICAD project.

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## Introduction

The Tisa Catchment Area is located in the eastern part of Europe and has a territory of 157 thousand square kilometres which is rich in natural resources such as water, mineral deposits and fertile soils and has a talented workforce with people from various cultural and ethnical backgrounds. This same area, however, has suffered tremendous losses by wars and animosities and is tormented by natural and technological disasters. Large stretches of land have become unproductive because of subsequent draughts and floods, wastewater has contaminated the waters, neglect and un-thoughtful developments have resulted in the decay of historic monuments, the obtrusive and by now often derelict manufacturing, mining and infrastructure developments have devoured the most beautiful landscapes, and the territory is also losing its most precious resource, people.

In March 2001 the Ministerial Committee of the European Council asked the concerned states (Hungary, Romania, Serbia and Montenegro, Slovakia and Ukraine) to cooperate in order to prevent disasters and plan for a sustainable development within the river basin. This has resulted in the Tisa Catchment Area Development – TICAD – transnational project, which has the aim to harmonise the integrated territorial developments implemented in the river basin, to facilitate the creation of a sustainable economic structure, to optimise the use of natural and cultural resources, to develop areas of competitive growth and to promote the establishment of the internal and external functional interdependencies of the network of settlements.

As part of the TICAD project, a spatial decision support system (SDSS), the TICAD SDSS, was developed to support the development of a transnational strategy. The objective of the TICAD SDSS was to support the goals of the TICAD project by:

- Improving the knowledge of spatial consequences of different measures (mapping of territorial conflicts, tracking the territorial changes in the light of historical processes);
- Harmonizing the use of natural and cultural assets (sustainable land-use, water management and environmental consciousness, shared responsibility for the Tisza river);
- Agreeing on the common development goals and promote the efficient allocation of investment funds.

The TICAD SDSS incorporates a spatially explicit integrated simulation model that allows exploring future developments of the Tisza basin. It encompasses a set of socio-economic and environmental indicators that allow policy analysts to assess and compare the impact of various policy alternatives on those aspects that are found important in the transnational strategy.

This document gives an overview of the TICAD SDSS in the next section, followed by its use potential in planning and policy support in section three. A comparative study between a business-as-usual scenario and the transnational strategy is provided in section four. The final section gives an overview of the project and the consortium partners.

# The TICAD SDSS

## Development process

The proper SDSS development is secured not only by the experienced staff of the DHI-RIKS Consortium but by the close cooperation with the TICAD partners, the users of the system. For this reason frequent interaction throughout the project has taken place to agree on the drivers and indicators to be incorporated in the system and to teach the users how to work with the system. A schematic overview of the process is provided in figure 1.

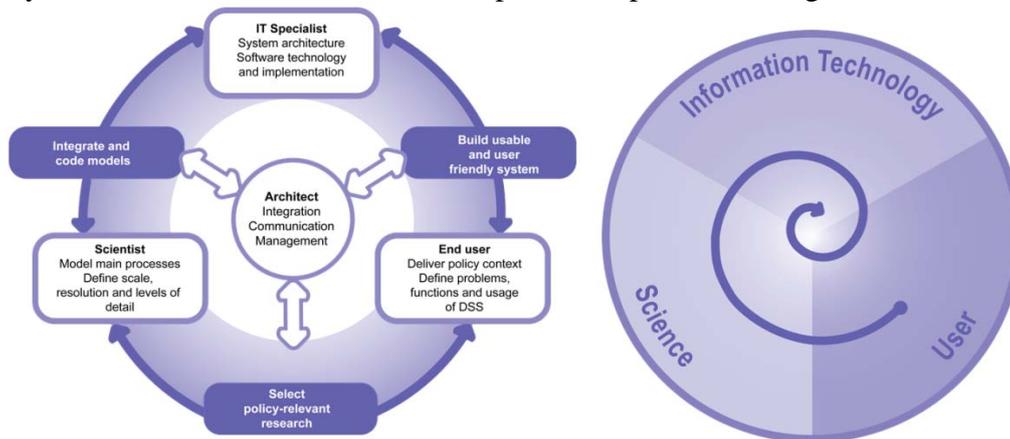


Figure 1.: Schematic overview of the groups involved in the development of the system and the iterative and interactive nature of the process<sup>1</sup>.

## Overview of the system

The developed Spatial Decision Support System (SDSS) is a forecasting tool for planners to simulate and assess the integrated effects of their planning measures in urban and regional development. It simulates the dynamics of changing land use patterns and hydrological conditions and is able to work for a time horizon of up to 30 years. The system consist of a global model covering the whole Tisza basin and three local case studies. The global model incorporates two spatial levels: the regional level and the local level, the latter being a grid of cells of 500x500 m. The case studies all operate at local level and use the same grid as the global model. The difference between the case studies and the global model is that additional information is included in the case studies, either through additional plans or through additional modelling.

The TICAD SDSS includes an embedded MIKE SHE model for the simulation of the water balance and groundwater impacts on land use change and an embedded Metronamica model to simulate the spatial implications of policy options and socio-economic drivers. Due to its integrated nature, information on the water balance and the groundwater table (from MIKE SHE) can be used for the land use allocation (in Metronamica) and the land use configuration (from Metronamica) can be used as input to calculate run-off and infiltration (in MIKE SHE). This link allows to simulate the impacts of climate change on land use developments and environmental processes, but also to simulate the impact of socio-economic growth, infrastructure development and spatial planning on the hydrological conditions. This integrated approach brings to spatial planning the environmental related components (which

<sup>1</sup> Van Delden, H., Seppelt, R., White, R. and Jakeman, A.J., 2011. A methodology for the design and development of integrated models for policy support. *Environmental Modelling and Software* 26: 266-279

are in many cases directly linked to water management) in early phases of the planning process as well as the integration between land use and water with mutual feedback loops.

The paragraphs below describe the three model components included in the TICAD SDSS as well as their interaction:

- A spatial interaction model for the interaction and distribution of population and jobs amongst the regions (Metronamica)
- A cellular automata model for simulating land use developments at local level (Metronamica)
- A hydrological model to calculate the water balance and groundwater levels (MIKE SHE)

### **Spatial interaction model**

At regional level a spatial interaction model caters for the fact that global (river basin wide) growth for population and jobs not evenly spreads over the modelled area, rather that regional inequalities influence the location and relocation of new residents and new economic activity and thus drive regional development. The model arranges the allocation of national growth as well as the inter-regional migration of economic activities and residents based on the relative attractiveness of the regions. For the allocation and relocation of people and economic activities, a standard potential based model is applied: each region competes with all the other regions for new residents and new activities in each of the economic sectors on the basis of its geographical position relative to the other regions, its employment level, the size of its population, the type and quantity of activity already present, and its location relative to the public and the private transportation systems. In addition to these, and novel in the context of interaction based models, summarized cellular measures obtained from the model at the local level -characterising the space within the regions- are factors determining the relative regional attractiveness. The latter are: the abundance of good quality land, the zoning status of that land, and its accessibility relative to the waterways, roads and public transportation. Regional activities are subsequently translated into area demands. Demands for land use classes not modelled by the regional interaction model –normally agricultural and natural classes– are entered as scenarios via the user interface.

### **Land use model**

At local level, a cellular automaton based land use model is used to allocate the land use demands provided by the regional model. Allocation takes place on a grid (the cell size used 500x500 m). Changes in land use at the local level are driven by four important factors that determine the potential for each location for each actor (see also Figure 2.):

1. Physical suitability, represented by one map per land use function modelled. The term suitability is used here to describe the degree to which a cell is fit to support a particular land use function and its associated economic or residential activity.
2. Zoning or institutional suitability, represented by one map per land use function modelled. For different planning periods the map specifies which cells can and cannot be taken in by the particular land use.
3. The accessibility, represented by one map per land use function modelled. Accessibility is an expression of the ease with which an activity can fulfil its needs for infrastructure in a particular cell, based on the infrastructure network(s).
4. Dynamic impact of land uses in the area immediately surrounding a location. For each land use function, a set of spatial interaction rules determines the degree to which it is attracted to, or repelled by, the other functions present in its surroundings; a 196 cell neighbourhood.

If the potential is high enough, the function will try to occupy the location, if not, it will look for more attractive places. New activities and land uses invading a neighbourhood over time will thus change its attractiveness for activities already present and others searching for space. This process constitutes the highly non-linear character of this model.

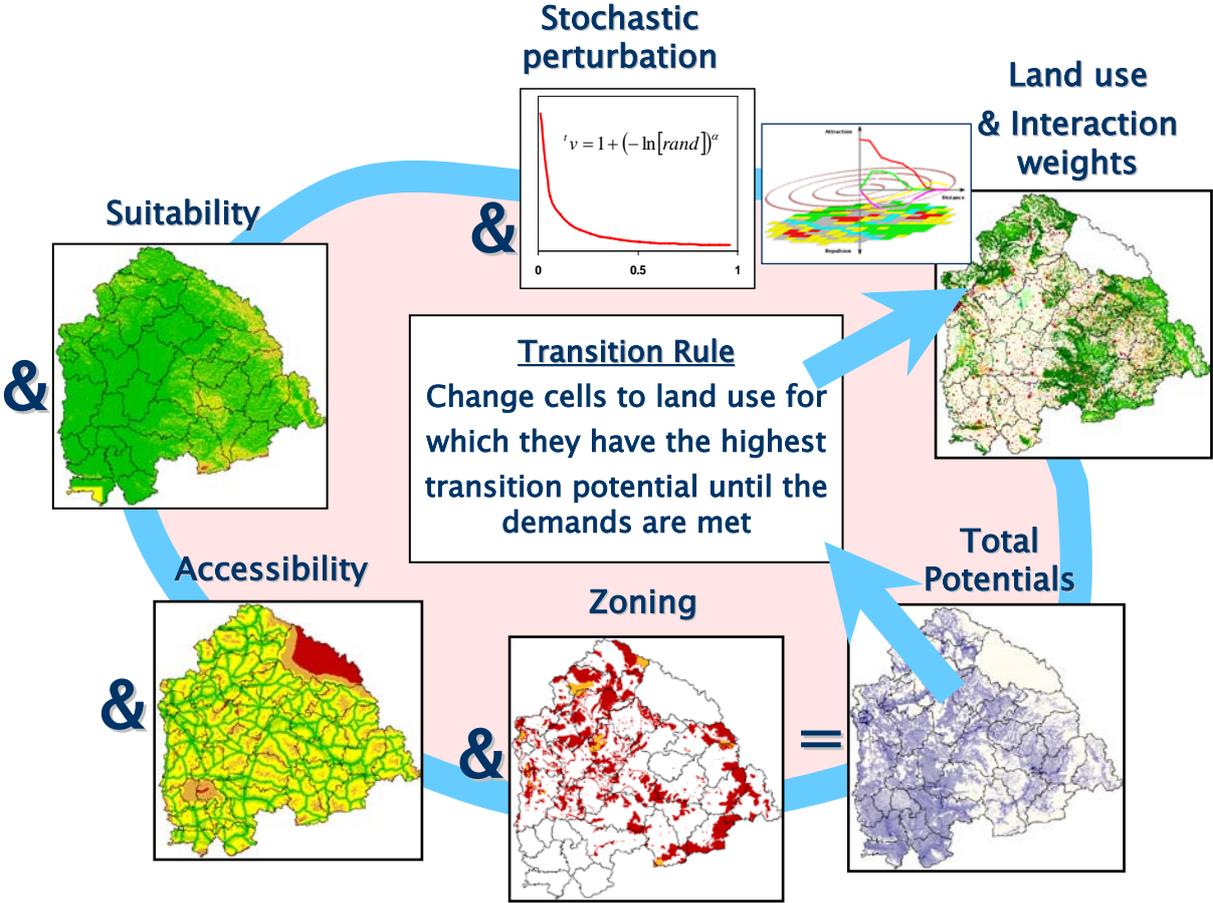


Figure 2.: Schematic overview of the driver of the local land use model. Input from the regional model is used to provide the total area demands for each land use, input from the hydrological model contributes to the suitability.

**Hydrological model**

MIKE SHE is a dynamic, user-friendly modelling tool for modelling hydrological cycles. It is an integrated modelling environment which enables to tailor the integrated model to the needs of the study area and question by selecting the relevant level of detail for each of the processes. The hydrological model enables to analyse the impact of climate change on the target area by providing information on the water balance and the groundwater levels to the land use model.

**Model integration**

The three models comprising the integrated model are all simulation models that start with initial values (if possible data) and use drivers to simulate future developments. For the integration it was therefore decided to use system dynamics as this technique works with stocks and flows, which match well with the modelling approach of the individual models. Figure 3. shows the linkages between the three models. First of all the regional interaction model provides the land use demands for socio-economic and planned land uses to the local allocation model, while the local allocation models provides information on local

characteristics to the regional model that are of relevance for the relative attraction between regions. The local model provides land use information (soil sealing) to the hydrological model, which is used in the calculation of the infiltration and the run-off. The hydrological model, in turn, provides the land use model with information on the depth of groundwater, and the water content in unsaturated zone. This information is used to complement the calculation of the suitability variable (maps for each specific land use) in as such provides input on the impact of drought, flood and inland water stagnation phenomena on the total area of various natural and agricultural land use classes and the allocation of all land uses. Furthermore, it provides the regional model with a change in the overall regional water balance and as such impacts on the total demand of agricultural land uses.

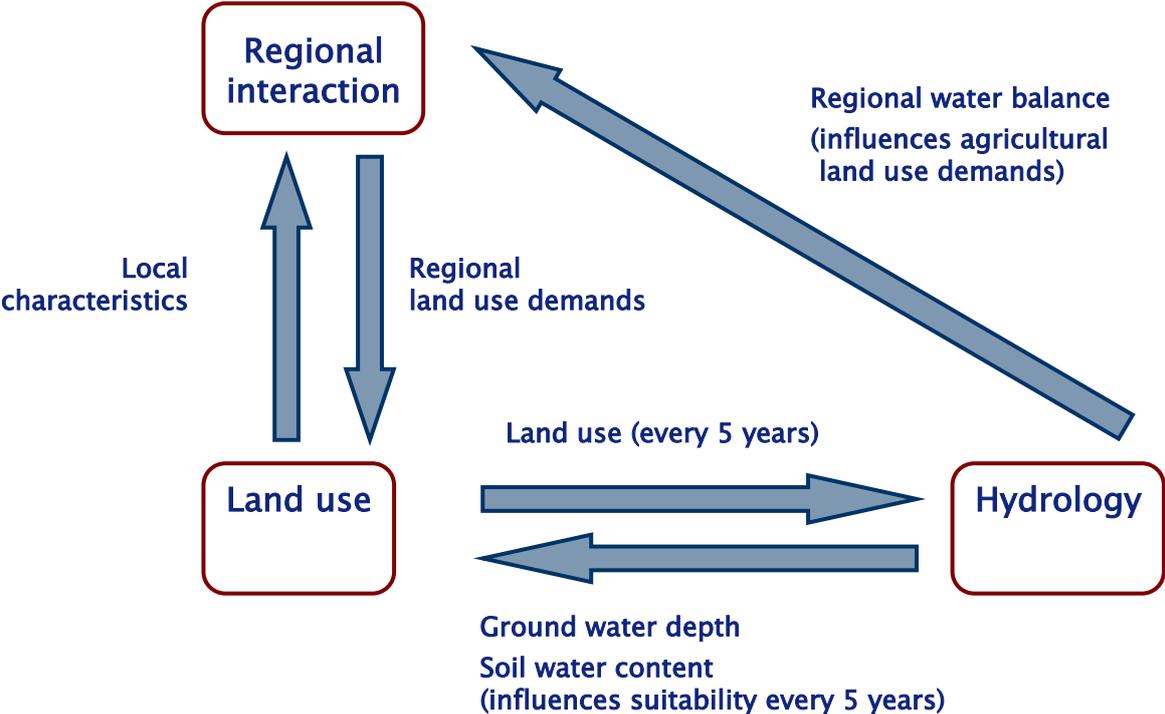


Figure 3: Schematic overview of the interaction between the three models incorporated in the TICAD SDSS.

Due to the connected Metronamica and MIKE SHE software, the relevant and processed climate scenario (CLAVIER project result for Tisza basin: <http://www.clavier-eu.org/clavier/>) was introduced and through the scenario runs its impact was assessed.

**Application**

The developed system includes a spatial interaction model and a land use model for the whole area (Tisza river basin), covering parts of several countries. This part of the application is identified as the global model, and contains the spatial interaction and land use models. The global model is supported by the three pilot area applications, which are embedded into the global model. The pilots enable the user to perform targeted detailed assessment for specific areas such as working with an extended database and perform climate impact assessments. However, as the pilot areas are incorporated into the global level, information from these areas also impacts on the global model. Moreover the same analyzes can be carried out for both levels due to their embedment.

## **Global model**

The application of the global model includes socio-economic data from the national databases of the five countries and from Eurostat and the Corine land use maps. Furthermore infrastructure data and base data for the suitability and zoning maps were provided by the TICAD partners.

The historic calibration of the model was carried out based on the 2000-2006 period, as it was understood that earlier developments would not be representative for future developments. Neighbourhood rules and accessibility parameters were thus set based on experience and historic calibration. The historic calibration was assessed using the Kappa statistics (for the local model) and the Root Mean Square Error (for the regional model) and showed that the calibrated model was able to outperform a neutral model.

In consultation with the TICAD partners it was decided what spatial plans should be introduced and how these should be interpreted. Furthermore planned infrastructure developments were introduced as scenarios.

## **Case studies**

The TICAD SDSS includes three case studies:

1. Somes catchment;
2. Hernad catchment;
3. Ecological network along the Tisza basin covering parts of the Hajdú-Bihar, Borsod-Abaúj-Zemplén and Szabolcs-Szatmár-Bereg regions.

For the first two case studies additional spatial plans provided by the TICAD partners are introduced, giving a more detailed representation of the planning in those areas. Various planning alternatives are included as different scenarios in the software.

For the third case study the MIKE SHE model was set-up and dynamically integrated with the land use and spatial interaction models to provide an integrated assessment of this area and to include the impacts of climate change on the water balance and as a result on the natural and agricultural land uses as part of this assessment.

A deterministic distributed integrated hydrologic type of mathematical model is being established for the third pilot area of interest. We are dealing here with water movement and water balance simulation in a model domain which is not defined as the commonly used “closed” river basin, where we expect surface divide as a model area border. Moreover, the model should be able to give forecasts of future changes for individual parts of the area (in a spatially distributed way).

Finite difference approximation of partial differential equations of water movement was used for most of the hydrological processes description. The MIKE SHE modelling tool scheme uses rectangular grid cells, covering whole area of interest. The grid cell size was set as 500 m, facilitating its integration with the Metronamica model. The modelled area consists of 213 x 234 computation grid cells.

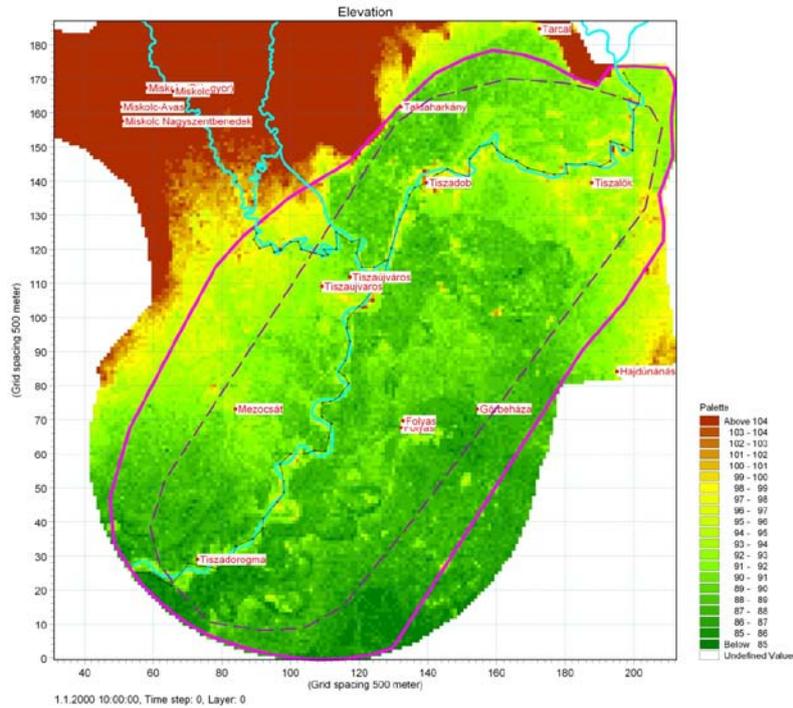


Figure 4.: Model boundaries and digital elevation model of terrain surface

The model area was established according to the project aims and terms as a pilot study, focusing on the riparian zone along a selected river reach. In connection with other areas, treated in the frame of the current project, a strip of wide flood plain in the vicinity of Sajó river confluence with Tisza was selected. The model area does not form any separate block, where we could expect non-permeable boundaries at edge of the model. Due to this, a specific approach was used for boundary condition approximation. The total MIKE SHE model area is limited by thick violet line (figure 4.), while the area where the model results are processed, exported and presented is limited by dark-violet dash line (inside of the previous one). The reason for this is to create some buffer, minimizing the influence of boundary conditions to the model results. This means, that even though the computation is conducted by MIKE SHE for the area between the two lines, this area is not taken into consideration for the water balance results and related data interchange with Metronamica, nor presented as a separate model result. The selected area fulfills the idea of simulation of processes in a “strip along the river” or “riparian zone area” as defined in the project proposal.

By the solution provided the MIKE SHE model supports the user with information for the 30-year modelled period via indicators sent into the SDSS and via the processed and automatically saved results (e.g. groundwater depths in ASCII format) corresponding to the long-term climate condition in Tisza basin.

## Planning and policy support

The TICAD SDSS has the aim to support planning and policy analysis. It is therefore crucial to bridge the gap from the (scientific) models to the policy context. In the development of the TICAD SDSS this has been done by first discussing the main policy themes, drivers and policy-relevant indicators. Based on this policy context drivers and indicators were selected for the TICAD SDSS that were both relevant for policy support and feasible from a modelling point of view. The sections below describe what drivers and indicators have been selected.

Besides a focus on the policy context, it is also important that the TICAD SDSS is a system that can be used by various administrations and organisations supporting the administrations. For this reason a Graphical User Interface (GUI) was created that is easy to use, gives access to different policy options and external factors, and visualises model output and indicators. The GUI gives access to all relevant model inputs and outputs and through its design provides insight into the structure and functioning of the model as well as guidance in the steps that need to be taken to carry out a scenario or impact assessment study.

Since the TICAD SDSS encompasses a complex integrated model, the GUI should be able to provide access to two different types of users: the policy analysts who use the system as part of their policy analysis process and who carry out impact assessment studies with the model, and the scientists, modellers and technicians who can update the underlying data and parameters and possibly even the model equations. The first group mostly benefits from a GUI that follows the steps of a scenario or impact assessment process, the latter prefers to look at the system in a more systemic way and values easy access to individual disciplinary models.

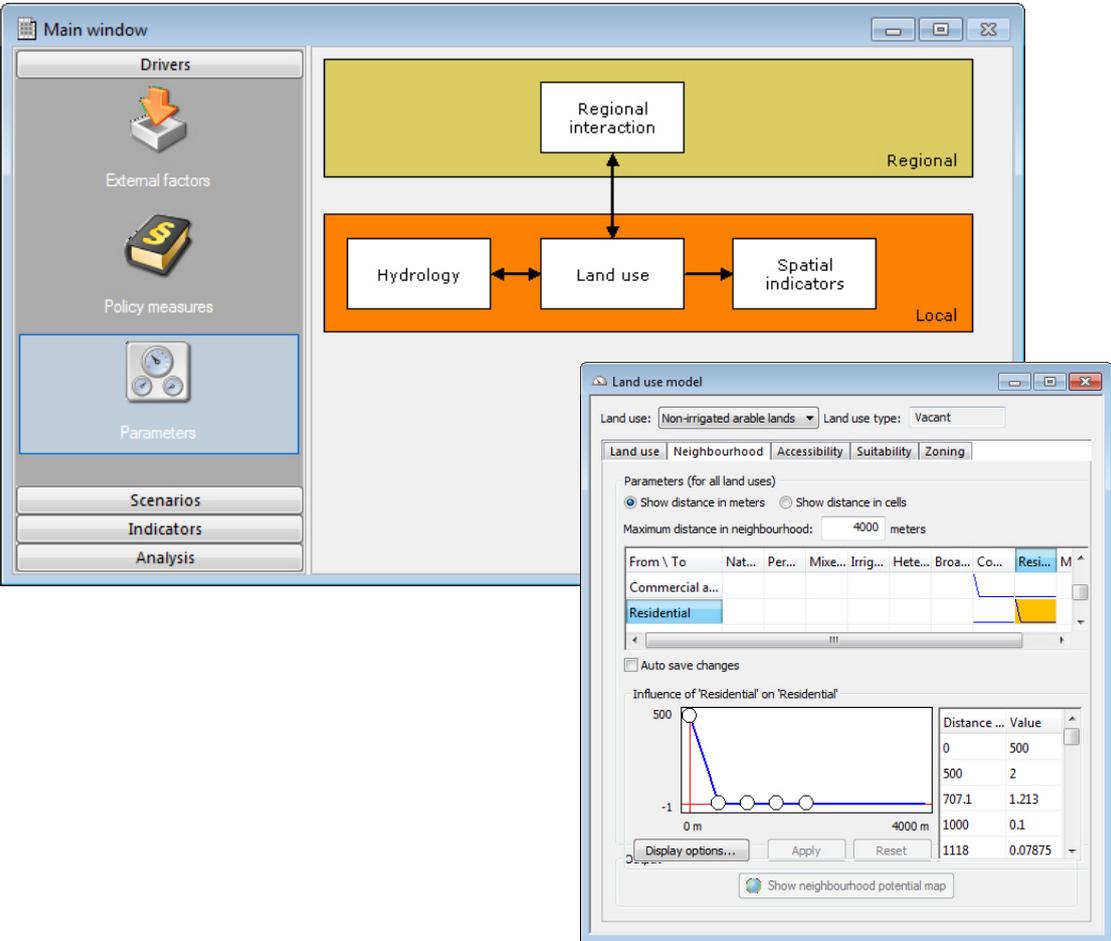


Figure 5.: System diagram of the TICAD SDSS. Clicking on each of the model components gives access to the underlying models. As an example the detailed interface of the land use model component is shown.

It's very important to keep the different goals of the two types of users in mind and show restraint in adding options to the policy user interface. In most cases, exposing the full flexibility that is offered by the models adds little value to a policy user. Providing them with a list of configuration parameters and leaving it up to them to decide the best combination for their specific use will surely not enhance its usability. Design of user friendly interfaces is about anticipating the user's needs, adopting their worldview and expressing the workings of a mechanism in a way that fits their experiences, needs, vocabulary and expectations – and requiring no more user action than strictly necessary.

In the development of the TICAD SDSS, much effort was given on balancing this dichotomy. We carefully examined every piece of functionality of the software (which mostly meant: every setting in the model) for its relevance to policy makers. Only those settings that could in the real world be influenced by policy makers or were found relevant for policy impact assessment studies were included in the policy user interface. The sub-models with all their adjustments are still accessible by scientific users through the advanced user interface. The elements of this latter part of the user interface are grouped per model; each individual model has its own access point through the system diagram, which is accessible through the Main window (see figure 5.).

Access to settings for the policy user is structured not by where they fit into the model, but according to their logical function. On a high level, access is organized by the steps that a user takes to carry out an impact assessment analysis: configure drivers, create integrated scenarios, run the simulation, review output through the indicators and do comparative analysis with the quantitative map comparison software package Map Comparison Kit ([www.riks.nl/mck](http://www.riks.nl/mck)). The policy interface can be found on the left-hand side of the Main Window (Figure 5.). Zooming in on those parts, we grouped settings and outputs by their type and their domain; for example all economic policy measures together, all external factors together, all ecological indicators together etc. An overview of the different steps a policy user has to take is provided in the paragraphs below.

### **Step 1: Setting up the drivers**

In the first part of the analysis the drivers can be entered and/or adapted (see Figure 5.). Drivers that are incorporated in the system are organised in two groups: *External factors* and *Policy measures*. When clicking on one of these groups, the user gets access to the underlying information and can see and adapt drivers and enter new data. Figure 5. shows also a parameter section. This is the way scientists can get more detailed access to the underlying models, data and parameters (see also Figure 6.).

External factors included in the TICAD SDSS are:

- Total population for the TICAD basin from 2006-2031,
- Total jobs in industry and commerce for the TICAD basin from 2006-2031,
- Area demands (totals) for natural and agricultural land uses from 2006-2031,
- Climate (temperature and precipitation) for the period 2006-2031.

The first three types of external factors are included through graphs, which can be set for the entire basin or the regions within the basin (see figure 5.). For climate change the user has an option to either choose the reference scenario or the climate change scenario.

The reference scenario is based on historic data for temperature and precipitation; the climate change scenario is developed based on information from the CLAVIER project and includes the following projection: 1) a general increase of the mean annual 2 m air temperature for all

of the subbasins, with 1.4-1.6 °C, with smaller changes for the spring period, and greater changes for the other seasons, especially winter; 2) great spatial variability in tendencies is foreseen for the annual precipitation with a slight increase up to 3.5% in Upper Tisza mountainous catchments and overall decrease in other sub-basins with 3-10 %, while definite increase for winter periods and general decrease in all other seasons with some exceptions in the highly elevated parts of the Upper Tisza (<http://www.clavier-eu.org/clavier>).

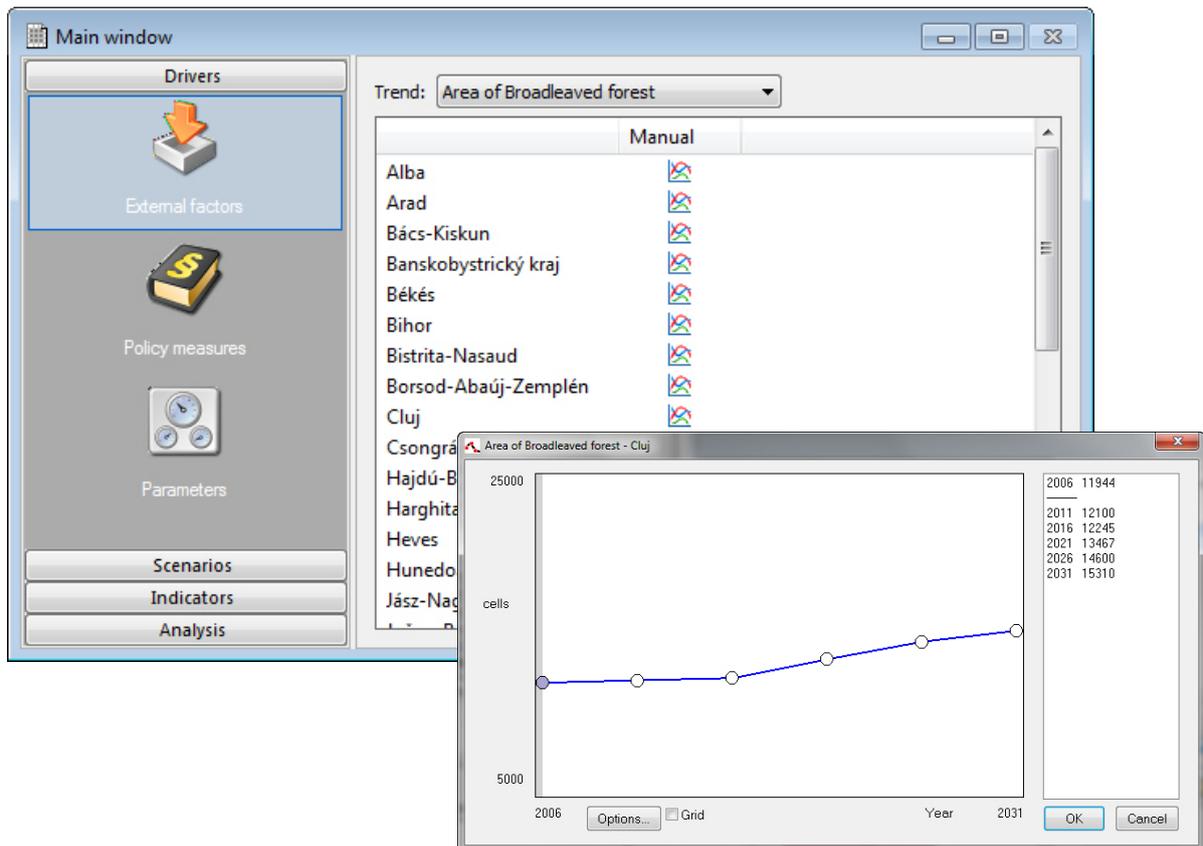


Figure 6.: Main window in which one of the external factors (Area demands for Broadleaved forest) is show. The graph shows the expected development of the total forested area in the Cluj region from 2006-2031 and can be adapted by the user to create alternative sub-scenarios.

Policy options included in the TICAD SDSS are:

- Spatial planning,
- Infrastructure development.

To incorporate spatial plans into the tool a dedicated zoning tool was developed in which all relevant plans stored in a GIS can be inserted and interpreted in terms of zoning regulations for the different land uses (Figures 5., 6. and 7.). The tool allows a hierarchical ranking of the plans to set their relative importance. Users are also able to set the time period for which the plans are valid.

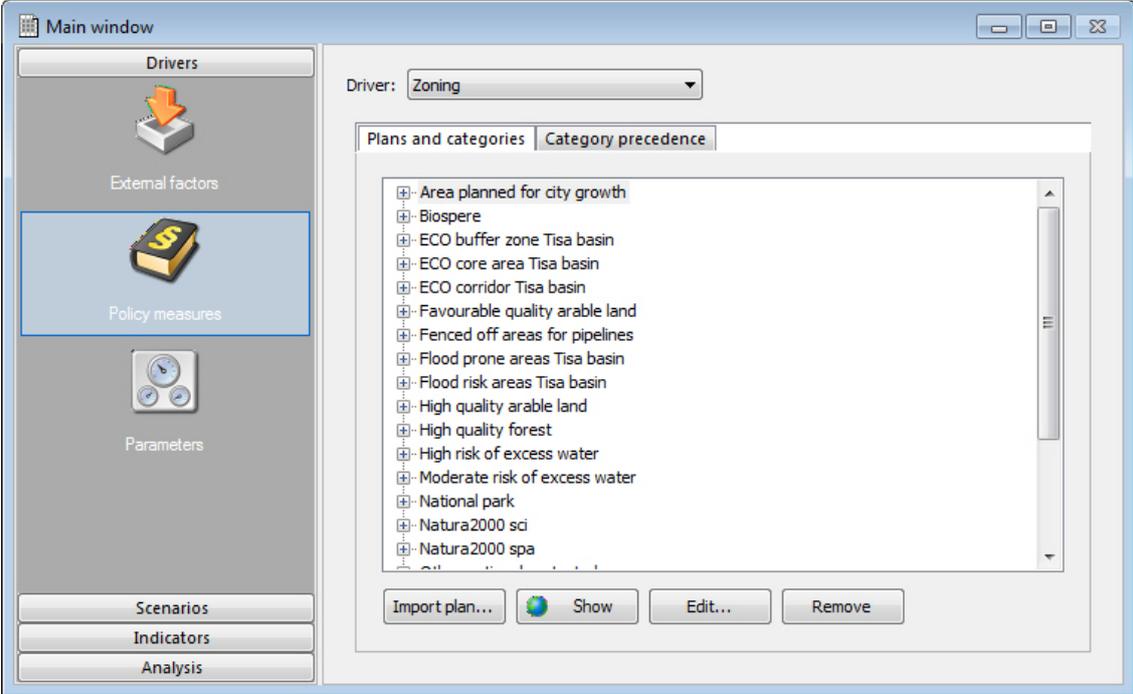


Figure 7.: Introduced plans in the TICAD SDSS

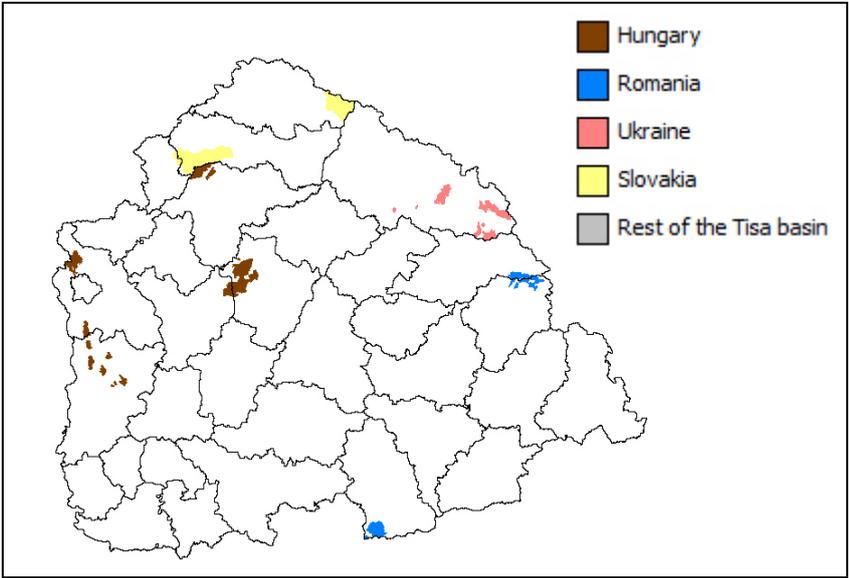


Figure 8.: Example of country categorization of maps to allow for a country-specific interpretation of the same spatial plan (in this example biospheres)

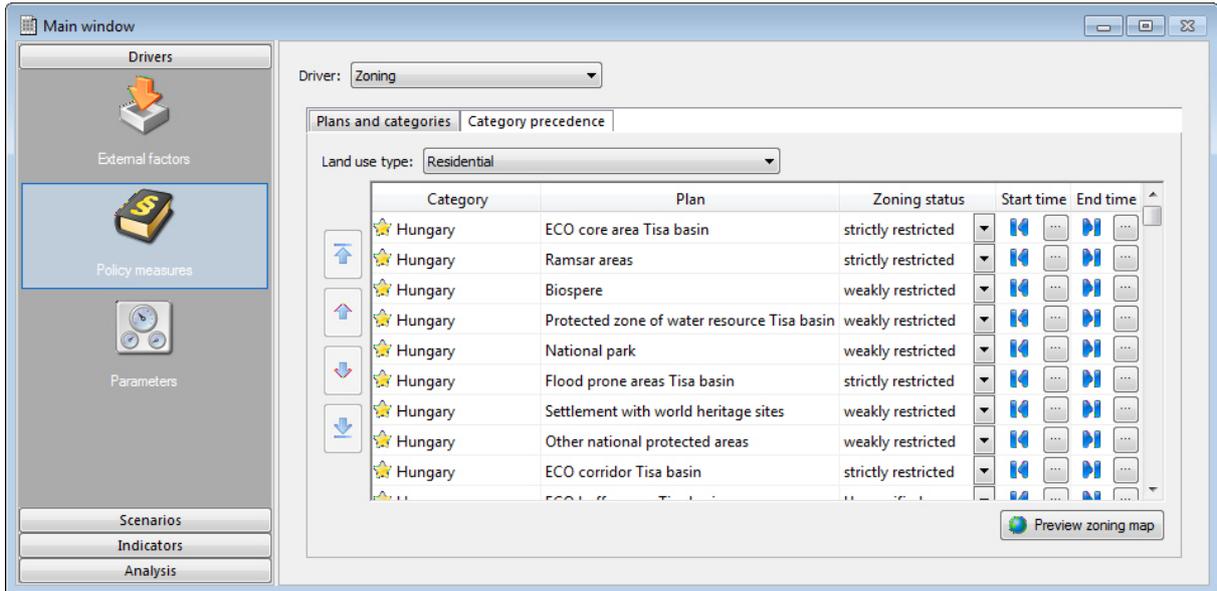


Figure 9.: Interpretation of categories in plans, ranking them in order of importance and setting their duration

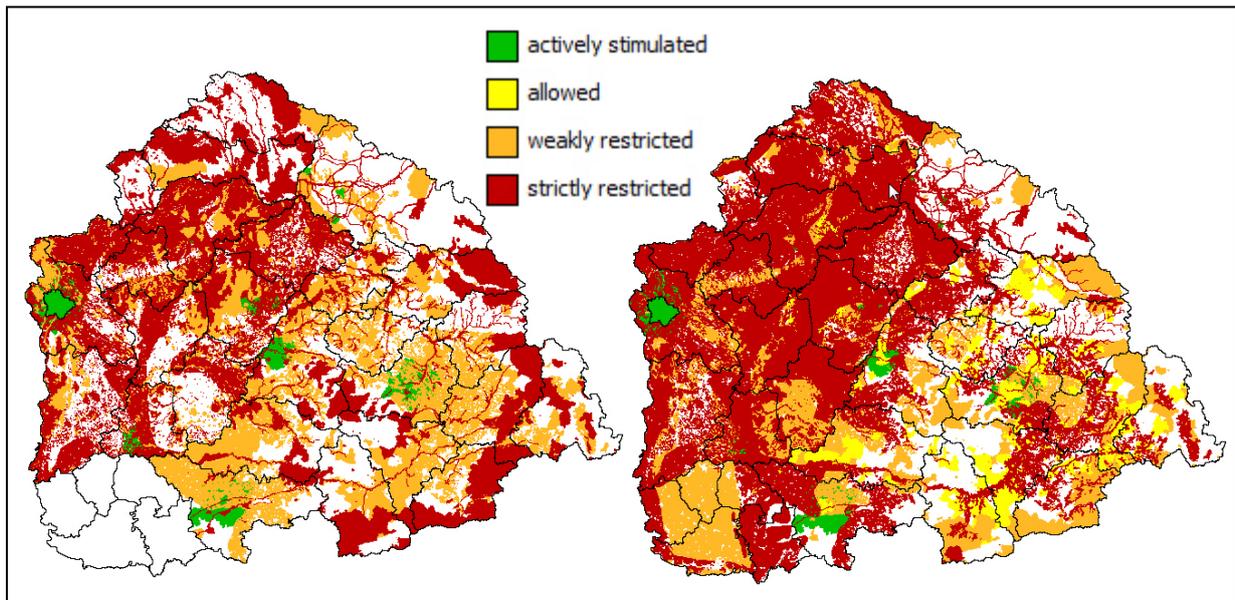


Figure 10: Zoning maps for residential development. The map on the left shows the resulting zoning map for the baseline scenario, the map on the right the zoning as proposed as part of the transnational strategy.

The resulting land use specific zoning maps indicate for each location if new development is allowed, stimulated or restricted and the enforcement that is applied for the latter category (strict or weak enforcement) - see Figure 10. Information on spatial plans and their interpretation was provided by the TICAD partners.

The second policy option is the possibility to expand, improve or remove infrastructure networks (road, railway, electricity, etc.), with the aim to enhance the accessibility of locations (see figure 11.). Users can include new network elements from a GIS and state at which year these developments should enter into force, thus allowing a temporal infrastructure planning as well as the assessment thereof. Networks and expected updates were provided by the TICAD partners. The DHI-RIKS consortium has interpreted the effects of the networks on the accessibility as part of the calibration of the system.

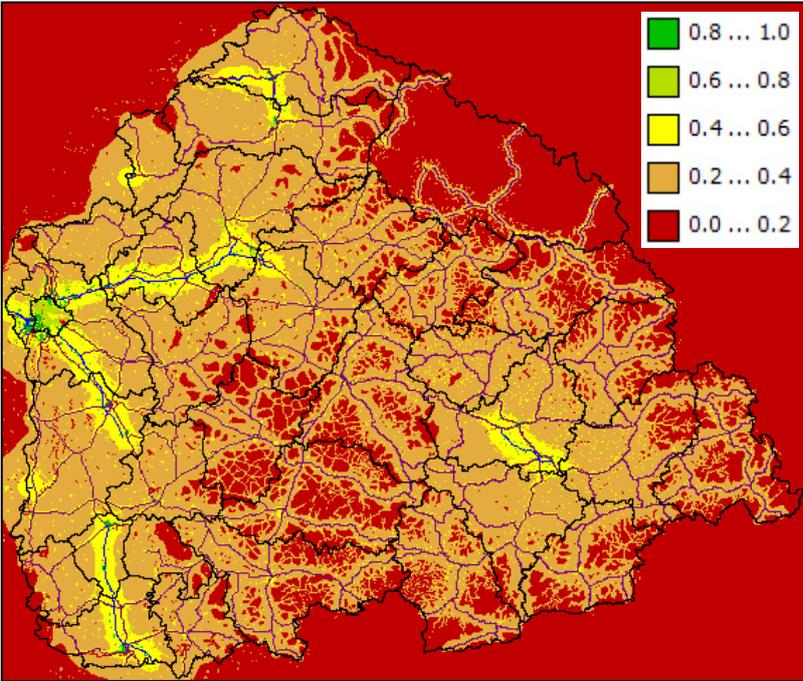


Figure 11.: Accessibility map for industry, showing for each location how well it is accessible from the point of view of industry. The accessibility map is overlaid with the high speed roads and the main roads (existing and proposed) to show that these roads have a high importance in the determination of the accessibility for industry

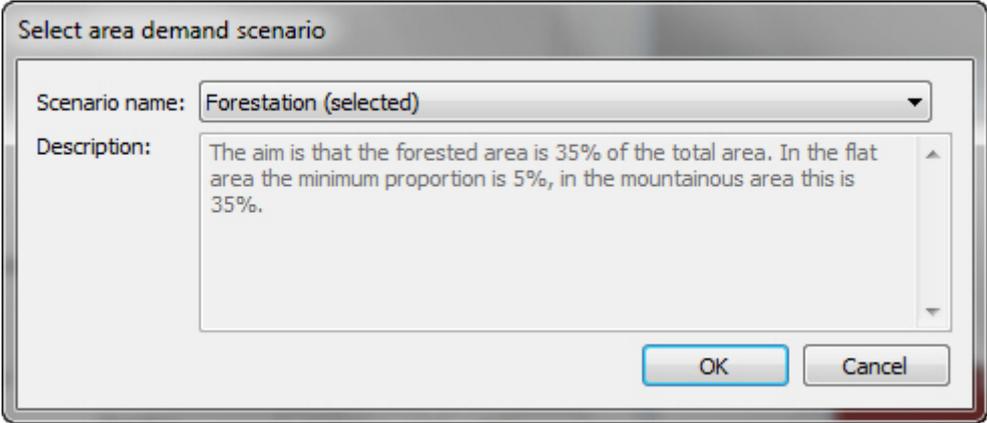


Figure 12.: Sub-scenario for the driver *Area demands* driver. The drop down list allows selecting the relevant sub-scenario for this driver, which is *Forestation* in the current example. The *Forestation* sub-scenario was defined by VATI as an example of a policy scenario to meet the aim of the transnational strategy to cover 35% of the total area of the Tisza basin with forest.

For each driver baseline settings are provided based on historic developments. Furthermore, for each of the drivers the user can create various scenarios, called sub-scenarios, for example a high growth scenario for population, a low growth scenario for population, a strictly enforced scenario for spatial planning, a scenario without spatial planning, etc (see figure 12.). When developing a new sub-scenario the user can build on existing sub-scenarios. For example, for the driver infrastructure, a baseline sub-scenario is incorporated in the system that includes all the baseline information provided by the various TICAD partners. If a user wants to build on this scenario he or she loads the baseline scenario, makes the required changes and saves it under a different name.

The result of the driver step is a set of sub-scenarios for each of the drivers. Since the different drivers are organised per discipline it is also possible that different users (with different expertise) prepare sub-scenarios for different drivers.

### Step 2: Creating integrated scenarios

In the second step of the policy interface, integrated scenarios can be constructed. Integrated scenarios consist of a selection of sub-scenarios constructed in step 1. The figures below show two screenshots of the scenario manager. Figure 13. shows how users can create an integrated scenario through selecting a sub-scenario for each driver incorporated in the system. Figure 13. shows an example of an integrated scenario (the Transnational strategy scenario) and the selection of sub-scenarios of which it consists.

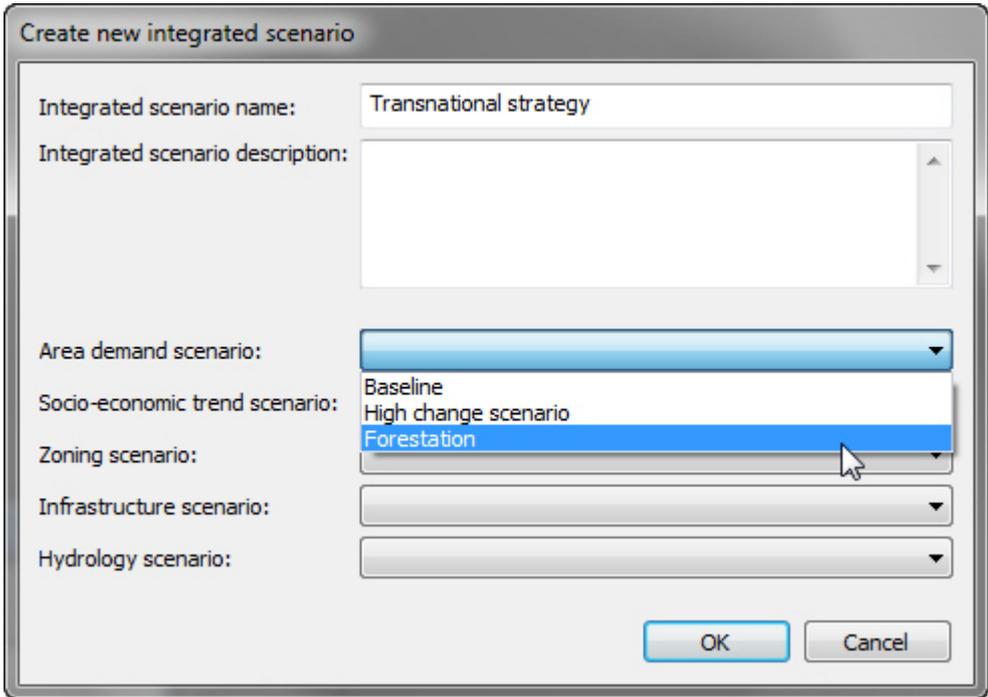


Figure 13.: Creating a new integrated scenario

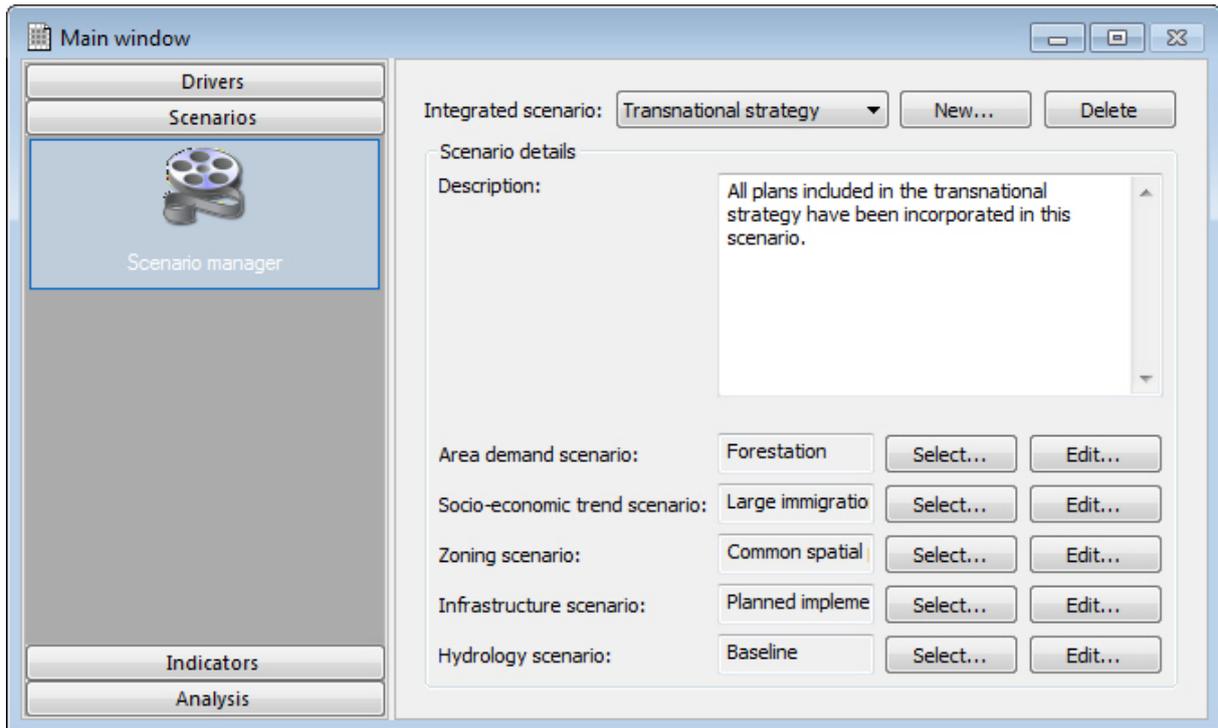


Figure 14.: Example integrated scenario based on a selection of sub-scenarios for Area demand, Socio-economic trends, Zoning, Infrastructure and Hydrology

The scenario manager allows users to create integrated scenarios in such a way that allows a comparison of alternative policies or a combination of policies (e.g. in the zoning scenarios plans to protect the floodplains and plans to protect environmentally sensitive areas can be combined). Furthermore the scenario manager helps to test the robustness of policy alternatives, by testing the same combination of policies under different climate or socio-economic sub-scenarios.

### ***Step 3: Running the simulation***

After integrated scenarios have been defined, the user is ready to run the simulation. As a preparation for this, users decide which results they want to have saved to disk while the simulation is running. The TICAD SDSS has three ways of saving results:

- Link to Excel (for all regional results) to have all selected model output directly written to Microsoft Excel so it can be used for analyses and post-processing after the simulation is finished.
- Log (for all map results) to save model output as maps, which can be opened in the analysis part of the system and in common GIS packages, for further analysis after the simulation has run.
- Animations (for all map results) to save all selected model output as little movies in Animated GIF format that can be opened in a viewer, but can also be readily incorporated in presentations.

While the system is running, the impact of various policy and external drivers on the future developments of the Tisza basin will be assessed in an integrated, consistent and coherent manner. At appropriate time-steps information is exchanged between the core modules of the TICAD SDSS: the hydrology model, the land use model and the regional model. This

approach allows to simulate the reciprocal relations between land use and hydrology and between regional and local processes at stake.

#### Step 4: Visualising indicators

After running the simulation, results of the TICAD SDSS can be analysed through an indicator framework which is part of the system itself. In this framework indicators are organised in two groups: socio-economic indicators and environmental indicators. Some of these indicators describe a state or a condition (e.g. agricultural land, grassland or forest in Less Favoured Areas), others a change over time (e.g. the Abandoned land map). For a proper assessment both the state and the change are important.

Indicators at local level are maps that show values per cell. These indicators are the result of post processing steps that use the current land use maps, and sometimes other maps such as the original map or a flood risk map. As all values are available as maps and computed per year, they can be logged or used to make an animation similar to the land use map. Indicators at regional level are either direct results from the regional model, or aggregated values from calculation at local level. Also regional indicators are calculated yearly. Table 1. gives an overview of the main indicators incorporated in the TICAD SDSS. The figures below provide examples of some of the indicators.

Table 1.: Overview of indicators incorporated in the TICAD SDSS, 1 indicates that the indicator is available at local level, 2 that the indicator is available at regional level

Socio-economic indicators	Environmental indicators
Urban clusters <sup>1</sup>	Land use <sup>1</sup>
Distance from residential to work <sup>1,2</sup>	Soil sealing <sup>1,2</sup>
Value at stake in flood prone areas <sup>1,2</sup>	Expansion of urban areas <sup>1,2</sup>
Population <sup>2</sup>	Forested areas <sup>1,2</sup>
Jobs in industry and commerce <sup>2</sup>	Abandoned land and natural land converted into agricultural practice <sup>1,2</sup>
	Habitat fragmentation <sup>1,2</sup>

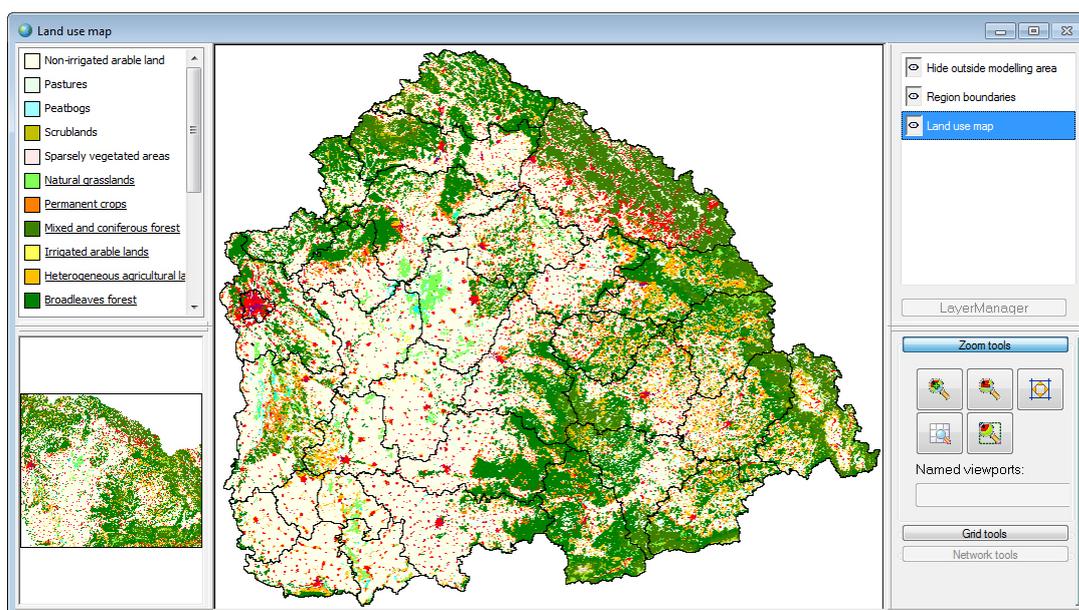


Figure 15.: Land use map of the Tisza basin, available for every year in the period 2006-2031

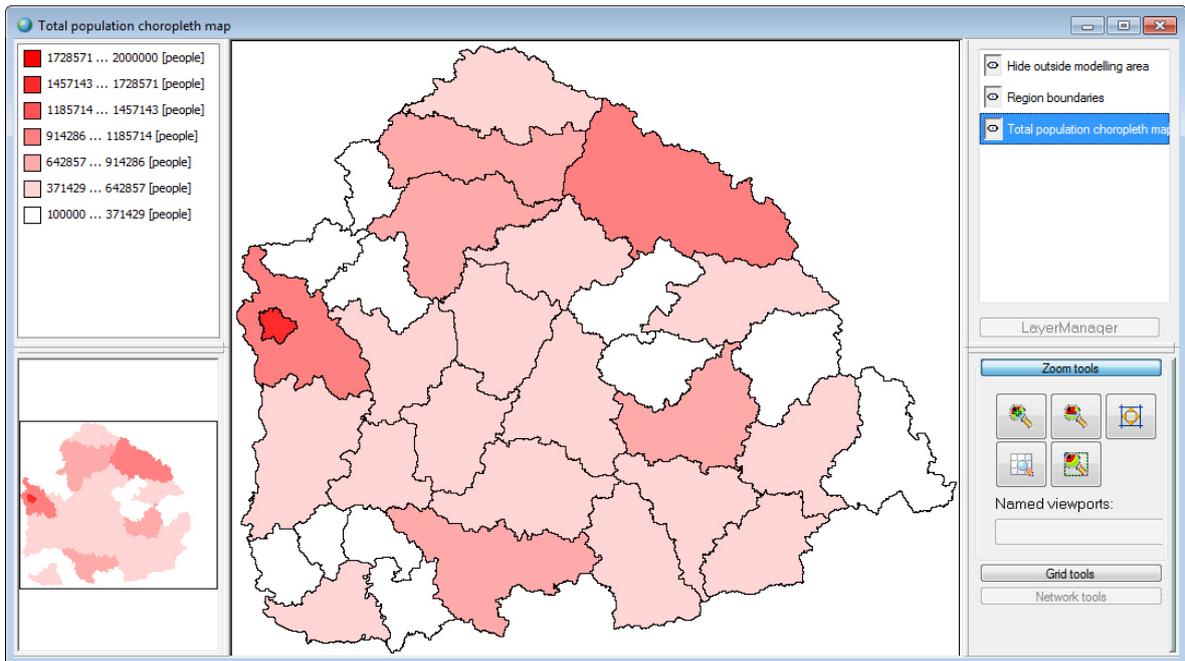


Figure 16.: Total population per region, available for every year in the period 2006-2031.

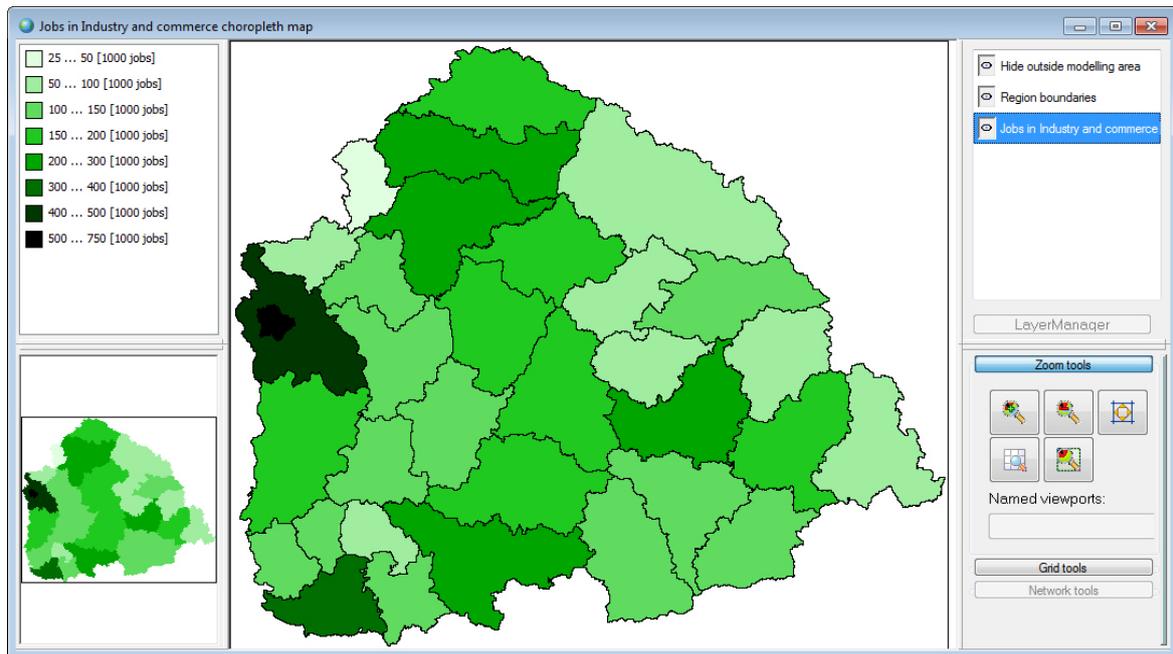


Figure 17.: Total number of jobs in industry and commerce per region, available for every year in the period 2006-2031.

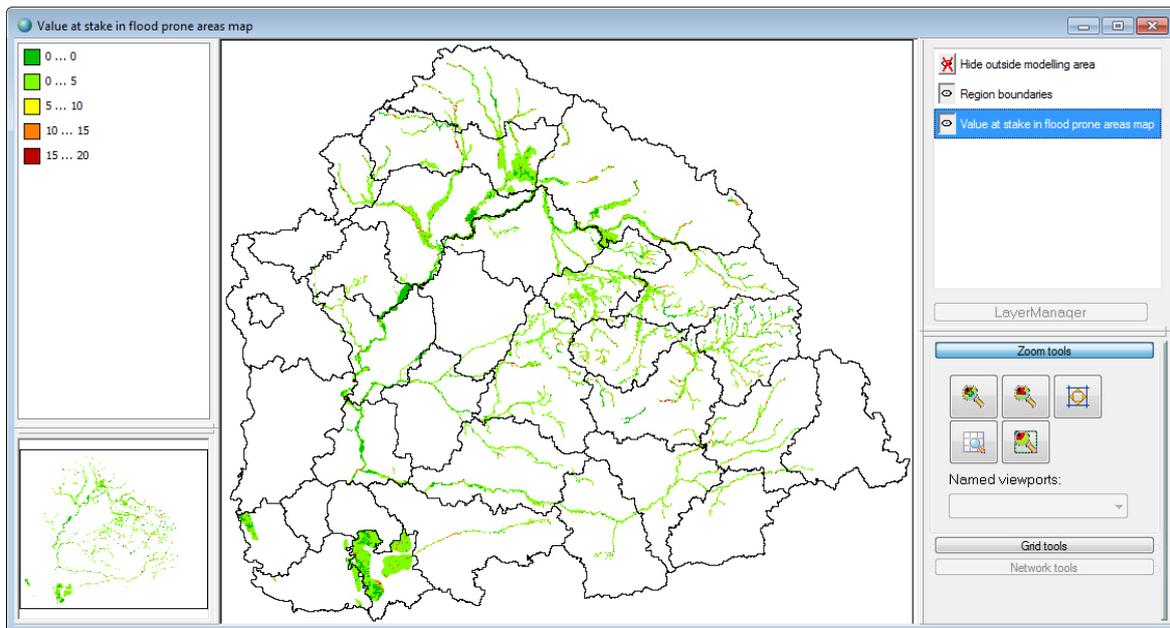


Figure 18.: Value at stake in flood prone areas. Map showing the value of each location (500x500 m grid cell) within the areas prone to flooding. The value at stake is determined by the land use occupying the area, where residential and economic uses have a higher value than natural uses. The indicator is available for every year in the period 2006-2031

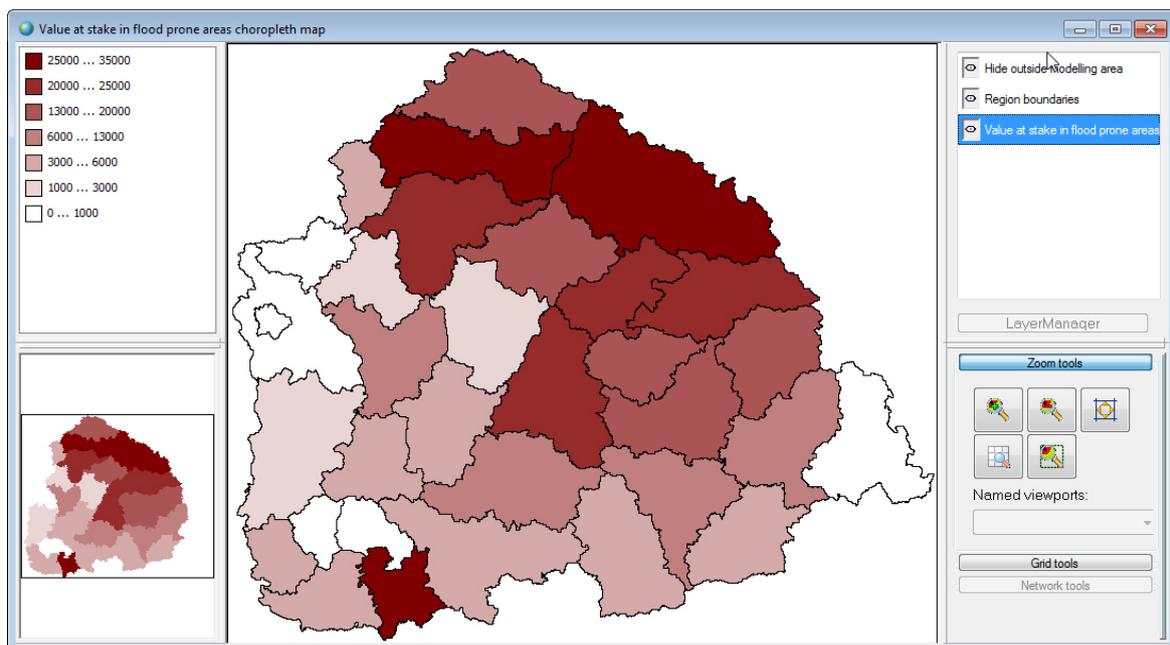


Figure 19.: Value at stake in flood prone areas. Map showing the aggregate value at stake in flood prone areas per region. The value at stake is determined by the land use occupying the area, where residential and economic uses have a higher value than natural uses. The indicator is available for every year in the period 2006-2031

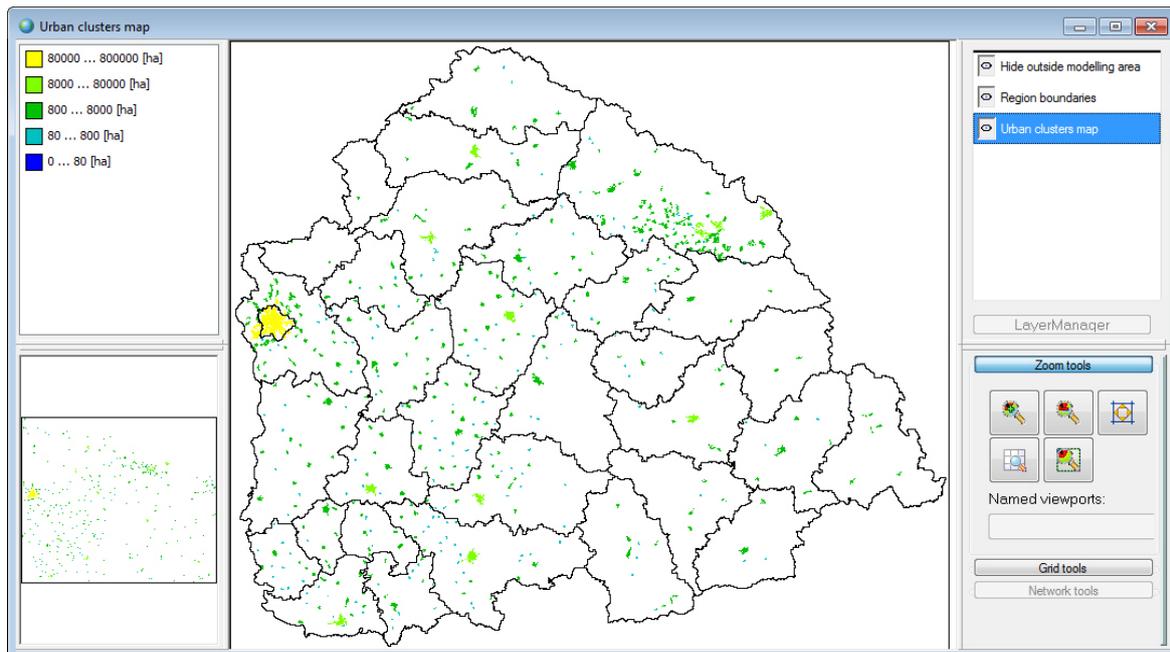


Figure 20.: Urban clusters shown by size of the cluster, available for every year in the period 2006-2031. For all land uses it is indicated whether they are an urban land use or not. All cells that are occupied by a non-urban land use will be ignored in the algorithm, as will all cells outside the modelling area. For the cells with urban land use, we then identify clusters of cells that are either horizontally or vertically adjacent and calculate their size. The value of each cell in a cluster is equal to the size of the cluster it belongs to.

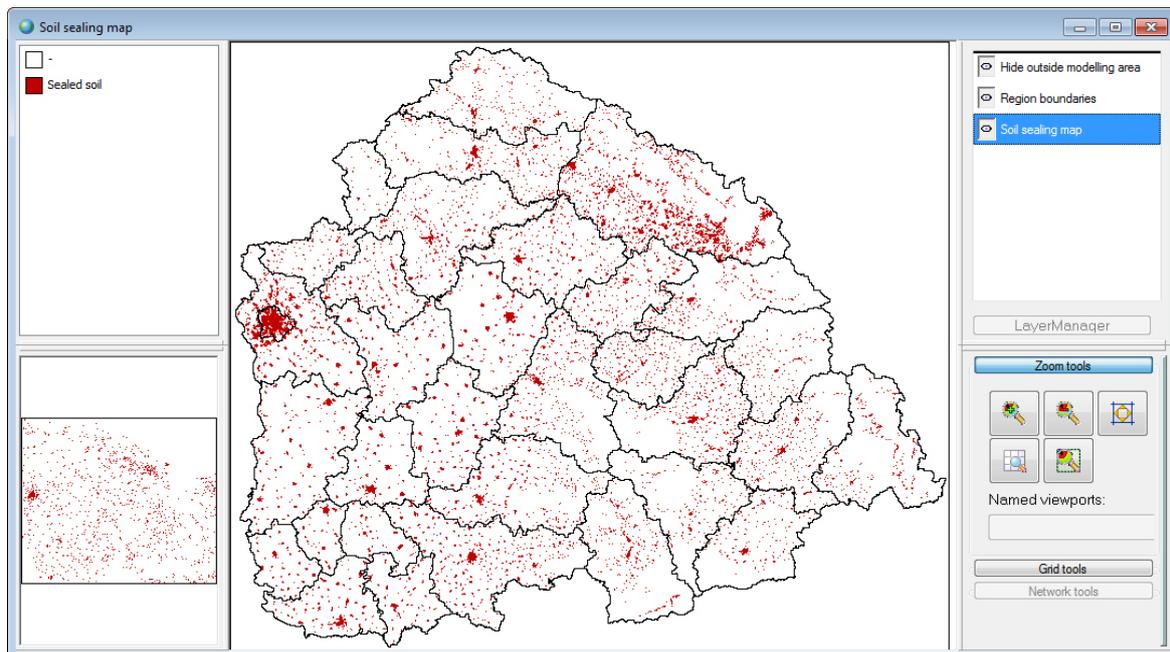


Figure 21.: Soil sealing, available for every year in the period 2006-2031. Locations occupied by urban land uses are classified as sealed soil.

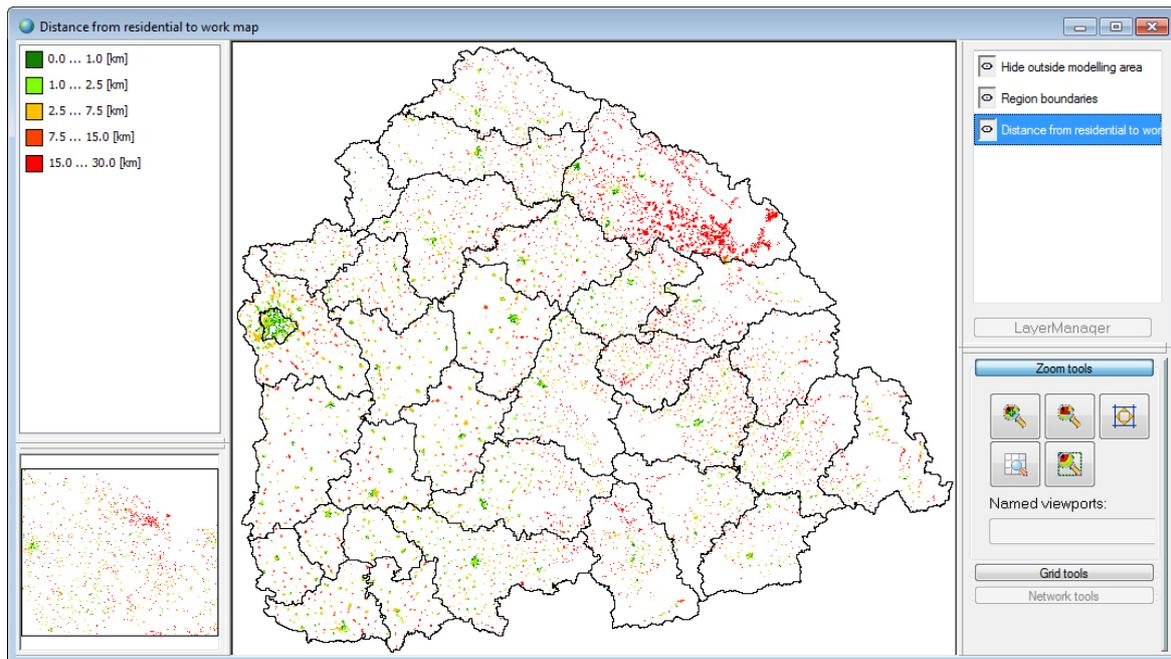


Figure 22.: Distance from residential locations to job locations, available for every year in the period 2006-2031. The map indicates that it is easier to find a job close to residential locations in the cities than in the countryside. This indicator calculates for each residential cell the smallest distance to a cell that is in the centre of a cluster of industrial and commercial cells. The centre cells of a cluster are those cells, for which all cells in the neighbourhood are industry and commerce. The distance between each pair of cells is approximated by taking paths from one cell to another that is horizontally, vertically or diagonally adjacent. This approximation overestimates the actual distance by less than 10%.

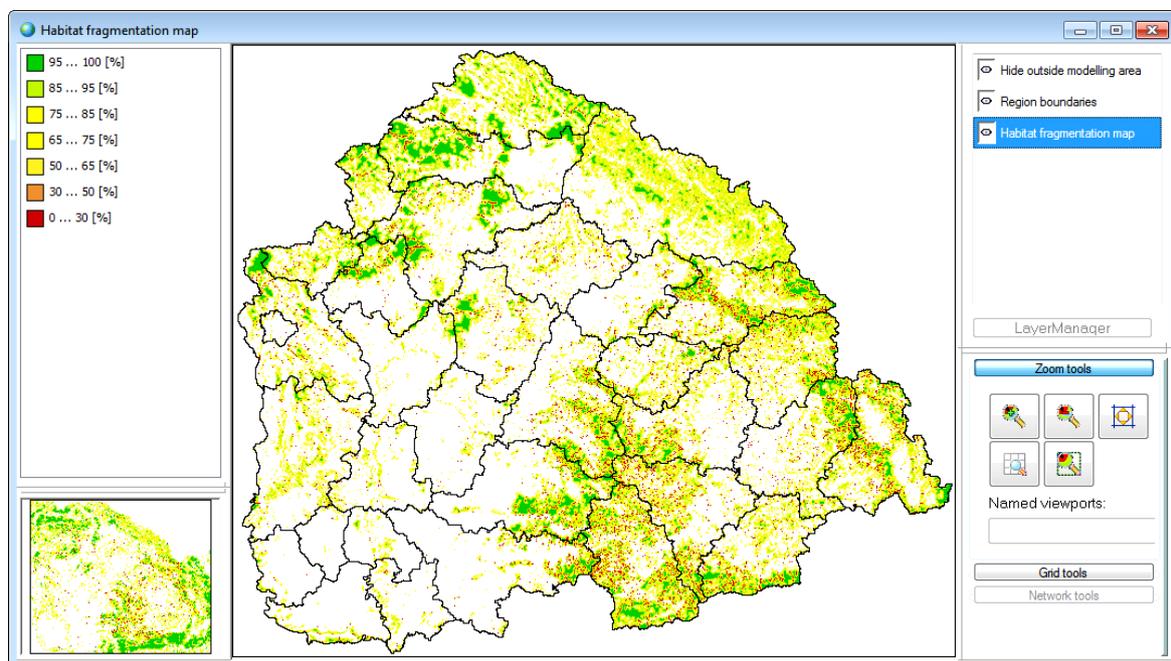


Figure 23.: Habitat fragmentation. Calculates the degree to which a location in a natural area is connected to other natural areas, which is taken as an indicator of potential biodiversity. It takes the perspective of an organism and distinguishes land-use types that are easy, neutral or difficult to traverse. Easy traversable are all natural areas, neutral are extensive agricultural areas and difficult are sparsely build areas and areas of intensive agriculture, very difficult to traverse are industrial and dense urban areas. In addition infrastructure elements can act as an obstacle as they are also difficult to traverse. By default all infrastructure elements are included as an obstacle, although it is open for discussion whether “Other roads” and “Local railways” are in practise an obstacle. This indicator is calculated in accordance with (Klepper, 1997).

## Step 5: Analysing results

The last step of the impact assessment study is to analyse results within a scenario (e.g. the temporal evolution of a scenario) or between scenarios. In step 3 of the assessment, the user selects the type of information he or she would like to analyse; this is the step in which the actual analysis is carried out. The Excel files that have been created can be analysed with Excel; the animations in a viewer and the land use and other indicator maps that have been saved can be compared and analysed with the Map Comparison Kit ([www.riks.nl/mck](http://www.riks.nl/mck)), which is an integral part of the system.

## Scenarios

The TICAD partners have carried out several scenario exercises with the TICAD SDSS, which are described in the Transnational Strategy and Policy Recommendation document of the TICAD project. In this document we describe the implementation and comparison of a baseline or business-as-usual scenario with the transnational strategy as developed by the project.

Table 2.: Relating objectives of the transnational strategy to the TICAD SDSS

<b>Main objectives in the transnational strategy</b>	<b>Element for inclusion in TICAD SDSS</b>	<b>Relevant driver and settings</b>
Increasing economic competitiveness and diversification of economic activities	Economic growth	Increase in the total number of jobs in industry and services in the Tisza basin
Promoting transnational and local transport connections	Proposed new infrastructure developments will be implemented	Addition of new infrastructure elements in road and train networks
Keeping young generation in the area	Lesser emigration	Total population decreases with a slower rate
Strengthening institutional cooperation in the field of spatial planning	Incorporation of a common planning strategy	Ranking and interpretation of spatial plans is the same in all countries
Limitation of impact of natural disasters by preventive measures	Flood control protection	Prohibiting further urban development in flood prone areas through spatial planning
Enhancing and protecting natural resources and the natural and cultural heritage	Reach the aim of 35% land covered by forest in the Tisza basin in 2030, varying between 5-45% for individual countries, depending on their geographical characteristics	Demand for forested areas is increased to meet the targets
Promoting land use which is suitable to the landscape characteristics	Stimulate the allocation of land use functions on locations suitable for them	Agricultural and forest developments on suitable locations are actively stimulated by incorporating suitability maps in the zoning tool, thus making it part of the spatial planning

To carry out this task, the following steps have been taken:

1. Extracting the main objectives from the transnational strategy and linking these to drivers available in the TICAD SDSS;
2. Defining the parameter setting for the Baseline scenario and the Transnational strategy scenario;
3. Running the simulations;
4. Comparing and discussion the results.

The result of the first step is table 2. Results of the second step are providing in table 3. As an example maps from one of the drivers, spatial planning for residential developments, are provided in figure 24. This figure clearly shows a more restricted planning scheme than is put in place at present.

Table 3.: Comparison of drivers in the TICAD SDSS for the two scenarios.

<b>TICAD SDSS driver</b>	<b>Baseline</b>	<b>Transnational strategy</b>
Area demand scenario	Area demands are computed as continuation of historic trends. The direction of change is the same, the rate of change is reduced relative to the calibration period (2000-2006).	Ensure that 35 % of the area is forest, rest of land use demands according to baseline. Combination of mixed and coniferous forest and broadleaved forest, but increases only in broadleaved forest.
Socio-economic trend scenario	Developments based on historic trend. The population is likely to decrease greatly in the forthcoming 20 years. Employment gradually increases.	Population decline is 50% less than in baseline (16.3 million people in 2031), economic growth is expected to be 50% higher than in the baseline scenario.
Zoning scenario	Each country keeps their own regulations.	There is a common spatial planning for all countries and land use developments are stimulated on suitable locations for the use under consideration. Furthermore nature protection is strictly enforced and further developments in the floodplains is prohibited
Infrastructure scenario	No new infrastructure developments are expected.	All proposed infrastructure is implemented.
Hydrology scenario	Climate scenario according to the CLAVIER project ( <a href="http://www.clavier.eu.org/clavier/">http://www.clavier.eu.org/clavier/</a> ).	Climate scenario according to the CLAVIER project.

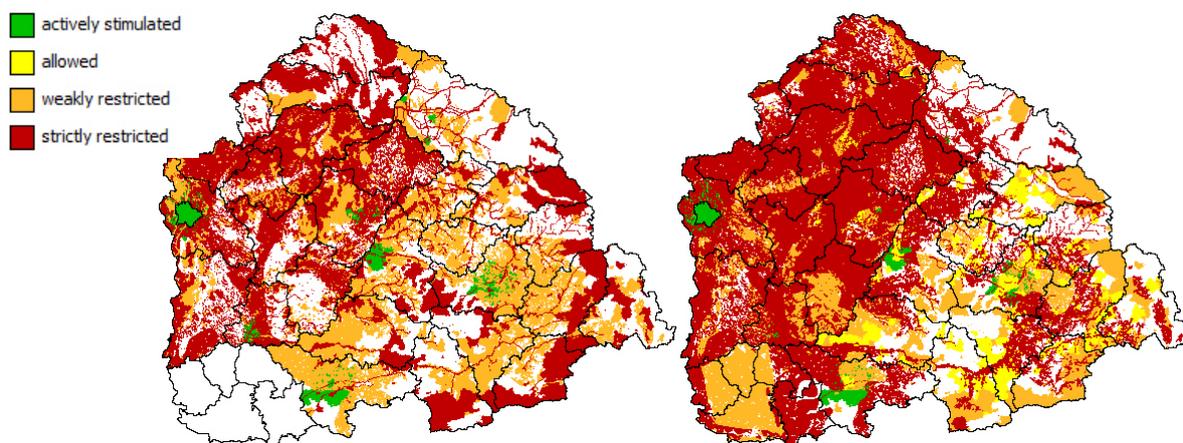


Figure 24.: Comparison of zoning maps for residential development. The figure on the left portrays the current planning practice, the figure on the right the common spatial planning strategy as proposed by the transnational strategy.

Result maps of the scenario exercise are provided on the next two pages. One of the obvious differences is the increase in forested areas, as is also in figure 25. From this figure it becomes clear that reforestation has taken place at the cost of non-irrigated agriculture, which has experienced large decreases over the period 2006-2031.

Looking at the aggregate values of some of the indicators (table 4.), we see that with a common strategy as proposed by the transnational strategy, it is possible to protect the natural areas from further development and to free the floodplains from further urban development. We also see that without such a strategy some parts of these areas will gradually be occupied by urban land uses due to their attractiveness. Looking into the details of the differences helps to understand what locations should be protected to ensure no future development will take place in these areas. What also becomes clear from the graph below is that additional measures would need to be taken to improve the 2006 situation. The current strategy maintains the status quo, but does not stimulate migration out of the natural and floodplain areas.

Table 4.: Comparison of the two scenarios and the current situation (2006) on a set of environmental and hazard related indicators

<b>Indicator</b>	<b>2006</b>	<b>Baseline 2031</b>	<b>Transnational strategy 2031</b>
Residential area (km <sup>2</sup> ) in floodprone areas	1886	1951	1886
Commercial/industrial area (km <sup>2</sup> ) in floodprone areas	192	203	192
Built-up area (km <sup>2</sup> ) in ecobuffer area	470	495	466
Built-up area (km <sup>2</sup> ) in ecocorridor area	643	642	642
Built-up area (km <sup>2</sup> ) in ecological core area	436	441	436
Built-up area (km <sup>2</sup> ) in biosphere reserve	138	138	138
Built-up area (km <sup>2</sup> ) in the Ramsar area	142	142	142

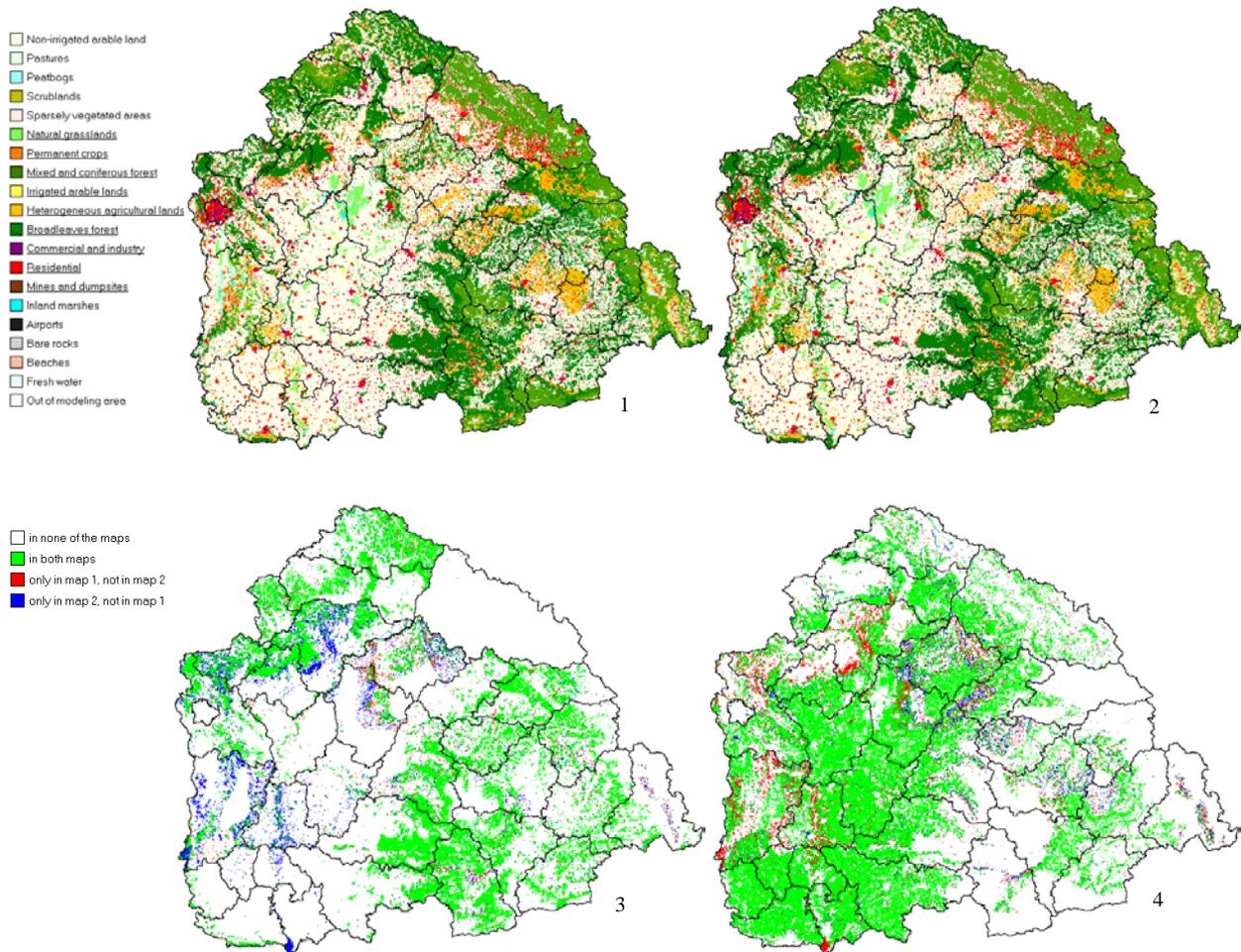


Figure 25.: Comparison of land use maps between the two scenarios. The simulated land use for 2031 for the baseline scenario is shown on the top left side of the figure (1), the land use for 2031 for the transnational strategy on the right side of the figure (2). The figures on the bottom show the comparison of the area occupied by broad-leaved forest (3) and non-irrigated arable land (4)

Figure 26. shows the impact of stricter spatial planning on the urban developments. The left side of the figure shows the zoning map (1) and the resulting land use in 2031 (3) for the baseline scenario, while the right side of the figure shows the zoning map (2) and the resulting land use in 2031 (4) for the transnational strategy. As also becomes clear from the two figures at the bottom, without strict planning satellite cities will develop in the surroundings of Budapest, having an impact on the fragmentation of the habitat, but also on e.g. the mobility and the environmental consequences thereof, as a large part of the people living in these areas are likely to often travel to Budapest (for commuting or business purposes) or attract commuters due to their economic development. The transnational strategy shows a more compact development with new urbanization on the outskirts of Budapest.

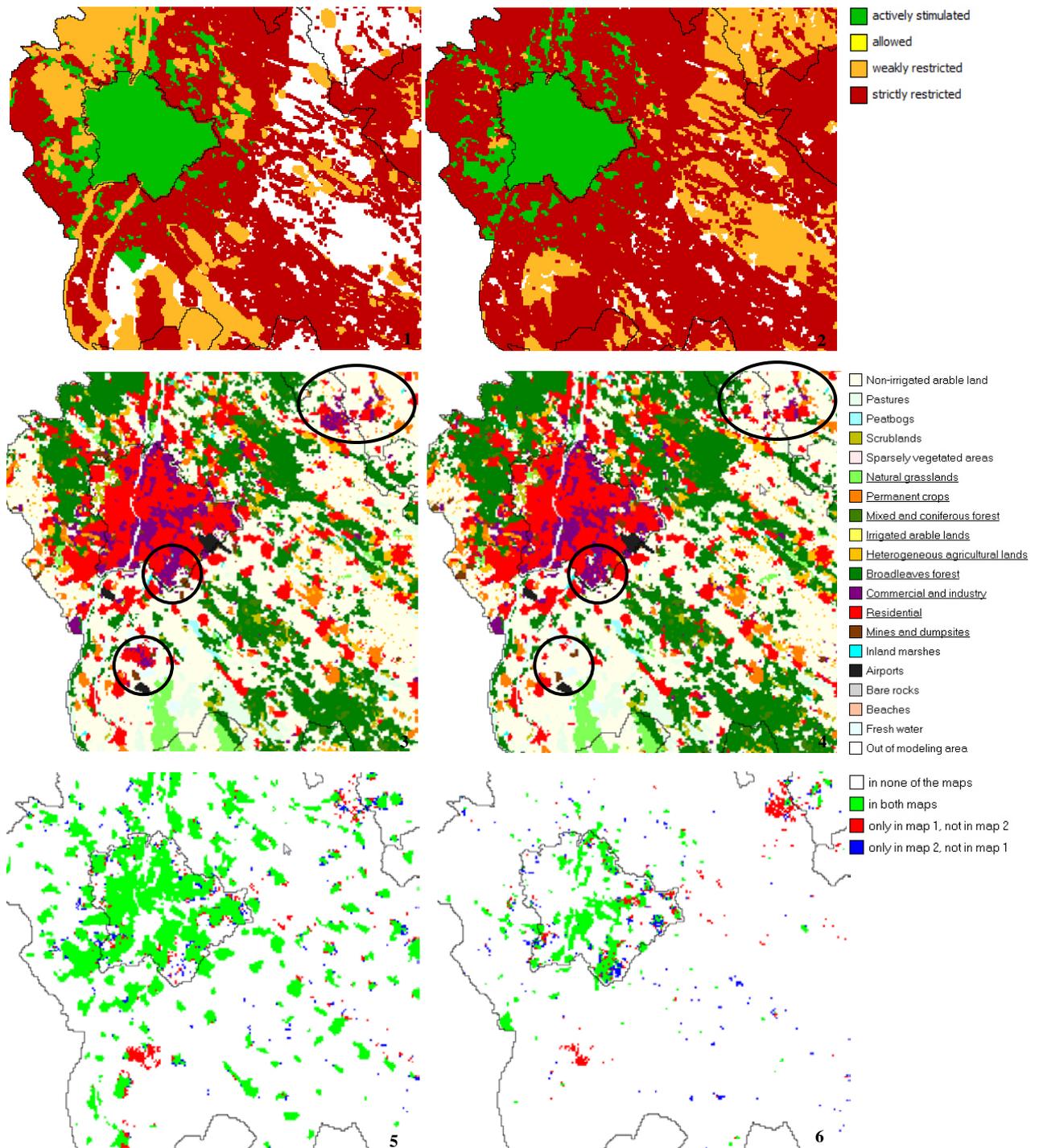


Figure 26.: Details of the impact of the spatial planning on urban developments. The top figures show the zoning maps for residential development in the Budapest area for the baseline scenario (1) and the transnational strategy (2), the next two maps show the land use in 2031 for the baseline scenario (3) and the transnational strategy (4), the bottom two maps show the comparison between residential (5) and commercial and industrial areas (6) in both scenarios.

## Project information

The TICAD Spatial Decision Support System was developed by a consortium established between DHI and RIKS (Consortium leader: DHI), in close collaboration with the partners of the TICAD project. The development of the TICAD SDSS was contracted by the Tisza Catchment Area Development (TICAD) (SEE/A/638/4.2/X) transnational project financed from South East Europe Transnational Cooperation Programme ([www.see-ticad.eu](http://www.see-ticad.eu)).

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Project period: 26/5/2010– 30/10/2011

Project budget: €300 000

Delivery: The project accomplished all conditions listed in the contract. Activities provided by the DHI-RIKS consortium were on a very good professional and organisational level and both organizations were recommended as credible partners for handling projects of this type.



## **Consortium**

The DHI-RIKS consortium is a collaboration between DHI a.s., located in Prague, Czech Republic and RIKS BV, located in Maastricht, the Netherlands. Both consortium partners are briefly introduced below.

### **DHI**

DHI is an independent, international consulting and research organisation. It is a not-for-profit organization with a board of directors appointed by the Danish Ministry of Science, Technology and Innovation. DHI offers a broad range of consultancy services, reference material, software and hardware products and tools within the following fields: Water utilities, Industry and technology, Transport and energy, Agriculture and aquaculture, Coastal and marine engineering, Rivers and reservoirs, Water resources and environmental management, and Health and safety risk assessment. DHI's consultancy services combine extensive physical/chemical and biological knowledge using the most advanced tools and technologies within numerical modelling, environmental laboratories and scale model test facilities, field surveys and monitoring programmes, and institutional capacity building and training. DHI has a staff of more than 800, the majority of whom are professional engineers and scientists with postgraduate qualifications and several years of consultancy and R&D experience.

Each year DHI invests approximately 25% of its human resources in Research and Development to extend its knowledge in the various fields related to water, environment and health and to improve its software products. This level of Research and Development enables DHI to continue providing partners with the latest know-how and the most advanced technologies.

DHI a.s. is seated in Prague, as a member of DHI Group. DHI a.s. is a regional Directorate for Southern-Eastern European territory, has 60 employees.

MIKE software developed by DHI is very popular because of its inherent flexibility for adoption to river basin planning, flow forecasting, and optimisation of hydro power and water distribution networks as well as analyzes of natural behaviour of or human intervention made processes in environment. With several thousand software installations around the world the MIKE software is the most widespread professional software for water modelling and is de facto standard in many countries.

With projects undertaken in more than 140 countries and subsidiaries in more than 20 countries DHI is truly an international organisation. Further details regarding DHI can be found on the website <http://www.dhigroup.com>.

### **RIKS**

For well over 20 years now, RIKS has been implementing state of the art research in software tools to support planners by allowing them to assess and analyse the outcomes of future policy decisions. Its main activities concern the design, development and use of innovative computer-based information systems for integrated spatial planning and socio-environmental policy-making. To perform these activities RIKS has an experienced team of scientists and software developers with backgrounds in among others social geography, physical geography economy, social sciences, GIS and water management.

RIKS has delivered numerous modelling frameworks for integrated public spatial planning and policy-making such as the one described in the Invitation to Tender. In order to implement these modelling principles and the encompassing Decision Support Systems, RIKS develops, commercialises and maintains the DSS software environment GEONAMICA. Typically our systems represent the decision domain by means of integrated, dynamic, and high-resolution spatial models running on top of GIS (Geographical Information Systems) data layers. They allow the user to get a deep understanding of the linked social, economic and environmental processes that evolve within the given physical and institutional constraints of the region and/or systems studied, while still providing enough abstraction and a user-friendly interface for non-experts to work with the system.

As part of the implementation of modelling frameworks and Decision Support Systems in the institutional processes of its customers, RIKS regularly holds workshops and training sessions to evaluate the way its systems are used and to fine-tune it to policy users' needs. Continuous feedback loops between users and scientists have been an integral part of the way projects are executed by RIKS employees for years. In our projects we have collaborated with private and public bodies in various countries all over the world, such as New Zealand, Germany, Puerto Rico, the Netherlands and the EU as a whole.

Additional information about RIKS can be found on [www.riks.nl](http://www.riks.nl).