SIMULATING URBAN AND REGIONAL EVOLUTIONS: SCENARIOS OF DEVELOPMENT IN THREE STUDY CASES: ALGARVE PROVINCE (PORTUGAL), DRESDEN-PRAGUE TRANSPORT CORRIDOR (GERMANY-CZECH REPUBLIC) AND FRIULI-VENEZIA GIULIA REGION (ITALY)

Laura Petrov, Carlo Lavalle, Valentina Sagris, Marjo Kasanko, Niall McCormick

European Commission
DG-Joint Research Centre, Institute for Environment and Sustainability,
Land Management and Natural Hazards Unit, Ispra, Italy

ABSTRACT

Among other causes the analysis of urban areas and their development has particular relevance because of their growing exposure to natural hazards, particularly floods and forest fires. Inappropriate regional and urban planning can exacerbate the negative effects of natural hazards. On the other hand good land management and planning practices, including appropriate land use and development control in natural hazard-prone areas, represent suitable non-structural solutions to minimise exposure and damage. This paper aims to provide a coherent basis for the spatial planning and management of landscapes in Europe.

The MOLAND urban and regional growth model (*Barredo et al., 2004; White et al., 1999*) is used to evaluate spatial planning for sustainable urban development and measures for natural risks reduction. A number of indicators set measuring various aspects of urban land use and population density can also be analysed. In this article we describe the application of the MOLAND model in three study cases presenting each a specific development condition: the Algarve Province in Portugal, the Dresden–Prague transport corridor in Germany and in the Czech Republic and the Friuli-Venezia Giulia Region (FVG) in Italy.

In modern Portuguese history, after the revolution in 1974, a “democratisation of tourism” occurred and profoundly changed of land use pattern throughout the country. On the other hand, in the last years, Portugal suffered an increased number of large forest fires. The Algarve Province was especially affected. The objectives of the work in Algarve are to monitor sustainable development trends, assess the impact of tourism and evaluate the problems cased by forest fires. The dynamic of land use scenarios are examined as a way to turn intuitive knowledge of a problematic situation into clear research questions that may be explored by analysing and forecasting. The future scenarios produced by the model are tailored to particular requirements such as the assessment of tourism and measures to improve regional needs.

The Dresden-Prague corridor is a very interesting European region because of its historical, present and future development. Many historical and political events and geographical circumstances have moulded the landscape. Recently, during the 2002 flood events have affected the territory destroying villages and inundating cities of Dresden and Prague, in both of which large parts of the old town were under water. How could the land be used in such a way to reduce the floods damages?

The Friuli–Venezia Giulia Region is located in the North-Eastern area of Italy. Because of its geographical positioning and configuration, the region presents a number of peculiarities which have characterized its land use dynamics. FVG has transformed from being a rural area into a dynamic urban region and vast changes have occurred in demographic terms and population movements being related to the Italian economic boom.The region has also suffered the impacts of severe natural hazards, the two major events were the heavy floods of 1966 and 2002 in Pordenone, showing how vulnerable this area is. Early results of this study show that the main driving force of natural disasters damage is not only increasing floods hazard due to climate change, but increasing vulnerability, mainly due to urbanisation in flood prone areas (*CEC, 2004; UN, 2004*).

The MOLAND model contributes to understand the landscape changes and drivers of the dynamics in the development conditions of each study area. It will help to answer where and at which intensity land-take for urbanization occurs and how spatial growth patters alter over time; how urbanization (e.g. sprawl) affects large areas overruling local and regional decisions and also calamities such as forest fires and floods; how climate change will affect us and the future generations and what can we do? How the people to interfere with natural processes, climate change, the continue changes of land uses and floods/forest fires phenomena?

Urban and regional simulations offer a useful approach to understanding the consequences of current spatial planning policies. The scenarios are considered to generate data of meaningful representations of the region's characteristics whilst still allowing the model to process data in real-time in response to the wide variety of possible policy decisions specified by the user. The new tool will permit in supporting European policies of sustainable development and derive current strategies regarding the adaptation to the extreme events.

1. INTRODUCTION

The European landscape is the result of technological, socio-economic and political developments as well as global environmental change and possibly cultural (*Bouma et al., 1998)*. Examining the historical trends can provide helpful guidance in identifying key factors that influenced the present urbanization and other changes in developed area. Further increases in developed areas will have significant implications for landscape and urban planning in future years and also can stress the negative effects of natural hazards.

Scenario development has become an important tool to develop plausible visions of how the future might unfold and compare the potential consequences of different future contexts of European land use (*Davis, 2002; Shearer, 2005*). A large number of studies using scenario approaches have been published during recent years (*Rotmans et al., 2000; de Nijs et al., 2004; Audsley et at., in press*).

The MOLAND urban and regional scenario simulation model (*Barredo et al., 2004; White et al., 1999*) is used to evaluate spatial planning for sustainable urban development and measures for natural risks reduction. By using MOLAND model, we create several scenarios of development which will serve for landscape management at the local and regional scales, complementing existing policies and programmes. We are focusing on the three case studies, the Algarve Province in Portugal, the Dresden – Prague transport corridor in Germany and in the Czech Republic and the Friuli-Venezia Giulia Region (FVG) in Italy.

In modern Portuguese history, after the revolution in 1974, a "democratisation of tourism" occurred and profoundly changes of land use pattern throughout the country and especially in Algarve. The population has moved from the inland to the shoreline and registers an annual increase of 0.5% during the eighties. This increase is rather due to internal migration than to natural demographic growth. The tourism is the driving force in Algarve region, led to a construction pressure especially residential area determining significant changes of the landscape, economy, social structure, and cultural behaviour. Among the consequences of that development style is the continuous growth of urban areas as very small disperse patches. On the other hand, in the last years, Portugal suffered an increased number of large forest fires especially in the Algarve region. Is that increase one of consequences of changes of the landscape, economy, and social structure in Algarve?

The objectives of the work in Algarve are to monitor sustainable development trends, assess touristy impact and evaluate the forest fires problem. The dynamic of land use scenarios are examined as a way to turn intuitive knowledge of a problematic situation into clear research questions that may be explored by analysing and forecasting. The future scenarios produced by the model are tailored to particular requirements such as touristy assessment and measures for improvement of regional needs. As well, to evaluate the impacts of forest fires hazard and understand the role of it in the environment.

On the other hand, cities and regions in Eastern Europe undergo a new face of urbanisation, changing dramatically land use pattern. The liberalization of economy after the collapse of communist regime and finally membership of EU led to the growing involvement to the European market. In spite of expected decrease of population in the new EU countries the average gross domestic per capita product is projected to triple and the number of households is projected to grow in spite of population decline between 2000 and 2030 (*EEA, 2004; 2005*). So that as a result of the urban sprawl inappropriate housing in high-risk areas (e.g. flood prone areas) increases the vulnerability and potential damage by natural hazard.

The second study area, Dresden-Prague corridor is a fast changing European region regarding its historical, present and future development. Many historical, political events and geographical circumstances have moulded the landscape. Very important geographical features are the Elbe and Moldau (Vltava) rivers which were for a long time the main development axes in the area. In recent times, the 2002 flood events have affected the territory destroying villages and inundating the cities of Dresden and Prague, in both of which large parts of the old town areas were under water. This event caused damages also to other several regions in Europe such as Austria, Germany, Slovakia, Poland, Hungary, Romania and Croatia. How could the land be used in such a way to reduce the floods damages?

In the third study area, the FVG, both the rising standards of living, on the one hand, and the increased mobility on the other, led to a de-centralization process, i.e. the formation of the so-called 'diffused city'. It can be defined as a multi-centered and networked urban structure with 'softened' functional hierarchies (*Bessusi et al., 1998*). In the period under consideration the ratio of urbanized land in FVG doubled in the 50-80's period and continues to grow. In some medium size municipalities a triplication of urbanized land could be observed.

FVG accommodates 1,183,000 inhabitants on a surface of approx. 7,850 km^2 and it is formed by provinces of Udine, Pordenone, Trieste and Gorizia. The provinces of Udine and Pordenone account for the 91% of the FVG's area. We analysed several spatial indicators in the form of maps describing population growth, spatial patterns, and the historical growth of built-up areas. Then, we show the results of a dynamic spatial model for simulating land use scenarios. The two future scenarios produced by the model were used for a flood risk assessment in Pordenone and the results confirm the initial statement about the increasing exposure to floods due to new urban development.

The MOLAND Model generates data in order to understand the urban landscape changes and drivers of these dynamics. It will help to answer where and at which intensity land-consumption for urbanization and how spatial growth patterns alter over time; how urbanization affects large areas overruling local and regional decisions and what can we do? How the future generations to interfere with natural processes and the continue changes of land uses and also calamities such as forest fire and flood phenomena?

This paper will focus on current land use and options for land use development in the future including a discussion of the associated environmental risks (floods and forest fires) in Europe and crucial factors governing land use change.

2. METHODS

The MOLAND Model used in this study is specifically developed for urban and regional scenario simulation; it is based on a spatial dynamics bottom-up approach, and can be defined as a CA-based model (*Barredo et al., 2004*). The model takes as input several geo-referenced datasets for the simulation of urban areas and/or regions. The inputs are five types of digital maps for the geographical area of interest: (a) actual land use types; (b) accessibility to the transport network; (c) inherent suitability for different land uses; (d) zoning status (i.e. legal constraints) for different land use classes; (e) socio-economic characteristics (e.g. population, income, production, employment). The information on land use types and transport networks is derived from the detailed GIS databases produced as part of the MOLAND activity. The output from the growth model is maps of predicted land use development over periods from ten to twenty-five years. The underlying spatial dynamics of MOLAND urban and regional growth model are determined by so-called 'transition rules' or weighting parameters which specify the interaction between neighbouring land use types. The model uses three types of land use classes: active functions, which participating in urban growth; vacant features where urban expansion actually takes place and fixed features, which remain stable during modelling process.

The stochastic parameter has the function of stimulating the degree of stochasticity that is characteristic in most social and economic processes such as cities (*Barredo et al., 2004*). Still the factor that makes the system work like a nonlinear system is the iterative neighbourhood effect, whose dynamism and interactivity can be understood as the basis of the land use dynamics. The iterative neighbourhood effect is found in the "philosophy" of standard CA, where the current state of the cells and the transition rules define the configuration of the cells in the next time step. An in deep description of the MOLAND Model can be found in Barredo et al. (*2003a; 2004*).

By modifying the input data (e.g. zoning, suitability, transport links), the MOLAND Model can be used to explore, in a realistic way, alternative future scenarios of land use development, population growth and spatial planning policies.

The assessment of the results test are carried out using two approaches: (1) verifying visually for comparing if the land use maps looks in a logical way; this procedure is a first idea of what the model is able to do; (2) quantitative evaluation of the degree of coincidence between the two land use maps using the comparison matrices method and Kappa coefficients in order to produce a fine-tuned version of the simulation and obtain accuracy values.

Once the results of the calibration are satisfactory, the future simulation of land use can be done for a period of 20-25 years time using the parameters of the calibrated model. It is supposed that the interactions between land use classes will remain relatively stable during the studied period. It is also fine-tuned to generate a sufficient number of new seed cells of various land use classes in new locations like rural area, which will change into residential, commercial, industrial areas etc.

3. RESULTS AND DISCUSSION

The analysis of the nature and causes of landscape changes in recent times show three main driving forces that act simultaneously in varying mutual importance. These are the accessibility, urbanization and globalization. An additional and unpredictable factor should be added the natural disaster (*Antrop, 2005*). Land use simulation models enhance a way to examine the impact of inappropriate future urbanization and alternative land use regulations on the environment before irreversible changes are made.

3.1. Assessing regional development in Algarve

Portugal is a mosaic of landscapes, partly due to natural causes but also because of the impact of human activity. Starting with 1970 important changes of land use pattern throughout the country and especially in Algarve occurred. A growing area of study involves the understanding of local forces (*Chavis et al., 1986*). The tourism is the key driving force in Algarve region that influenced significant changes of the landscape, economy, social structure, and cultural behaviour. The total surface of Algarve Province is 781.5 km² and the total urbanized area was 32.2 km² in 1950, respectively 119.1 km² in 1990.

The changes in the last 30 years led to a construction pressure especially residential area and tourism facilities. The major land use changes occurred in agricultural and natural areas, which were converted into artificial surfaces, mainly in residential areas. The growth in artificial surfaces occurred mainly next to the existing urban settlements and to the shoreline. The statistics shows an increase of 64% of development of residential area from 1972 to 1986. In the past decade was observed an increase of industrial building by 8.7%. The larger conversion of agricultural into residential areas was during the period of 1986 – 1998. The major development of industrial areas occurs in the eighties and of commercial areas in the nineties with the appearances of the major commercial units in the country. The green area had an increase due to construction of golf courses in the tourist areas as well increasing of natural areas due to abandonment of agricultural areas. It was also observed a decreasing of wetlands and water bodies.

Nowadays, big hotels on the shore and large apartment buildings are not built anymore, but instead golf courses and holiday villages spread along the Algarve coast. The urban areas continue to grew up as very small and disperse patches along the shoreline.

In the last years, Portugal suffered an increased number of large forest fires, particularly in 2003 faced the worst fire season in the last 23 years, which destroyed an important part of its landscape. The Algarve region was one of the most affected in the south of the country, where the fires burnt in August 2003 more than 35.745 ha of forestland and in September 2003 more 25.894 ha, devastating all the Serra of Monchique. In 2004 were much less serious forest fires although some of the meteorological conditions carried the same high risk as 2003 (*MURBANDY, 1999*).

3.2. Modelling land use dynamics in Algarve

A first simulation for the seashore area of Algarve has been produced using the historical land use database for the years 1986 and 1998. The area modelled is represented as a mosaic of 259,050 grid cells, each representing an area of 100 by 100 m. The land use were classified in 25 categories, 10 of which are land use functions, 8 are vacant land uses, and 7 are land use features into the model.

For the case of future simulations, the accessibility is a very important factor in land use change and was taken into consideration the following transportation links: fast transit roads, other roads, and railways. The stochastic parameter was set at $\alpha = 0.6$ where the urban patterns appears to have a logical distribution (more scattered).

It was observed that the built-up area has expanded significantly over the past 12 years. A significant increase was observed concerning residential continuous medium dense urban fabric from 0.59 to 1.10%, residential discontinuous urban fabric from 0.88 to 2.83%, and residential discontinuous sparse urban fabric from 4.74 to 9.61%. As well, a relevant increase was noted by industrial and commercial areas. The most affected land use classes were arable lands, which decreased by approximately 12%.

The results showed satisfactory calibration compared with other different values attributed to stochastic parameter. For the main land use classes the Kappa coefficient shows an acceptable agreement e.g.: Forests: 0.70; Residential continuous dense urban fabric: 0.87; Residential discontinuous sparse urban fabric: 0.7; Industrial: 0.6.

Based on the tested simulation, two future scenario simulations were produced for the seashore area of Algarve Province covering a twenty-year period 1998-2018. In this case, the demands for each land use class were calculated on the basis of land use growth trends from recent years. Changes between the start and end of the decades in question are largely determined using the MOLAND Model scheme shown in fig. 1.

For testing the feasibility of the model, in the second stage of the work, it was simulated the whole Province of Algarve using CORINE land use datasets for the years 1990 and 2000. The land use pattern of the area is represented by 1,026,744 grid cells of 100 by 100 m each one. In this case, the land use were classified in 20 categories, 5 of which are land use functions, 8 are vacant land uses, and 7 are land use features. For the predictions of future simulations, the demand for land is also calculated in relation with the accessibility of the area to the transport network (e.g. fast roads, roads, other roads, and planned roads).

During the ten year period (1990-2000), the land use classes with most relevant increase were discontinuous urban fabric, with a growth of 2,588 cells (0.51%), and industrial and commercial areas (343 cells), whilst arable land (943 cells) and open spaces with little or no vegetation (887 cells) decreased.

The weighting parameters were also calibrated in order to minimise the differences between the simulated and actual land use maps for 2000. Then, based on several runs of the model the stochastic perturbation parameter was set at α = 1.4. And, the Kappa coefficients confirmed the accuracy values between maps produced e.g. Forests 0.89; Continuous urban fabric 0.86; Discontinuous urban fabric 0.71; Industrial and Commercial areas 0.62.

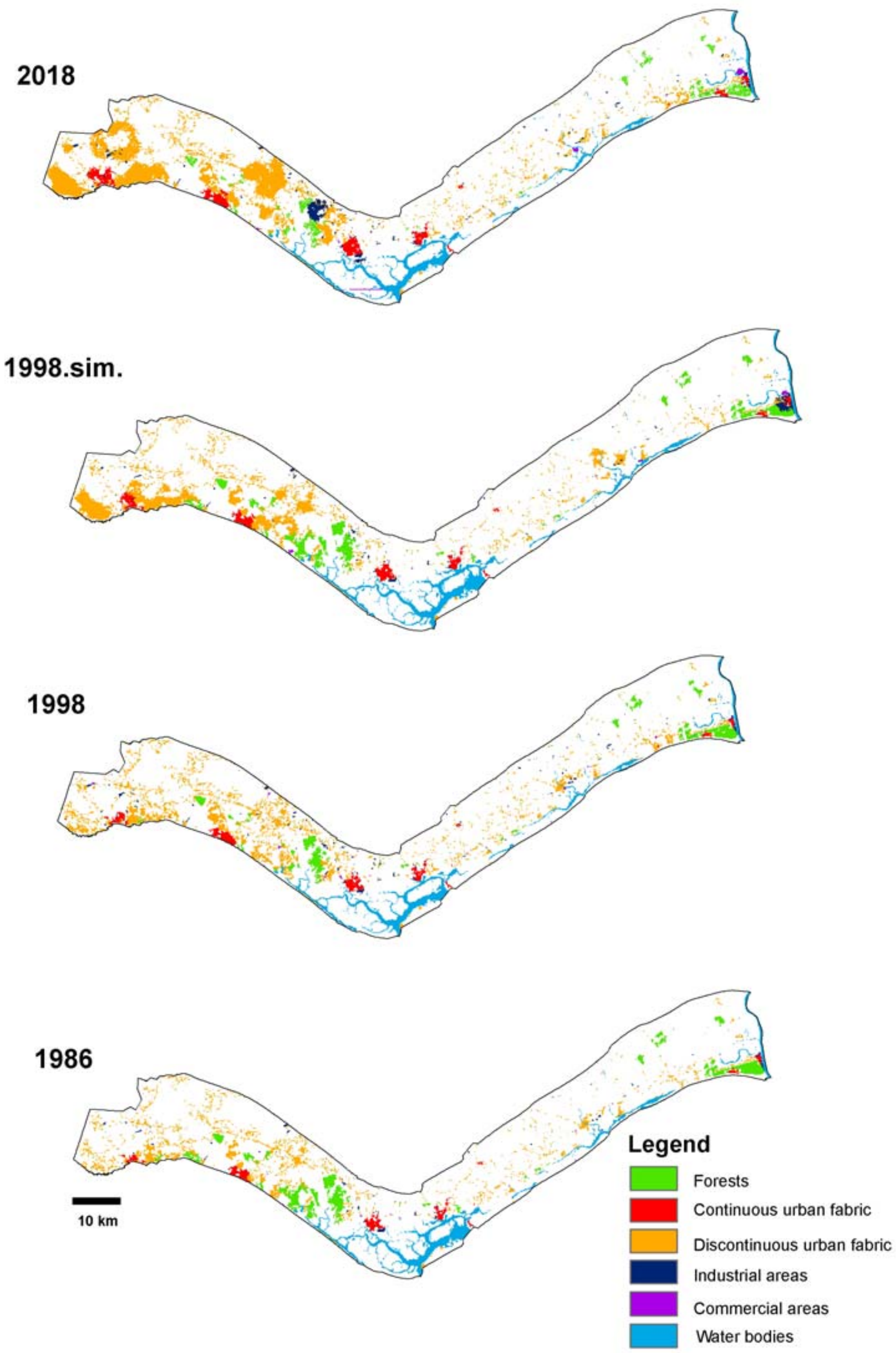

Figure 1. Algarve seashore area. Land use maps and simulations for the year 2018.

Subsequently a future scenario simulation for twenty years was undertaken for the period of 2000 – 2020 using the calibrated model. It is foreseeable that there will be an important increase in built-up areas as continuous urban fabric by 1.2 km² discontinuous urban fabric 21.76 sq. kilometres and industrial and commercial areas 6.9 sq. kilometres in the next 20 years. However, the general form of the developed areas in Algarve based on the initial transport network and land use is not drastically changed (fig. 2).

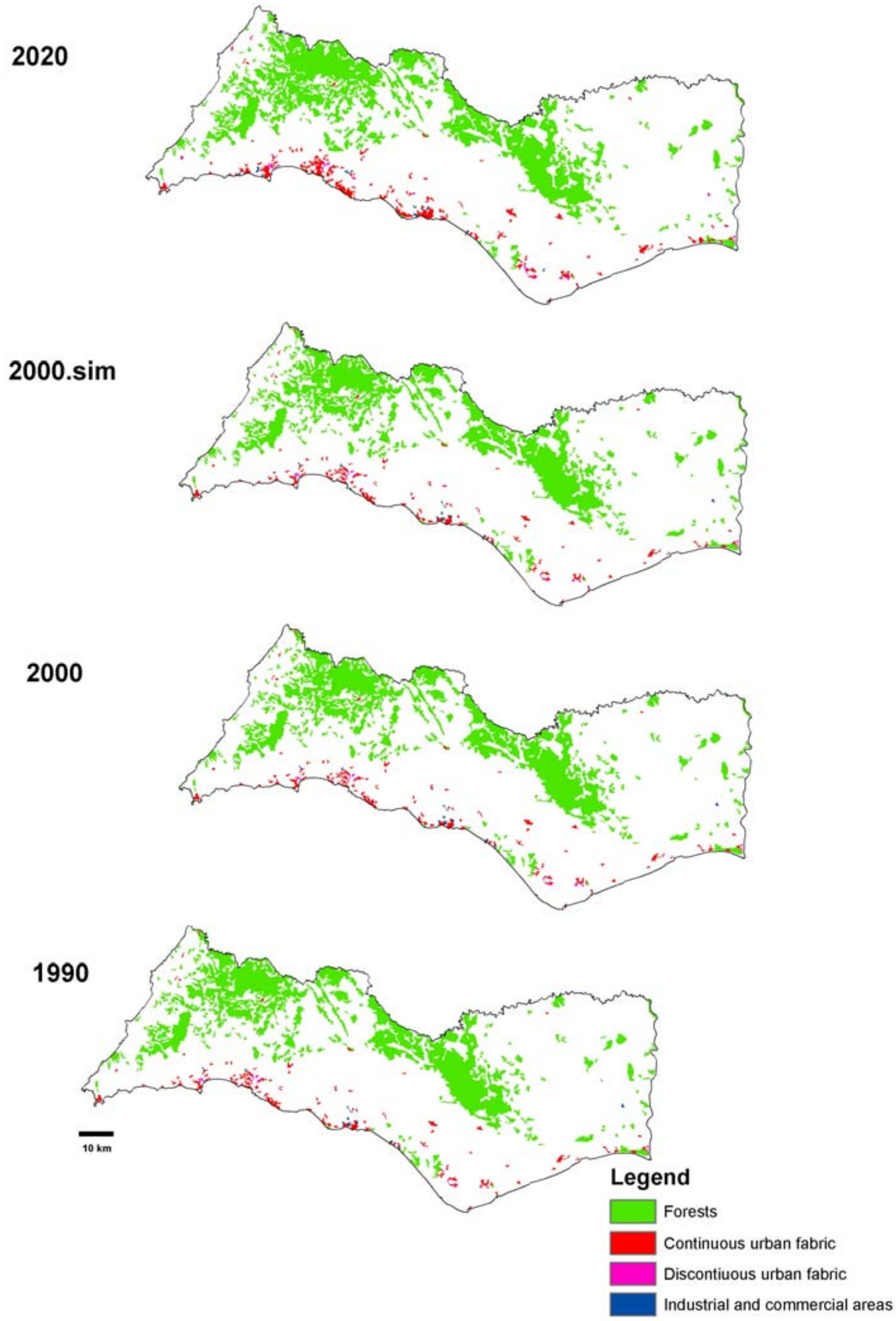

Figure 2. Algarve Province. Land use maps and simulation for the year 2020.

The above scenarios are a relevant information for the use in understanding the role of the impacts of forest fires hazard in the environment of large area of Algarve (current and forecasted). Fig. 3 shows the burnt areas in Algarve in the period 2003 and 2004.

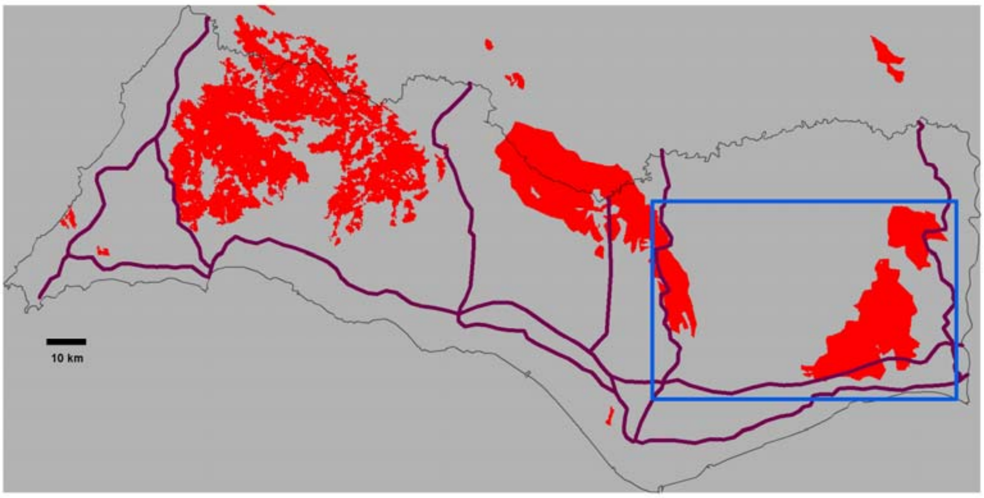

Figure 3. Algarve Province: burnet areas in 2003 and 2004.

3.3. Assessing regional dynamics in the Dresden-Prague corridor

The database for Dresden-Prague corridor test site is composed from three different sources: Dresden (*MURBANDY, 1999b*), Prague (*MURBANDY, 1999a*) and the transport corridor Dresden-Prague. The transport corridor is defined on the basis of the motorway D8 on the Czech side and A17 on the German side (fig. 4). This is a corridor of 110 km length and includes a number of municipalities of Northern Bohemia (Czech Republic) and Southern Saxony (Germany). The corridor is defined by a virtual buffer of 10 km on both sides along the motorway. The overall coverage of the three adjacent datasets is about 4,885 km².

The statistics for land use dynamics were obtained by using historical 1986-1989 and reference 1998-2000 datasets. For Dresden the artificial surfaces are roughly 25% of the overall area and increased by 8% during the period. The main contributors are residential, industrial and commercial areas showing a very dynamic development. The urban green areas are considerably small, however it rose up to 20%. The open land fell by 2%. The main losses are registered in agricultural land decreasing by 3% and natural areas decreasing by 3.7%.

Based on the statistics obtained from Prague, the artificial surfaces occupy 35% of the overall area and increased by 3% during studied period. The main contributors are industrial and commercial areas; and, the construction sites increased by 75%. The main landscape affected is the agricultural land.

The evolution of urbanised areas in the transport corridor shows high dynamics, its increase being of 6% mainly due to new residential, commercial and industrial areas. The growth of commercial sites (33%) is associated mainly with towns' centres and outskirts, which demonstrate mainly re-structuring of urban space.

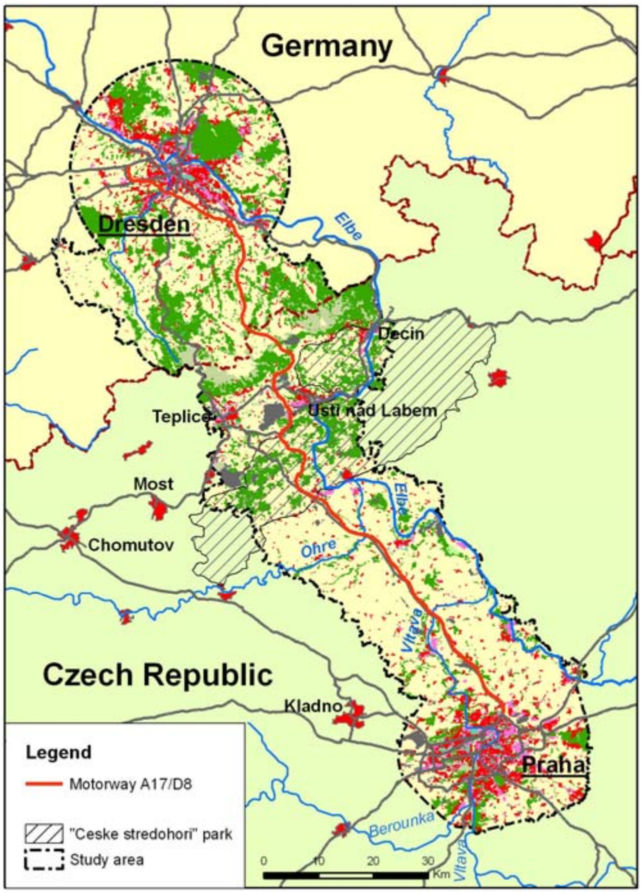

Figure 4. Dresden-Prague transport corridor.

3.4. Land use dynamics and scenario simulation in the Dresden-Prague corridor

The MOLAND Model was calibrated by using historical 1986-1989 and references 1998-2000 land use/cover datasets. The land use classes were classified in 25 categories, 9 of which are active, 8 are vacant and 8 fixed features. Transport network layers have been also used in order to simulate the effect of accessibility on land use dynamics.

The simulation for the period of 12 years (1988-2000) was initiated using the historical datasets in order to test the results by comparing them with the actual land use from the reference dataset. The statistics of real changes between historical and reference datasets in terms of territory were incorporated into the model in order to handle land demand for each particular land use class.

The assessment of changes in land use pattern for a set of three different scenarios were developed and for each scenario the simulation model was established for a 20 years period from 2000 up to 2020.

Business as usual scenario (fig.5) was produced by using the trends from the end of the 90's. The land demands for urban land use classes were calculated according to the trends of the last 4 years of the calibration period. Concerning the industrial area it is foreseen not to grow. In fact, abandoned industrial areas can be re-developed and used by new commercial or industrial activities. The importance of the motorway and the accessibility to certain land use classes, such as industry, commercial, has not increased yet considerably. The results show that the development of the two main cities occurs on the outskirts and the industrial and commercial activities moves from the core centre to more peripheral areas. The steady demand for single family houses leads to the proliferation of low density residential areas in the outskirts of the cities of Dresden and Prague. A minor urban development can be seen around the cities of Northern Bohemia. It can be observed the absence of changes in predominantly rural countryside where decrease of population and economic activities are likely to take place. The main types of urban processes in this scenario are de-centralization and edge development.

Built-up expansion scenario is based on economical and environmental assessment called European baseline scenario, published by EEA (2005). Here, the demand for residential land increases by 50% for low and medium built-up density classes. For commerce and services the land demand even doubles and importance of fast transport links grows. As a result, in old core centres new development gradually turns to appearance of advanced commercial and services centres. The growing building activities on outskirts of the big and medium size cities determine an increase of commerce, industry and services so that new urban cores appear. These new urban clusters are located around old villages or related to transport links. Development in rural areas is still moderate. The main types of urban processes here are de-centralization and polycentric development.

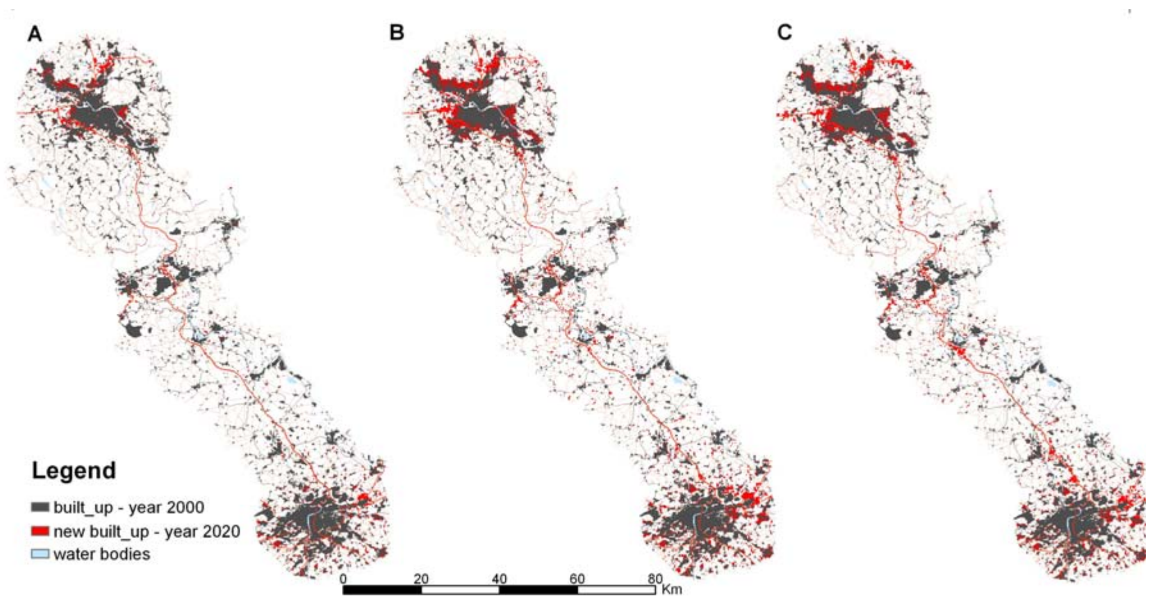

Figure 5. Scenarios of urban land use development for the corridor Dresden-Prague. A (Business as usual scenario) shows a moderate urban growth. Scenarios B (Built-up expansion scenario) and C (Motorway impact scenario) are examples of extremely high development. In the scenario C the role of the motorway is reinforced.

Motorway impact scenario is characterized by the same land demands for urban classes as in the built-up expansion scenario but the role of the motorway between Dresden and Prague is reinforced in terms of regional development. This leads to the setting up of commercial and services sites in its surroundings, which currently are predominantly rural areas. For the Northern Bohemia cities i.e. Teplice, Usti nad Labem and Decin and their surroundings, the increase of commercial activities is of great relevance regarding the development of the region with the new motorway connection.

The three scenarios show that urbanisation in the corridor area will most likely take place around main cities. In the case of Dresden, a spread and diffuse development style is foreseen. In Prague, a more concentrated and clustered urban pattern is devised. The influence of transport networks will be higher in immediate vicinity of developed centres and either in predominantly rural areas. The motorway has an important role, as new development axis, which can reinforce the urban growth in the countryside. However, real changes will be strongly depended on general economic situation and/or special structural policies and regional projects.

Based on both the MOLAND land use historical database of the Dresden-Prague corridor and the three future scenarios provided by the MOLAND model presented above can be said that according with the first scenario, built-up areas in flood prone zones in the corridor are expected to rise by 11 km² in the future. Regarding the case of the second and third scenarios, the built-up areas in flood-prone areas will increase from 21 to 24 km² (fig. 6).

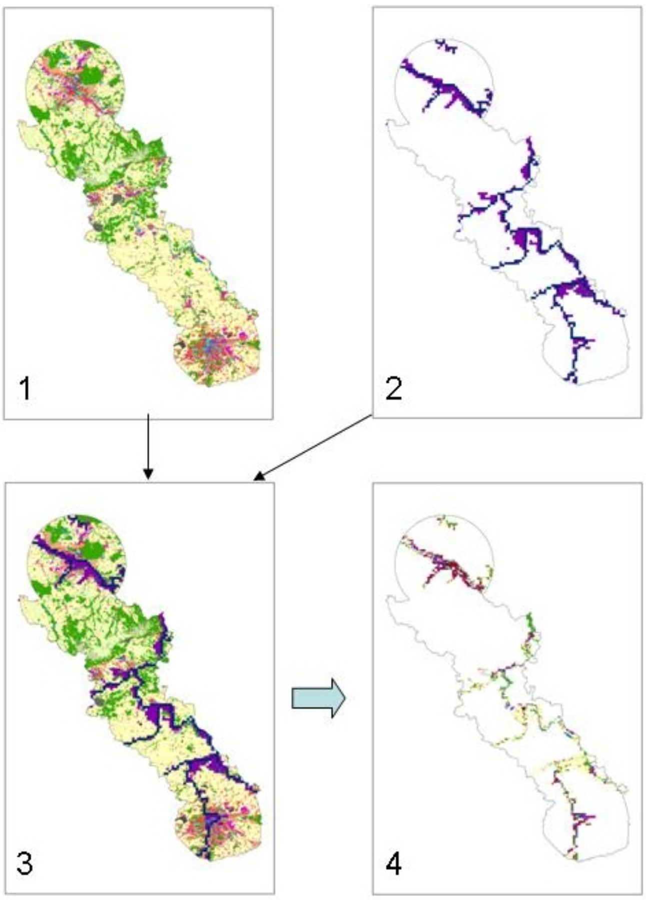

Figure 6. Dresden-Prague corridor. Scenario approach for flood risk assessment. 1) Scenario simulation for 2020. 2) Flood hazard map. 3) Overlay of 1 and 2. 4) Exposure to floods on the basis of the several scenarios produced for the corridor.

3.5. Assessing regional dynamics in the Friuli-Venezia Giulia region

In terms of land use, the territory of FVG could be subdivided on large and scarcely populated mountain and foot slope areas, with share of natural lands over 75% in the north. In the southern lowlands the predominant landscape is composed by extensive agricultural and urban land uses, with a low share of natural areas-under 25%. This pattern has remained stable during the study period of fifty years, showing very slow dynamics in mountain areas and large-scale changes in urban land use on the plain area. The population dynamics can be differentiated in terms of territory. In mountains and foot slope areas there has been a systematic depopulation process. In the lowland areas have showed a population increase in province centers in the 50's and the 60's related to the Italian economic boom.

We analyses several spatial indicators in the form of maps describing population growth, spatial patterns, and the historical growth of built-up areas. Then we show the results of a dynamic spatial model for simulating land use scenarios. For the purpose of the study, the regional version of the MOLAND model (*Lavalle et al., 2004*) has been used and an integrated database has been built up with data and information on land use, transport and socio-economic sectors from 1950 onwards.

Urban simulations offer a useful approach to understanding the consequences of current spatial planning policies. The spatial and demographic trends identified were represented in the simulation model for Pordenone. Within this approach it is feasible a realistic representation of the future land use in Pordenone based in such trends.

The model for Pordenone was calibrated and tested by using time-series data on land use (see Barredo et al. 2003; 2004) and through a set of spatial metrics. The simulation for the period 1980-2000 initiates using the historical datasets for the year 1980 in order to test the simulation results using the reference datasets for 2000. Two future simulations have been produced until 2020. The first one (2020-a in Figure 7) represents a fairly compact development style for the urban nuclei in the Province of Pordenone. A second simulation more in line with the past trends shows a more scattered development style for the new built-up areas (2020-b in Figure 7). In both cases the influence of roads is taking into account for the growth of new built-up areas. The results of the simulations are realistic and achieve a high level of detail, showing in the second case the effects of current trends on the future urban land use in Pordenone. Note that in Figure 7 the original land use legend of 24 classes have been grouped into two classes: built-up and non built-up areas. Nevertheless, it is noticeable the capability of the model for simulating several types of urban land use classes simultaneously.

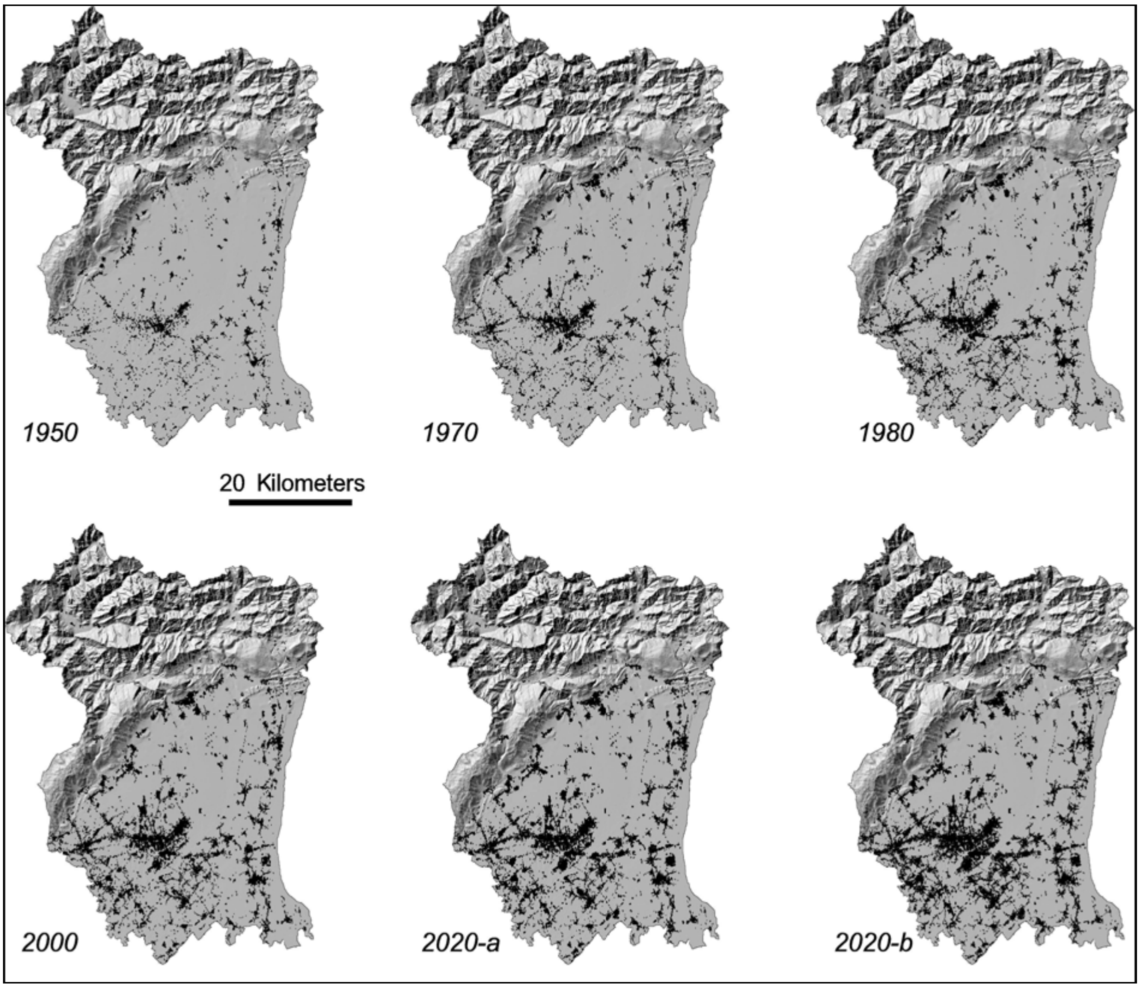

Figure 7. 1950-2000 built-up areas in Pordenone Province. 2020-a and 2020-b are two simulations for 2020 year. 2020-a) Simulation showing Organic growth 2020-b) Simulation showing Spontaneous growth (built-up areas in black).Source Barredo et al., 2005.

3.6. Flood risk assessment in Pordenone Province

We show in this section some preliminary results of a flood risk assessment carried out in Pordenone Province. Historical land use datasets and two future simulations were used for the risk assessment. Pordenone is a highly flood-prone area. Two heavy floods hit Pordenone in the last years, the floods of 2002 with 580 mm rain in 36 hours, and the still worse flood of 1966, which can be described as the 100-year flood event.

The flood risk assessment is based on a flood hazard map for the Livenza River catchment area. The map has been produced by the regional Water Authority (*Water Authority for the North Adriatic Rivers, 2003*). By simple map overlapping it is worth noting the current built-up areas at risk of flood in the Livenza catchment area. It can be seen that a number of dwellers are placed as well in flood hazard areas. Even if structural measures for flood protection have been undertaken in the last years in the Pordenone Province's floodplain, it is foreseeable a number of dwellers and properties affected in the case of new heavy flood in the area as such of 1966 (*see Barredo et al., 2005*).

4. Conclusions

Using scenarios is one way to address the concept of sustainable development. Each day decisions are made by land managers about where, when, and how to implement construction, and re-development initiatives. An important aim of such scenario analyses is to enhance the decision maker's understanding of the future by providing 'perceptions' of several possible future environments against which decisions can be tested. The goal of these analyses is not to predict the future but rather to help manage the present and build bridges between scientists and decision-makers.

Urban simulations offer a useful approach to understanding the consequences of current spatial planning policies. The objectives of this approach are to monitor sustainable development trends and to assess the effect of natural hazards (e.g. floods and forest fires) in urban areas and regions. We propose the use of future urban scenarios in order to forecast the effects of urban and regional planning policies.

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