Modelling the impact of public policies on socio-economic parameters with cognitive agents

Johannes Scholz, Eva Haslauer, Michael Andorfer and Manfred Mittlboeck

Research Studio iSPACE, Research Studios Austria Forschungsgesellschaft

Schillerstrasse 25, A-5020 Salzburg

Email: {johannes.scholz, eva.haslauer; michael.andorfer; manfred.mittlboeck}@researchstudio.at

Abstract

The research project MOSIPS utilises agent-based models to simulate the effects of public policies on small and medium enterprises (SMEs). Due to the fact that changes in SMEs are directly related to socio-economic phenomena, we propose that there is a relation between socio-economic phenomena and land use and land cover changes. The relation between SMEs and socio-economic phenomena is justified by e.g. a promotion of the Information and Communication Technology sector in a city, which attracts particular groups of people with certain levels of education and wealth. These people commute or move permanently to the city which has an impact on future land use and cover in the city under investigation. The research question of this paper elaborates on the impacts of public policies on SMEs and the subsequent effects on land use and land cover. The modelling and simulation environment utilises cognitive, generic agents that act in the simulation environment, considering the spatio-temporal context of each agent.

Introduction

Land cover and land use is a result of human activities on the surface of the Earth. Humans gather together and live in communities, try to "produce" food, and develop an economy. Due to the fact that each action "consumes" a certain piece of land, the original land cover and/or land use is altered. Hence, this paper is based on the assumption that the behaviour of people has an impact on the environment, as humans and their actions are the primary driving factors for land use and land cover changes. We are currently witnessing a steady population increase in cities and urban areas, which can be justified by the greater number of job opportunities as compared to rural areas. This trend is challenging urban planners as space is a scarce "good" in a city. This is especially true for cities surrounded by mountains or any other type of natural limitation for settlement or other types of human action.

Furthermore, this paper elaborates on the effects of public policies on land use and land cover (subsequently LU/LC). Due to the economic crisis in the last years, decision makers want to support key economies of a region in order to maintain the economic well-being. Hence, public policy makers often have the primary goal of creating new jobs in a certain area, but the impacts on LU/LC are hardly highlighted. Thus, this article deals with the effects of public policies, and in more detail with the impact of funding certain economic sectors, on the LU/LC. Here we assume that people are attracted by new jobs that are created as a result of the funding activities through public policy makers, and subsequently make a permanent shift closer to their workplace. As a consequence, residential areas suffer the pressure of an increased population density and a tendency to change the land cover of areas adjacent to residential areas can be observed.

The hypothesis of this paper is as follows: There is an effect of public policies – i.e. the funding of a certain economic sector and/or key industry – on land use and land cover. In this paper we focus on a study region in the province of Salzburg, where we highlight the impact of exactly one funded economic sector, present two examples of the emergence of new medium sized industrial facilities, and evaluate the LU/LC change respectively. In order to model the impact of public policies, an agent-based modelling approach is used, which utilises generic agents moving around in space, capable of making independent decisions. This article does not elaborate on the effect of multiple public policies and competing public policies of e.g. different administrative regions.

The paper is organised as follows: The introduction is followed by a literature review of related scientific publications. Consecutively, the methodology of this paper is described, which follows the idea of agent-based modelling. The experiment is highlighted followed by the results achieved, and a detailed discussion of the outcomes.

Relevant Literature

When defining a social system, agents generate spatio-temporal actions affecting their environment and neighbourhood, and interact with other agents over the utilization of space. If several agents are defined in a system it promptly reflects the diversity and the heterogeneity of a system. Due to the fact that Agent Based Models (ABMs) represent a broad variety of a world's characteristics, they became very popular in the last years. Thereby the world as a whole, as well as its regional and urban sub-structures and the related physical components became analyzable in terms of change and development.

The spatial component of geo-modelling is often so strong, that generic modelling is prevented. . Just recently models, or rather, generic frameworks were developed as an initial step. Afterwards they were applied to a special problem, delineating the simulation, which is particularly necessary.

In terms of model development, Cellular Automata (CA) were created prior to Agent Based Models. SLEUTH or METRONAMICA present some generic modelling packages, however, CA for geographical systems are not too elaborated. Microsimulation systems are even more tailored to focus on space. Therefore, both microsimulation models (MM), as well as ABMs can be applied as spatial models. MM can even evolve into ABM. It is a similar case for CA and ABM: According to Torrens (2012) CA and ABM can be merged together with GIS, forming geographical automata systems (GAS). The difference is that general packages have only been developed for ABM being applicable to a variety of problems, e.g. SWARM, Repast or NetLogo. To a certain extent ABM even cover CA models. In many cases, e.g. Iltanen (2011), Batty (2009) CA represent the environment in which agents move and behave.

CA are often considered as a special form of ABM changing their state – within a defined area - from one to another. These changes are based on rule-sets considering the behaviour of the cells and their adjacent neighbours. One example is the segregation model of Schelling (1978) in which a cell's state changes according to its surrounding cells. In this case a cell is equivalent to an agent. Such cells host an individual with an intrinsic opinion. If a cell changes its state, it represents the individual changing its opinion. The behaviour of agents is often considered to be reactive or proactive (M. Batty et al. 2011).

CA are considered to be simple mathematical models, used for modelling discrete dynamic systems. These models evolve due to a repeated application of simple, deterministic rules (Wolfram 1982). CA basically simulate a spreading out from given point into adjacent neighbouring cells not differentiating between time and space. The surrounding is considered to be equivalent to the population at any state in a neighbouring cell, in other words, the population is related to a location at a certain time. Spatial scales in CA models are often large, e.g. in urban or land-cover models, whereas temporal scales are at any rate one year intervals. CA are suitable for modelling land developments from the supply point of view, or they try to reach equilibrium between supply and demand during their model process. They generally do not cover and model socio-economic topics as demographics are included, rather they focus on physical topics (Batty 2011). What is characteristic to a CA model is that the cells location does not change, the automaton's location doesn't move, but they change their state (Crooks and Heppenstall 2011).

The strength of those models is the simplicity of their implemented transition rules, which provide more flexible system behaviour than other models. CA calculate the transition (e. g. from non-urban to urban landscape) of a system, imagine cells in a grid space, depending on the neighbourhood: Land use changes are a typical field of application (Crooks and Heppenstall 2011) as the state of a certain cell depends on the previous land use at this location, or the state of land use of its neighbour cells. These approaches allow a numerical analysis of non-numerical geographic systems (Kim & Batty 2011).

ABM on the other hand are in many terms similar to CA models, but they do not treat environment and population separately (Batty 2011). ABMs in general simulate actions of autonomous agents, and display their behaviour and the dependencies between those agents and to other agents. The aim of ABMs is not to reach equilibrium, but to find out how a system does adapt to changed conditions. (Macal 2010) According to Mandl (2003) ABMs generally incorporate an environment with a spatial dimension, as well as a number of objects in the environment, which are passive and can be recognised, created, destroyed, and changed by the agents. ABMs consist of a community of agents, which are active and moving. They can be physical or virtual entities, interacting with a natural or artificial environment, communicating with other agents, they can have certain "goals" to reach, and can reproduce and show individual behaviour. Mainly population is influencing ABM, since it is represented as agents with individual behaviour. During modelling the environment is often the passive part, and population serves as stimulant for change processes (Batty 2011). In an ABM, relations exist, which connect objects and operations that allow agents to recognise, create, consume, transform, and manipulate objects. Operators apply operations and represent reactions of the world to changed conditions. Van Berkel & Verburg (2012) mention an ABM in which the willingness of agents, their opportunities and choices are simulated.

As just mentioned, ABM can simulate interactions between individuals, groups of individuals or also, for example between policies not being represented by individuals. This approach is also used in land cover modelling.

However, the core task of an ABM in the field of geography is the representation of change processes that affect the respective system. The possible interaction of agents with one another and with the environment as such, and the related changes, enable ABM to co-operate with open systems as no other modelling approach is able to. In this context it is important to recall the fact that agents act together with other agents and interact with their environment. This is also strongly related to the topic of integrating networks in an ABM analysis or framework, as a lot of developments diffuse in space and time

When thinking about dynamics and behaviour in the context of ABM one has to consider the fact of cognition. It determines how and to which extent agents are adaptive and how they recognise their surroundings. Finally one also has to bear in mind the scale of those models. Agents often act across scales, but basically they behave on the individuals' scale. In this context is has to be taken into account that agents become less predictive the coarser or larger their scale of activity gets (Batty et al 2011).

As mentioned before, CA are very simple models also in the field of urban modelling. They mix population and environment, i.e. the objects of the environment are similar or practically the same as the objects of the population, one environmental cell is thus one population object. So, a cell can have one or more states referring to varied characteristics of the population object. In CA, which are a bit more sophisticated, a cell can cover more than one population object. This is often considered as the interface to an ABM (Batty 2011). CA can have one population object with many attributes or states as well as more than two states which represents e.g. changes in LU/LC classes or changes in the type of population (age, income …). One cell can just influence its adjacent neighbours (Von Neumann or Moore neighbourhood).

CA can have different cell states reflecting land-use states in a specific cell at a defined time. So, CA can be simplistic modifications of an ABM with cells representing agents and the cells' states their attributes (Batty 2011). As Crooks and Heppenstall (2011) state, today many models are yet a mix of ABM and CA with a fuzzy distinction, which stand for more flexibility and power. This combination is also inherent in the approach that was used in the proposed model by the authors. Although the modelling approach was implemented with ESRI ArcGIS Agent Analyst, the performance of the model strongly reminds of a CA visualizing the cells' state as environmental characteristics influencing the agents' behaviour.

Stillwell and Scholten already determined in 2001, that land use and thus also land use changes are strongly influenced by environmental and economic explanations. Yet due to their complex character, there was great difficulty in comprehensively communicating past land use developments. But the more challenging task is the future prediction of land use changes.

Methodology

This section describes the methodology used in order to evaluate the effect of public policies on LU/LC. In addition, the agent-based approach used in this paper is described in detail. Thus, this section describes the approach to model the natural population growth, the population growth induced by public policies (i.e. funding of an economic sector or key industry) and the pressure on LU/LC generated by population growth.

Agent-based modelling approach

In order to model the population growth and the impact of public policies on land use and land cover respectively, we utilise an agent-based methodology. The approach is comprised of polygon agents that "act" in space, which is similar to the CA (Crooks and Heppenstall, 2011). Nevertheless, the population can be exchanged between neighbouring polygons, which allows the incorporation of dynamics in population modelling. In addition, each polygon agent can change its land use/land cover based on pre-defined transition rules.

The ABM approach in this paper comprises polygon agents that are arranged in a regular grid with 500m resolution – overlapping with CA. Each agent – i.e. polygon – holds information on its LU/LC state and the population resident in the polygon. Additional layers are available, giving information on the natural population growth and the population growth induced by public policies. Hence the population of a cell *x,y* ($Pop_{C_{x,y},t_x}$) in a certain point in time t_x is defined: $Pop_{C_{x,y},t_x} = Pop_{C_{x,y},t_{x-1}} + \Delta Pop_{C_{x,y\_nat}} + \Delta Pop_{C_{x,y\_PP}}$. In this equation $\Delta Pop_{C_{x,y\_nat}}$ denotes the natural population growth per year and $\Delta Pop_{C_{x,y\_PP}}$ the population growth induced by public policies.

In addition, for each LU/LC class a population threshold is defined that defines the maximum number of citizens "living" in a polygon (agent). If the number of people living in a cell exceeds the threshold value, the agent has two options:

- convert the LU/LC type
- transfer the population above the threshold value to a neighbouring cell

These options are described in detail in the section "*Land use and land cover changes due to population growth".*

Central to any ABM simulation is the temporal dimension. Thus, the approach in this paper cannot neglect that issue, as the simulation approach covers a time interval that is some time in the future. As time in ABM engines is represented by ticks, we defined that each tick equals one year. Hence, the temporal granularity of the model in this paper is exactly one year, which means that no statements can be made on the intra-year variations of population distribution.

The ABM approach in this paper relies on the following overall process sequence, depicted in Figure 1. Based on the population present in 500m raster cells and the LU/LC data, the time is rolled forward by one tick/year. Based on the annual natural population growth $\Delta Pop_{C_{x,y\_nat}}$ and the population growth induced by public policies $\Delta Pop_{C_{x,y\_PP}}$ – subsumed under "Auxiliary data" – the population of each cell/agent is updated. The updated population value for each cell is compared with the population threshold for the corresponding LU/LC class defined beforehand. If the updated population in the cell is lower or equal than the threshold value, the cell/agent is updated in the next iteration – at $t=t+1$. Otherwise the following approach is applied: The agent tries to change its LU/LC type based on the defined transition rules. If a transition is not allowed, the population exceeding the threshold is moved to a neighbouring cell. Subsequently, the agent and the cell where the population is shifted to, have to be checked regarding the population threshold value. Only if all cells have their population lower than or equal to the threshold value, the algorithm will roll one year forward in the simulation. In general the simulation is run for a predefined number of steps, which is expressed in the maximum number of ticks.

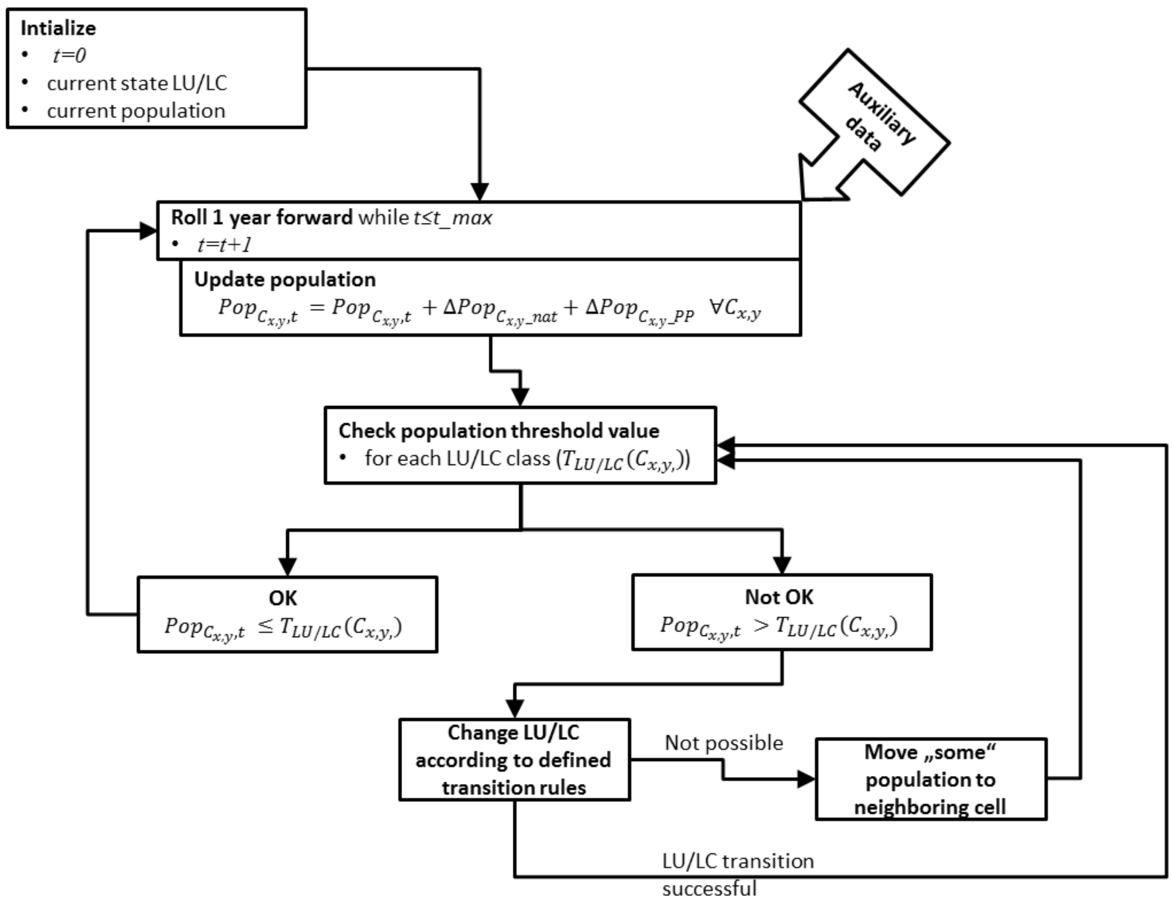


Figure 1: Simulation process to evaluate the impact of public policies on population and LU/LC.

Population Growth: natural and induced by public policies

In order to model the population growth in this paper, we consider the population growth to be two-fold: On the one hand there is the natural population growth, on the other hand the population growth induced by public policies, i.e. a funding of a certain economic sector or of the support to start a key industry. The latter has an effect on people moving to the vicinity of the location where jobs are created. Hence, there is a growth of population that has to be “digested” by the area under investigation.

In order to model the natural population growth, we employ census data of the last and the second last census, in order to calculate an annual population growth value for each 500m raster cell. The calculation of the population growth induced by public policies is dependent on the statistical data of the number of employees per census district per ÖNACE class. Based on the dataset a specific ÖNACE economic sector – i.e. one ÖNACE *(*Nomenclature statistique des activités économiques dans la Communauté européenne in Austria) class – is chosen. Furthermore, a simple "funding schema" is fixed that defines the percentage of newly created jobs per year through the application of the public policy in relation to the existing ones.

The starting a key industry at a specific location is modelled through a single hotspot where the new jobs are created at once. Hence, if a company or an agglomeration of companies starts at a specific hot spot, the authors assume that the jobs are created at once, not gradually. Once these hotspots are established, only natural growth can be applied to those cells.

Furthermore, it can be assumed, that each new job causes the movement of a person close to the workplace. In most cases the family of the person filling the vacant position would join. In this paper we neglect that issue for the sake of simplicity. Hence, only the person filling the vacant position is considered here.

Land use and land cover changes due to population growth

The LU/LC under consideration in this paper is similar to Scholz et al. (2013). In this approach Corine Lancover is the basis for LU/LC classes for population disaggregation purposes. In this paper, Corine Landcover data are used to extract the LU/LC classes of interest for the simulation. Here, we consider only four basic LU/LC classes:

- Populated areas
- Agriculture
- Forested Areas
- Water bodies

Each LU/LC class is assigned a population threshold value that defines the highest population density possible on a certain raster cell. The values assigned to each LU/LC class are defined in section "Experiment Setup". If the population in a raster cell exceeds the threshold, due to natural population growth and/or population growth induced by public policies, there are two options:

- convert the LU/LC type
- transfer the population above the threshold value to a neighbouring cell

In this paragraph we concentrate on the transfer of the land cover type (see Figure 1). If the population threshold is exceeded, and the LU/LC type <u>can</u> be changed – due to a given transition matrix – the LU/LC of the cell <u>is</u> changed. The LU/LC class can only be changed to a LU/LC class related to a higher population threshold. For example, "Agriculture" can be switched to "Populated Areas" but not vice versa. In addition, there are LU/LC classes that cannot be changed, due to e.g. legal restrictions, natural barriers, or spatial planning decisions. In this paper, we consider natural barriers and legal restrictions to define possible transitions in LU/LC change.

Population shift due to exceeded population threshold

In order to cope with a population in raster cells that exceeds the defined threshold value, the population is transferred to neighbouring cells. The reasons for population numbers exceeding the threshold are natural population growth and growth induced by public policies. Thus the population exceeding the threshold is only switched to neighbouring cells if these are capable of hosting some more population (i.e. current population below the given threshold).

In the course of the population shift from a target cell to the neighbouring cell, the algorithm considers a 3x3 neighbourhood (Moore neighbourhood). The actual cell(s) where the population is shifted to are determined based on randomization. Hence, all neighbouring cells – taking into account a 3x3 neighbourhood – are checked regarding their capability to host the population number. Only the cells that can receive the population numbers are considered as candidate cells. The cell, where the population is transferred to, is chosen based on a random selection process. If no candidate cell is found one cell is chosen – denoted as *non-eligible candidate* – and the population is moved into the next neighbouring cell of the non-eligible candidate. This procedure is repeated until the population is added to a cell, respectively.

Evaluation approach

To evaluate the results with the methodology highlighted in the paragraphs above, we propose a methodology to numerically and visually analyse the results at hand. Hence, the authors analyse the LU/LC change in the area of interest – i.e. the transition of cells – based on certain simulation scenarios over a given simulation period. In order to be able to evaluate the impact of public policies, a simulation run without any population growth induced by public policies is conducted. This serves as baseline scenario for the comparison of the different simulations. Based on this baseline scenario the impacts of public policies are analysed both visually and numerically.

Experiment

Based on the methodology elaborated on in the previous chapter, an experiment is conducted that allows the evaluation of the methodology and results in numerical values for a given test area. Thus, this section highlights the preliminaries for the experiment as such: the area of interest, the data used for this study, the parameterization of the algorithms, the software environment, and the scenarios, which the experiment is based on.

The area of interest in this paper is a rectangular shaped clip, covering parts of the provinces Salzburg and Upper Austria (see Figure 2). Due to data un-availability, the study area only covers the parts of the rectangular area that are located completely within Austria. Nevertheless, the original rectangular area has an approximate size of 60*41km. The study area includes rural areas that are covered with forest and lakes; this is visible in Figure 2 (areas in green and blue color). In addition, one major city – Salzburg – is located within the study area, besides a number of cities of local importance.

The data used throughout the experiment originate from the Austrian Census Bureau – Statistik Austria – and the European Environmental Agency. In order to model the population and the natural population growth the following data are used:

- census data from 2011: raster data set with 500m resolution
- census data from 2001: raster data set with 500m resolution

To provide the number of jobs in different NACE classes we use a dataset provided by the Austrian Census Bureau that lists the number of employees per NACE category for each parish for the year 2001. The LU/LC is generated based on the Corine Landcover 2000 (EEA-ETC/TE, 2002).

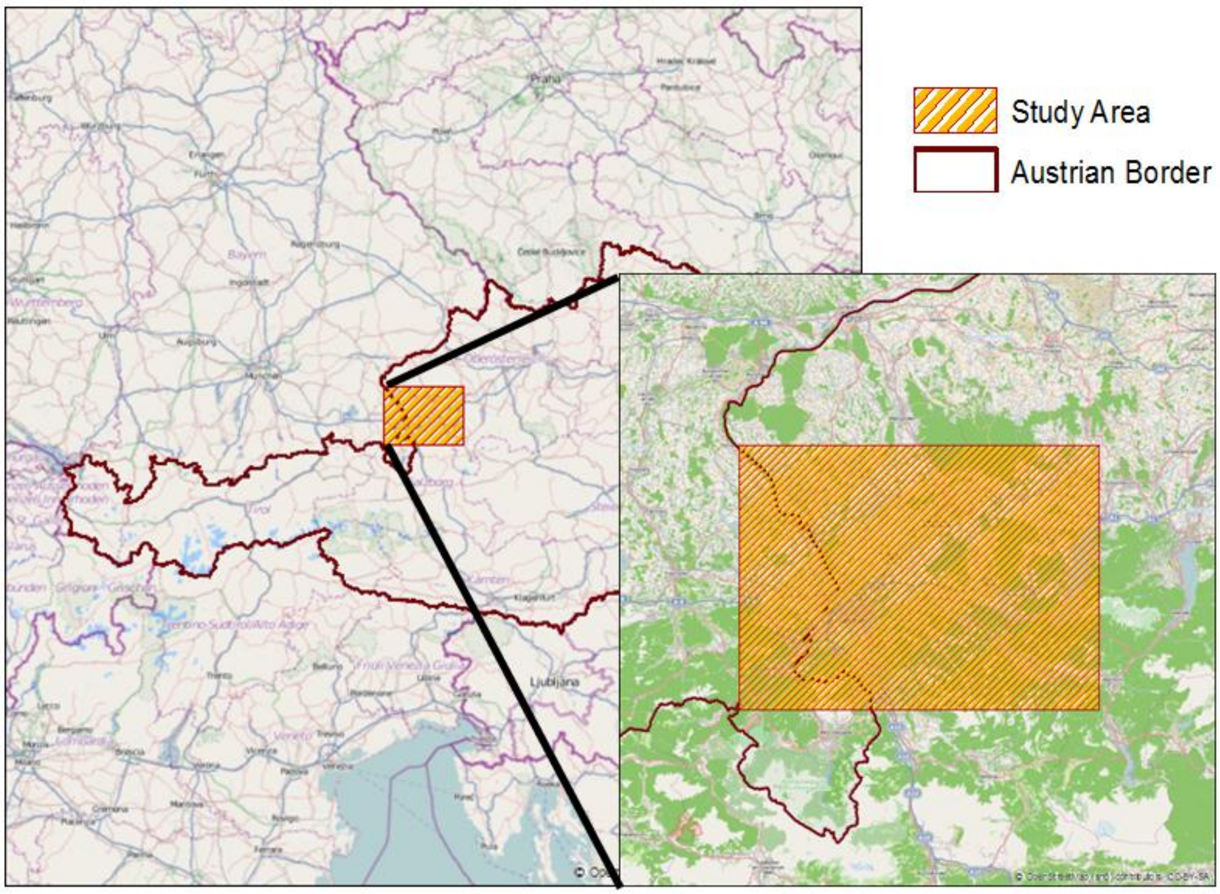


Figure 2: The study area of the paper is located in Salzburg and Upper Austria; note: only the Austrian parts of the orange rectangle are part of the study area.

The software environment used for the experiment is based on standard industry software. We employ ESRI ArcGIS 10.1 as the Geographical Information System for analysis and visualization purposes. The ABM is done with Agent Analyst v1.0b (Johnston, 2013), due to the fact that this piece of software integrates seamlessly in ESRI's ArcGIS. The experiments were carried out on standard Windows 7 based personal computers (Intel i7 vPro processor, 8 GB RAM).

In order to evaluate on the impact of public policies on LU/LC we defined four simulation scenarios that are calculated using the model described in the previous chapter. The simulation scenarios range from a baseline scenario that has only natural population growth, to a scenario "*etInc*" reflecting natural growth and population growth induced by public policies, to scenarios where key industry is located at a specific location (i.e. through a business park, business incubator center etc.). In detail the authors defined the following scenarios:

- Scenario 0 "*natgroRef*": In this scenario only the natural population growth is modelled. Thus, the obtained results serve as a reference for the other scenarios.
- Scenario 1 "*etInc*": Here the economic sector with NACE code *S* (i.e. "other services") is funded, which results in a population growth induced by the policy and the related emerging natural population growth. In detail, the algorithm to fund the sector is as follows: We assume that another 20% of the current jobs in a 500*500m raster cell are created per year by the funding activities. Due to the fact that NACE sector *S* is not a very prominent one, the number of new jobs per year ranges from 0 to 6.48.
- Scenario 2 "*hall*": In this scenario two key industries or business parks are started in the city of Salzburg and the city of Hallein. In each location a number of 9,000 new jobs are created that have an impact on population.
- Scenario 3 "*mds_stg*": Two key industries are opened up in the city of Mondsee and the city of St. Georgen im Attergau – two rural cities with local importance.

In order to model the impact of population growth on LU/LC the authors defined the following threshold values of each LU/LC classes. The threshold values define the maximum number of people living on a raster cell (500*500m). If the number is exceeded the LU/LC can be changed or the population that exceeds the threshold can be moved to neighbouring cells. The threshold values applied in the experiment are given in Table 1.

Table 1: Population threshold values for given LU/LC classes.

LU/LC class	Threshold value (max. population)
Populated Areas	1000
Agriculture	200
Forested Areas	100
Water Bodies	0

As mentioned in the last paragraph, the transition of LU/LC classes is crucial if the population threshold of a cell is exceeded. Hence, the authors defined the following simple transition rules for LU/LC classes, which are depicted in Table 2 . Due to the fact that we assume that "Water Bodies" are not turned into dry land, water bodies cannot be transferred into any other LU/LC class. Similarly, "Forested Areas" cannot be turned into any other LU/LC class, due to legal regulations in Austria that strictly control the transition of forests into any other LU/LC due to a permanent removal of trees. Concluding, the only transition that is allowed is defined by the authors and concerns the conversion of "Agriculture" into "Populated Areas".

Table 2: Transition rules for given LU/LC classes.

Original LU/LC class	Transition to LU/LC class

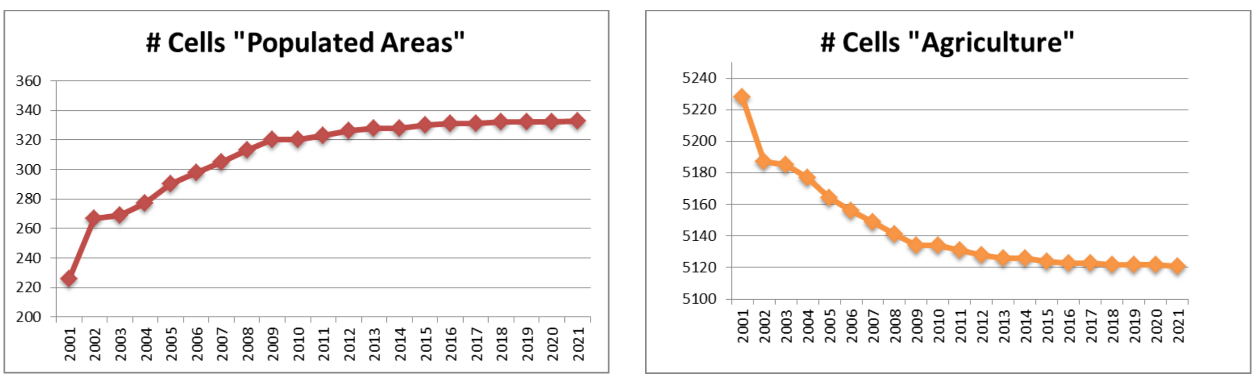
Populated Areas	Populated Areas
Agriculture	**Populated Areas**
Forested Areas	Forested Areas
Water Bodies	Water Bodies

The simulation conducted in this experiment starts with the year 2001 and generates results until the year 2021. Hence, the simulation period is 20 years.

Results

The results of the experiment described above are highlighted in this chapter. In detail, the results of the scenarios, defined in this paper, are evaluated. Besides a numerical analysis, the resulting maps are depicted, in order to give a visual impression of the achieved results. In general, the results show that public policies may have an influence on the LU/LC.

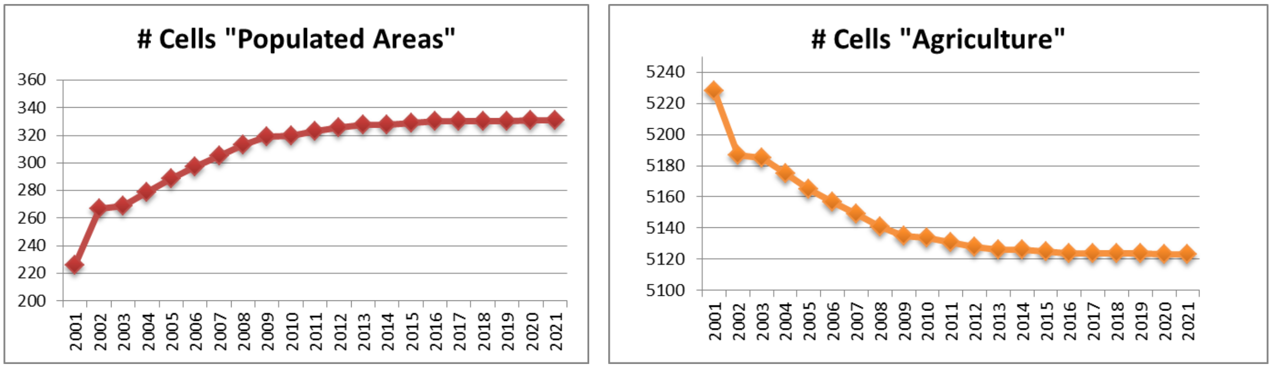
First, the scenario "*natgroRef*" is analysed in detail, which represents the baseline scenario, without any population growth due to public policies. In Figure 3 the gradual transition of "Agriculture" to "Populated Areas" is depicted. The growth rate is high in the beginning and declines as the simulation continues. In Table 3 and Table 4 the numerical results for the initial and the final situation are presented. The results reveal that a total of 107 cells are transferred into "Populated Areas". This equals to 5.10 ±8.80 cells per year.



(a) (b)

Figure 3: Chart showing the shift of LU/LC "Agriculture" to "Populated Areas" in the simulation of scenario 0 " *natgroRef* ".

Secondly, we elaborated on the scenario 1 "*etInc*", which assumes a natural population growth and a growth induced by public policies. The chart depicted in Figure 4 shows the change of "Agriculture" to "Populated Areas" over the simulation period. Noticeable is the fact that the transition is fast in the beginning and slows down towards the end of the simulation period. In Table 3 and Table 4 the numerical values for the initial and the final situation are given. Due to the results, in scenario 1 "*etInc*" 105 cells are transferred from "Agriculture" to "Populated Areas". This equals to 5.00 ±8.77 cells per year.

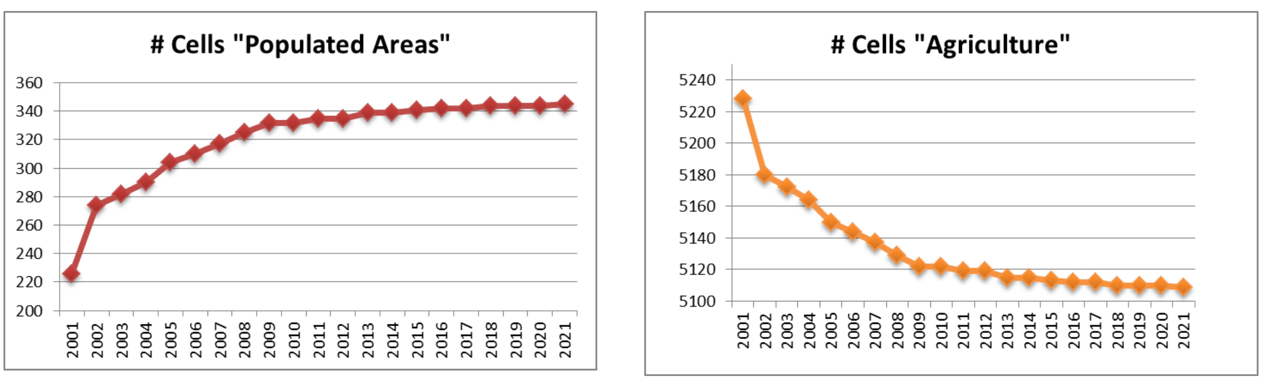


(a) (b)

Figure 4: Chart showing the shift of LU/LC Agriculture to Populated areas in the simulation of scenario 1 "*etInc*".

The results for scenario 2 "*hall*" and scenario 3 "*mds_stg*" look similar to scenario 1. Hence, the charts presenting the shift from "Agriculture" to "Populated Areas" are found in Figure 5 (for scenario 2 "*hall*") and in Figure 6 (for scenario 3 "mds_stg"). Scenario 2 "*hall*" results in a change from agriculture to populated areas of 119 cells (500*500m), which equals 5.67 ±10.20 cells per year. Furthermore, Scenario 3 "*mds_stg*" shows the most significant switch from "Agriculture" to "Populated Areas" of all scenarios of 124 cells, equal to 5.9 ±9.96 cells per year.

In addition Table 4 shows further numerical values of the scenarios calculated. Of interest are – besides the absolute values – standard deviation, skewness and kurtosis. Scenario 1 shows the lowest standard deviation, whereas scenario 3 shows the smallest skewness value. Besides, all scenarios share positive skew, meaning that their distribution has a long tail and the mass of the distribution is concentrated at the left of the chart, due to a low number of high values. This behaviour is justified by the low number of great shifts from "Agriculture" to "Populate Areas" in terms of cell numbers. These great LU/LC changes occur in the beginning of the simulation. In addition, each change distribution shows leptokurtic behaviour – i.e. the change distribution has a small peak around the mean and prominent tails.



(a) (b)

Figure 5: Chart showing the shift of LU/LC "Agriculture" to "Populated Areas" in the simulation of scenario 2 "*hall*".

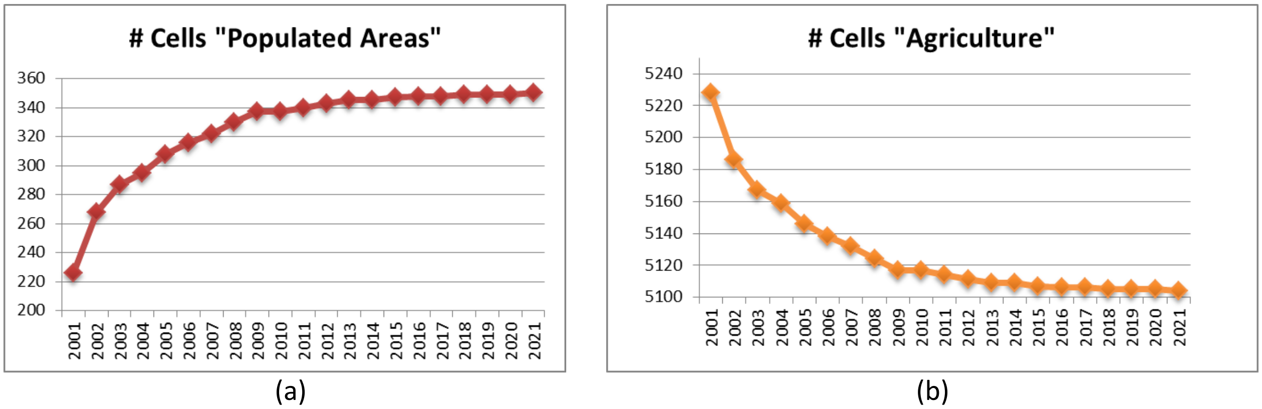


Figure 6: Chart showing the shift of LU/LC "Agriculture" to "Populated Areas" in the simulation of scenario 3 "*mds_stg*".

Table 3: Simulation results expressed in number of cells (500*500m) in the corresponding LU/LC class for each scenario.

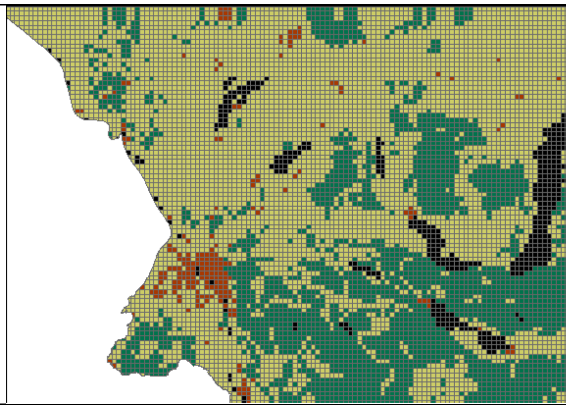
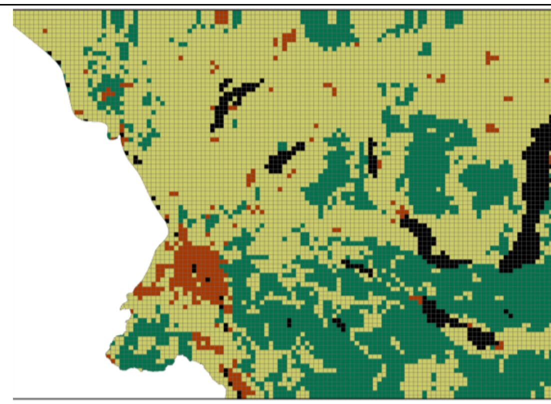
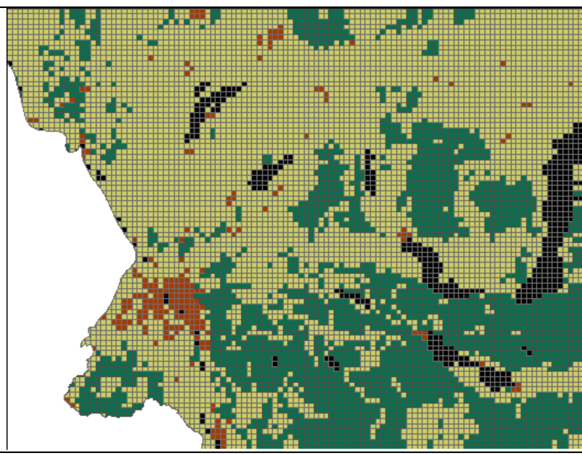
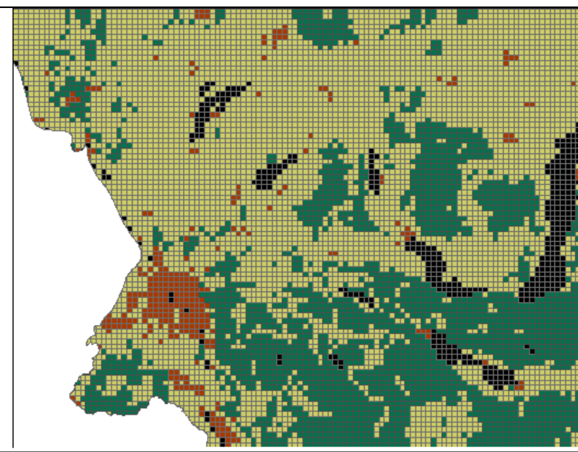
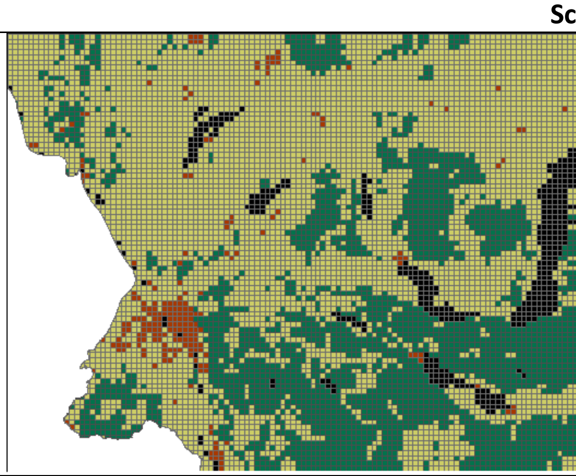
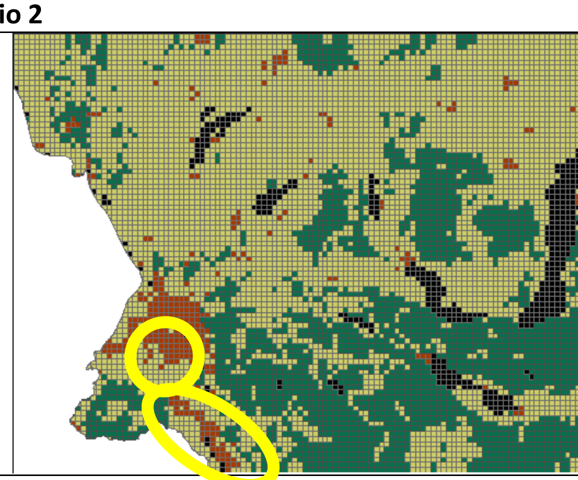
LU/LC | Scenario	Scenario 0		Scenario 1		Scenario 2		Scenario 3	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Populated areas	226	333	226	331	226	345	226	350
Agriculture	5228	5121	5228	5123	5228	5109	5228	5104
Forested areas	2585	2585	2585	2585	2585	2585	2585	2858
Water bodies	417	417	417	417	417	417	417	417

Table 4: Numerical analysis of the LU/LC change of each simulation year.

LU/LC change (Agriculture > Populated Areas)	Scenario 0	Scenario 1	Scenario 2	Scenario 3
Absolute	107	105	119	124
Average per year	5.10	5.00	5.67	5.9
Standard dev.	8.80	8.77	10.20	9.43
Skewness	3.44	3.50	3.63	2.93
Kurtosis	13.53	13.98	14.71	9.96

The visual interpretation of the results is realized with ArcMap 10.1 where the results are displayed accordingly. The initial and the resulting maps of each scenario are depicted in Figure 7. The reader can determine the visual differences between simulation results of the scenarios 0-3. Noticeable is the difference depending on where the key industry is located, which is highlighted in yellow. Interesting are the differences in the simulation results in scenario 2 and 3 which establish a high number of jobs in hubs/business parks. These activities seem to have an impact on the surrounding areas as well, which is especially visible in the final results of scenario 2.

The visual interpretation of the maps created with the simulation algorithm – depicted in Figure 7 – give the impression that the impact is considerably higher around cities. Looking at the simulation results in the city of Salzburg underpins that argument. This can be justified by the fact that there is a trend to migrate into the cities, which is partially reflected in the historic population growth figures. Thus, the population in cities and their surroundings grows faster than in rural areas, which increases the pressure on LU/LC in urbanized areas. As a result there is a stronger tendency to transform agricultural areas adjacent to urban areas to residential areas or commercial areas.

Initial Status	**Final Status**
Scenario 0	
	
Scenario 1	
	
Scenario 2	
	
Scenario 3	

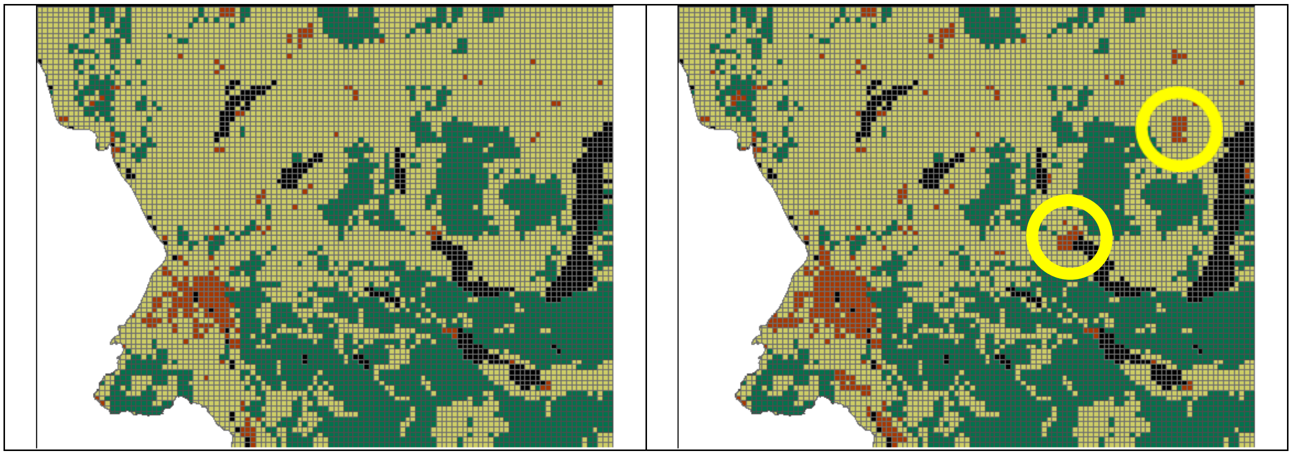


Figure 7: Visual representation of the simulation results in ArcGIS for each scenario 0-3. In the left column the initial status and in the right column the final status of the simulation is depicted. The populated areas are marked with red color, agriculture in yellow, forest in green and water bodies in black.

The visual results give evidence that public policies have an impact on the LU/LC. Based on the results given in this section, the numerical and visual results give evidence that there is an influence of public policies in comparison to the simulation having only natural population growth. Depending on how the public policy is designed, the effects on LU/LC are different. In detail, scenario 2 and 3 present public policies that create jobs in designated “hubs” – i.e. locations. Both result in a higher absolute number of cells that are switched to “Populated Areas” in comparison to scenario 1. Thus we assume that the starting of such key industries/business parks has an effect on the LU/LC as it applies pressure on “Populated Areas”. As a consequence they may spread out and “transfer adjacent cells of “Agriculture” to “Populated Areas”, if the pressure reaches a certain level. Worth mentioning is the fact that in scenario 0 and scenario 1 the number of transferred cells is nearly equal (107 vs. 105 cells transferred from “Agriculture” to “Populated Areas”). This seems remarkable in the first place as the effect of public policies seems to vanish. Nevertheless, as a relatively small economic sector was chosen in scenario 1, one can assume that the impact of the public policy is weak. This can be justified by the range of the number of new jobs created in this scenario which is between 0 and 6.48. In total a number of 334 jobs are created per year, which is spread over the area of interest. Thus the pressure on LU/LC here is considerably low in comparison to the one on hubs/business parks in scenario 2 and 3.

Of further importance are the characteristics of the shift from “Agriculture” to “Populated Areas”. Figure 3, Figure 4, Figure 5, and Figure 6 show that the growth rate of populated areas is high during the first simulation years. After approximately 10 years the transition process “cools down” and the number of cells shifted from “Agriculture” per year decreases gradually. This behaviour can be explained due to the fact that populated areas spread out in the first years because the cells soon get fully populated – either through natural population growth or supported by public policies. The population above the threshold is then “transferred” to other cells, which might not work out very well if the neighbouring cells are also close to the population threshold. Hence, a close agricultural cell is transformed into a populated area in this case. Due to the fact that the cells in the population dataset used in this study are already nearly fully populated it becomes evident why there is a high likelihood that a great number of agricultural areas are shifted to residential areas. If “enough” cells are transformed, these cells have to be “filled” with population until the populated areas can spread out further. Based on the fact that the population growth – either natural or induced by public policies – takes some time to "generate" population reaching the threshold, there is no need to transform additional agricultural cells.

Conclusion and Outlook

The paper elaborates on the effects of public policies on LU/LC with agent based systems. In detail, we are analyzing the impact of the economic funding of specific sectors on LU/LC in a designated study area. The hypothesis formulated in the introduction is as follows: There is an effect of public policies – i.e. the funding of a certain economic sector and/or key industry – on LU/LC. Based on the results achieved and highlighted, the authors have no reason to reject the hypothesis with respect to the experiments conducted. Based on the defined scenarios and the simulation runs, the impact of public policies on LU/LC can be verified. In addition, the establishment of specific hubs with a great number of newly established jobs has a greater effect on LU/LC than a scenario with no spatial focus. The latter has – with respect to the number of created jobs –only minor pressure on LU/LC to change to residential areas per year. The experiments show that the speed of the transition into "Populated Areas" is high in the beginning of the simulation and decreases gradually. Visually, one can observe that well established cities of a certain size tend to expand into agricultural areas – thus showing urban sprawl.

Future research items include a number of improvements of the simulation model. First, the LU/LC transition rules and the LU/LC classes could be modelled in more detail in order to represent reality more accurately. In addition, the modelling of the behaviour of people commuting or relocating could be modelled in order to simulate the pressure on LU/LC accordingly. So, one could analyse the educational profile obligatory to fill the newly generated jobs. If there are no potential employees available on the job market, the algorithm could search for them farther away (e.g. in the next cities) and try to attract agents accordingly. So they would have to relocate in order to live close to the company offering the new job. Furthermore, the modelling of funding schemes could be altered in order to work with "real" funding programs. This would enable us to compare the effects of the funding program and the results of the simulation at hand within a sensitivity/plausibility analysis

Acknowledgments: The work at hand has been funded by the European Commission under Framework Programme for RTD 7 through the project ''Modelling and Simulation of the Impact of Public Policies on SMEs (MOSIPS)''—Grant agreement no.: 288833.

References

BATTY, M., CROOKS, A. T., SEE, L. M. & HEPPENSTALL, A. J. (2011): Perspectives on Agent-Based Models and Geographical Systems. In: HEPPENSTALL, A., A. T. CROOKS, L. M. SEE, M. BATTY (Eds.) (2012): Agent Based Models of Geographical Systems. Dordrecht, Heidelberg, London, New York Springer.

BATTY, M. (2009): Urban modeling. In KITCHIN, R. and N. THRIFT (Eds.): International encyclopedia of human geography, 12, pp. 51-58. Oxford: Elsevier.

CROOKS, A. T., HEPPENSTALL, A. J. (2011): Introduction to Agent-Based Modeling. In HEPPENSTALL, A., A. T. CROOKS, L. M. SEE, M. BATTY (Eds.) (2012): Agent Based Models of Geographical Systems. Dordrecht, Heidelberg, London, New York: Springer.

EEA-ETC/TE (2002): Corine land cover update, Technical guidelines, http://www.eea.europa.eu/publications/technical_report_2002_89.

ILTANEN, S. (2011): Cellular Automata in Urban Spatial Modeling. In HEPPENSTALL, A., A. T. CROOKS, L. M. SEE, M. BATTY (Eds.) (2012): Agent Based Models of Geographical Systems. Dordrecht, Heidelberg, London, New York: Springer.

JOHNSTON, K.M. (2013): Agent Analyst: Agent-Based modeling with ArcGIS. , Redlands, CA: ESRI Press.

KIM, D., BATTY, M. (2011): Calibrating Cellular Automata Models for Simulating Urban Growth: Comparative Analysis of SLEUTH and METRONAMICA. UCL Working Papers Series, no. 176.

MANDL, P. (2003): Multi-Agenten-Simulation und Raum – Spielwiese oder tragfähiger Modellierungsansatz in der Geographie? Klagenfurter Geographische Schriften, Heft 23, 5-34.

MACAL, C. M., NORTH, M. J. (2010), Tutorial on agent based modelling and simulation. Journal of Simulation 4, 151-162.

SCHOLZ, J., ANDORFER, M., & MITTLBOECK, M. (2013). Spatial Accuracy Evaluation of Population Density Grid Disaggregations with Corine Landcover. In Geographic Information Science at the Heart of Europe (pp. 267-283). Springer International Publishing.

STILLWELL, J., SCHOLTEN, H. (2001): A Framework for European Land Use Simulation. In STILLWELL, J., and H. SCHOLTEN (Eds.) (2001): Land Use Simulation for Europe. Dordrecht, Boston, London: Kluwer Academic Publishers.

VAN BERKEL, D., VERBURG, P. (2012, in press): Combining exploratory scenarios and participatory backcasting: using an agent-based model in participatory policy design for a multi-functional landscape. Landscape Ecology, published online 20 March 2012.

WOLFRAM, S. (1982): Cellular Automata as Simple Self-Organizing Systems. Caltech preprint CALT-68-938.