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Actors and factors – bridging social science findings and urban land use change modeling

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Abstract: Recent uneven land use dynamics in urban areas resulting from demographic change, economic pressure and the cities' mutual competition in a globalising world challenge both scientists and practitioners, among them social scientists, modellers and spatial planners. Processes of growth and decline specifically affect the urban environment, the requirements of the residents on social and natural resources. Social and environmental research is interested in a better understanding and ways of explaining the interactions between society and landscape in urban areas. And it is also needed for making life in cities attractive, secure and affordable within or despite of uneven dynamics.

The position paper upon "Actors and factors – bridging social science findings and urban land use change modeling" presents approaches and ideas on how social science findings on the interaction of the social system (actors) and the land use (factors) are taken up and formalised using modelling and gaming techniques. It should be understood as a first sketch compiling major challenges and proposing exemplary solutions in the field of interest.

Keywords: *social science concepts; behavioural rules of agents; empirical knowledge; land use change models; demography; statistical functions; survey data; DPSIR; impact analysis; quality of life; ecosystem services.*

1. THE CHALLENGE

Recent uneven land use development patterns and demographic change in urban areas challenge modellers, social scientists and spatial planners. Processes of growth and decline specifically affect the urban environment as well as the demand on natural resources. Social and environmental research is interested in a better understanding and ways of explaining the interactions between society and landscape in urban areas. Planners and policy makers are in charge of making life in cities attractive, secure and affordable. Moreover, sustainability and green infrastructure gather increasing importance in cities' profiles.

The discussion paper upon "Actors and factors – bridging social science findings and urban land use change modeling" presents some basic ideas on how novel social science findings on the interaction of the social system (actors) and the landscape (factors) are taken up and formalised using modelling techniques. It should be understood as a first sketch compiling major challenges and proposing exemplary solutions in the field of interest.

The discussion paper is structured as follows. After this introduction some major and novel social science and urban land use findings are presented that represent operational and empirical challenges for urban (land use change) modelling. In a third section we select a number of different social science concepts in terms of their core ideas and novelties. Proposals are made how to "translate" these social science concepts and findings into a model and thus to formalise it, make it transferable. In addition, each example is used to ask important questions that have been raised during this modelling exercise. These questions should particularly encourage the discussion at the workshop. Participants and interested colleagues are invited to contribute to both the discussion paper and the workshop in Barcelona.

2. SOCIAL SCIENCE ISSUES TO BE ADDRESSED

In terms of social science concepts and findings on urban systems, particularly demographic and land use dynamics questions such as

- How does demography modify human demands on natural resources, real estate, housing space and transportation networks?
- What are the spatial, land use and environmental effects caused by demographic change such as an increase of new household types like single households, cohabitation, single-parent families or flat-sharers?
- What are the socio-environmental consequences of ongoing urban sprawl and of the opposite process of urban shrinkage characterized by large residential and commercial vacancies?

are high on the political agenda of many cities worldwide. Major factors of uncertainty can be found in the complex structure of the social systems, demographic and household pattern as well as of the respective housing markets.

Often, land use transitions are closely connected with humans acting on the real estate and land market. Land use changes thus can be understood as the consequences of actions. Since they are a heterogeneous group the behaviour of the "urban actors" is characterized by highly heterogeneous and controversy decisions that directly impact on and shape of land use change (in terms of the intensification of land cultivation, the amount of land take as well as forms of land abandonment).

This is the field of social sciences (sociology, political science, psychology, spatial planning) which carry out field research on effects of demographic change, urban sprawl and shrinkage. Their work delivers innovative empirical results in form of questionnaire survey data, series of interviews, perception data, agent profiles, behaviour settings through document analysis and observation.

Land use change model approaches have their strengths in setting up causal relationships between variables and to quantify them. Models generally aim at depicting multiple relationships and complex systems in a formalised and less complex way. They use major variables to realise important stocks, flows and communication processes to reduce the real complexity to a point where we can see and analyse the influence of single parameters of the system. In urban land use change modelling there have been developed different modelling approaches such as system dynamics, cellular automata, and agent-based modelling.

Incorporating social science concepts and knowledge into modelling – bridging actors and factors – together we shall discuss the following questions in accordance with the above mentioned ones:

- How do we use social science concepts and findings to define the purpose of respective models?
- How to translate them into a) a formal way and b) into a model?
- What kind of empirical evidence we can use to a) feed and b) to verify the plausibility of our models? How can we formalise qualitative outputs from social science studies?
- How "reliable" and transferable case study based social science questionnaire data are in terms of applying them to other cases / regions?
- In terms of agent based models: How do we measure actors' behaviour and translate it into formal agents' rules accurately? Since persons are unique in their decision making, could we define a "mean person" as representative agent for an entire agent class?
- How do we depict trees, priorities and ranking of choices related to a given situation or scenario?
- Can we use a respondent stated choice as realistic? Some studies show that the intention to do some action stated in the survey does not always imply that people will actually do that. Is this fact worth considering in transferring survey data into ABM rules? If so, then how should we account for it?
- And finally, how can we test the plausibility and quality of social science (concepts) based model formalisations?

Bringing together the strengths of both social science and modelling the workshop integrates factors and actors and thus intends to endeavour ways of bridging social science and quantitative as well as qualitative modelling to find answer on the above posed questions and others related to them.

3. ISSUES TO BE DISCUSSED AT THE WORKSHOP

3. 1 Example I: Household formation framed by a Second Demographic Transition

At present, large parts of Europe undergo considerable demographic changes (Cloet, 2003; Lutz, 2001). Related processes summarised as a Second Demographic Transition (SDT) such as an individualisation and institutionalised individualism of the (industrialised) society (Beck and Beck-Gernsheim, 2002), a worldwide decline in total fertility (up to <1.1 children per woman; Council of Europe, 2005) and a rising life expectancy, which results altogether in ageing of the total population. Furthermore demographers report the postponement of childbearing or the renouncement of the family phase in the life cycle (Buzar et al., 2005, 2007), respective changes in age group spectra and size, structure and the stability of household patterns (van de Kaa, 1987; Ogden & Hall, 2000; Haase et al., 2005; Bösch-Supan et al., 2005), which altogether results in a diversification of lifestyles as well as a considerable labour, (replacement) and retirement migration within Europe and worldwide followed by an increasing share of nationalities at national labour and residential markets (Bell et al., 2007).

These socio-demographic alterations enormously impact on lifestyles, expectations on quality of life as well as affiliations and motivations of residential mobility. Those – again –

challenge current land use patterns, housing markets and the development of urban space (Deutsch et al., 2003; Ekins et al., 2003).

Changing household structures in line with this second demographic transition (van de Kaa, 2004; Lestheaghe & Surkyn, 2002) brought about by societal processes, economic developments (rise of the service sector) and new fertility patterns (declining TFR[1]) are assumed to be preconditions of the current household formation: Households have become smaller in size and less stable since individuals shift from one living arrangement to another several times during their life course. In an EU FP5 project households had been classified according to their type based on empirical findings for different European cities[2]. Non-traditional or non-familiar household types such as one-person, cohabiting couples, single parents and young adults sharing a flat account for a good portion of the pluralised landscape of household types since their number has significantly increased. While the pluralisation of living arrangements is to be observed Europe-wide, the concrete forms are dependent upon cultural and societal specifics (Council of Europe, 2005).

Contemporary households act very situation-sensitive, i.e. their decision holds the capacity (and necessity) to adapt to changing internal and external conditions. Households are defined more subject-oriented, and living arrangements are adapted to individual life scripts (Buzar et al., 2005; van de Kaa, 2004; Ogden & Hall, 2000).

In terms of the rural-to-urban gradient, particularly the inner city (here understood as the part of city closed the city centre) is highly adaptable to the preferences and needs of SDT-sensitive households. It exhibits a range of appropriate characteristics – e.g. closeness to the city centre and to places of work, qualification and leisure, easily accessible by public transport. Their housing structures allow for flexible adaptations to changing personal circumstances and often the dwellings there are for rent, even in societies which are predominantly owner-occupied. Especially among non-traditional/non-familiar households, urban life with its central notions of density and diversity of both people and opportunities possesses a high value. In both cultural and symbolic terms, the inner city is transformed by these selected socio-demographic groups, their habits, interests and behaviour. But also for families, inner-city housing seems to be more attractive and desirable than hitherto assumptions of urban research have presumed (cf. a.o. Gober, 1990).

The questions:

For our workshop challenging questions emerge how this demographic transition and the related changes of lifestyles and household types detected by social scientists can be transferred into socio-demographic and spatial (urban) land use modeling? How far we can rely on these novel social science findings, are they replicable or transferable in a more mechanistic way of understanding? Could we "scale" them, aggregate or disaggregate them, too? Answers to such questions will be proposed in this discussion paper as well as touched during the workshop in Barcelona.

3.2 Example II: A new concept of uneven urban development and shrinkage

Among urban scholars the hypothesis raised whether current demographic decline, de-economisation and structural crisis are bringing about a new evolving type of urban development. In doing so, we present a novel social science concept of urban shrinkage that goes beyond the focussed population-related view of shrinkage (Kabisch et al., 2006). It rather comprises the features of non-growth, on-going sprawl and upcoming reurbanisation alike, or if reurbanisation represents, on the other hand, merely a short interplay in a long-term period of desurbanisation under the condition of demographic change and decrease in population: the core city is gradually shrinking because of demographic decline.

Nevertheless, in the course of reurbanisation, the core city will be able to remain, or become again, compared to the outskirts and surroundings, as we can already see in cities that follow a consequent policy of strengthening the inner city. The less abrupt demography

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[1] Total Fertility Rate

[2] FR5 EU Project Re Urban Mobil (www.re-urban.com)

change the better the possibilities of cities to force reurbanisation and to support the development of their central areas are. Admittedly, reurbanisation takes place in a selective way and isles of reurbanisation arise within a context of emptiness and shrinking (Haase et al., submitted).

The questions:

There exists a multitude of urban land use change models varying from cellular automata (Silva and Clarke, 2002; Clarke et al., 1997; White et al., 1997; Wu and Webster, 1998; Wu, 1998) over stochastic models (Landis & Zhang, 1998a, b; Landis, 1994), rule- and agent-based approaches (Miller et al., 2004; Waddell, 2002; Ben-Akiva and Lerman, 1985; Horowitz et al., 1986; Klosterman, 1999) displaying urban growth and sprawl phenomena. According to mainly morphological or historical criteria cities expand into their hinterland. Protection of open or arable land is implemented using planning and protection restrictions. Such models assume that most of the urban land use change occurs at the periphery and the urban core remains more or less stable. We know from social and policy science that this is only half of the urban truth: how do we incorporate the concept of urban shrinkage into our land use change models? Is it a process that relates to built-up structures, age of urban structures, distances and accessibility or could it be better explained looking at households' residential or investor's decision-making? What variables do we have to include when we focus on urban shrinkage compared to growth? And how we model when suburban growth, reurbanisation and shrinkage, interact and occur simultaneously?

Using a system dynamics approach we apply this social science concept in a simulation model which uses variables emerging from this concept as descriptors for typical shrinkage related population, household, residential and other land use processes and pattern (McIntosh et al., in press). For the model implementation we had to "translate" non-numerical and only partially quantifiable social science knowledge into model variables such as urban stocks, flows and trends.

In our presentation we show the simulation of different urban development scenarios assuming a range of population and household formation changes, a further increase of single and single-parent households, effects of ageing and related altering demands and preferences on residential space and places to live. Accordingly, we simulate pattern of residential vacancy and potential sites of demolition (Haase & Seppelt, submitted). Based on these simulations we can show under which demographic conditions urban growth and shrinkage simultaneously occur or even dominate the development of a city/urban region.

3. 3 Example III: Understanding human decision-making

Identifying decision criteria and getting closer to human behaviour is fundamental for the understanding of decision-making processes and actions that shape our landscape and its environmental resources (Bharwani, 2006). Often we are confronted with multiple reasons for land use decisions of multiple actors that have a stake on one resource (e.g. land, water resources, soil fertility etc.).

Participatory methods such as Knowledge Elicitation Tools (KnETs) represent a new and reproducible way to formalise this knowledge using computational techniques and, what is more, to implement scenario techniques within the interviews. KnETs can be understood as an amplified methodology of classical social science empirical tools such as interviews and questionnaire surveys. It produces input data for the logic of agent-based models (ABM), decision trees or decision ranking. KnETs link qualitative and quantitative representations of stakeholder knowledge. The fusion of both is realised in form of an iterative process that incorporates a set-up phase of the game conducting interviews, a formalisation phase of the game, an empirical data collection phase of "gaming" with respective respondent groups of interest and a resulting decision tree creation and interpretation phase. Finally, another game round is conducted with a non-involved respondents' group to verify the results of the models and to assess our gained knowledge on decision making (Bharwani, 2006).

In the workshop two applications of the KnETs games methodology will be presented and discussed for firstly, getting insides in criteria and thresholds of decision making by municipal representatives pro or contra soft mitigation paths in flood risk management in the Ukrainian Tisza valley and, secondly, decision making of households to 'reurbanise' and to settle at recycled land within the inner city (success test of the realisation of a so-called 'program of urban villas'). The resulting trees shed light on what knowledge is used for decision making and how different criteria are weighted in these choices.

3. 4 Example IV: Mapping out the social impacts of land use: Soft-GIS and Choice-Based Conjoint Analysis as integrative methods

People's experiences of place are affected by planning strategies as much as community-based behaviours and emotions can affect planning and development. Residents' experiences of their environment are geographically located, since people can attach their experiences, memories, and feelings to specific locations. By allowing participants to locate these experiences, researchers can not only identify their specific affordances but also analyse and visualize the information for research and planning practices. This example aims to:

- Examine how soft-GIS and choice-based conjoint methods can help accurately measure the perceived importance of quality of life indicators and incorporate them into the impact assessment process by allowing researchers to map out the quality of the living environment and forecast land-use scenarios;
- Explore ways of analysing "soft knowledge" together with other geo-demographic data to understand land use in peri-urban areas. For example, to examine how people's preferences and perceived affordances relating to land use is affected by membership to different groups and segments in the population, such as older people and groups of immigrants;
- Discuss how these participatory methods can help build a bridge for more effective collaboration between researchers, stakeholders and planners and to provide a more holistic picture of the quality of the environment.

3.5 Example V: Mapping Survey Data into Agents' Behavioural Rules for ABMs: Motivation and Challenges

Modeling land use change inevitably involves modeling of an individual behaviour of land users in addition to modeling of spatial environment. The processes in the latter usually follow some physical laws. However, it is less straightforward for a modeller how to describe the process of human decision making (Berger and Schreinemachers 2006; Brown and Robinson 2006; Stites 2006). As it is observed by ABM-modellers, it is relatively easy to model the mechanical part of an ABM such as spatial environment, because their dynamics is described by a set of straightforward deterministic rules (with some uncertainty intervals sometimes).

In contrast, for human-beings it is not possible to say exactly how they (i.e., we) make decisions. Theoretically, land use behaviour is well formalized in economics. Farmers' (von Thünen 1826 (reprinted in 1966)), households' (Alonso 1964; Strazsheim 1987) and firms' (Fujita and Thisse 2002) decision making with respect to land is fully based on the assumption of a rational maximization, equilibrium, and representative behaviour.

In reality, people are boundedly rational, their behaviour is often unrepresentative, they choose different strategies in the same situation, their decisions are biased by previous experiences and emotions, and people sometimes make irrational decisions. All these observed characteristics of human behaviour make it difficult to use stylized theories of human decision making at the micro level.

Thus, how people make decisions (e.g. about land use) remains a black box for a modeller. The only way to open it a little bit is to analyze real world micro level *data*. These data could probably be obtained either by observing a land-user decision-making in the controlled environment (for example in the setting of a role-playing game (Barreteau et al. 2001; Bousquet et al. 2005), from interviews with stakeholders and during participatory workshops with them, or by gathering data in the form of surveys (Brown and Robinson 2006; Fernandez et al. 2005).

At the workshop we would like to discuss challenges and open questions with respect to using survey data for feeding ABMs. No doubts that surveys provide very valuable data about micro level decision making. However, the following issues might arise here:

1. It looks more straightforward to parameterize the initial agent population in the ABM with empirical data than to generate agent behavioural rules. If one uses statistical data for the latter then he can actually run into a problem of transferring aggregated data into agent rules, which are supposed to be heterogeneous (e.g., ask an agent to reproduce if she reaches a certain age) (Axtell et al. 2002). What is the best way to interpret survey data in term of agents' rules? Should we better categorize survey subjects into several groups and then clone them in the ABM? Or assign each agent a specific rule adopted from the survey with some probability (which might correlate with the percent of the sample, which has chosen it)?
2. Very often surveys produce qualitative measures. How can those measures be translated into formal agents' rules accurately? For example, how can we accurately transfer a likert scale into agents' behavioural rules? May the middle point choice of one agent on a likert scale mean the same as the low point choice for another agent? Can we use a respondent's stated choice as realistic? Some studies show that the intention to do some action stated in the survey does not always imply that people will actually do that. Is this fact worth considering in transferring survey data into ABM rules? If so, then how should we account for it?
3. With respect to climate change influencing human demands for housing: we are particularly interested in how perception of risk of flooding affects households' location choices in and outside flood-prone areas. How is it incorporated in the individual choice for housing and consequently in the aggregate demand for housing in the urban zone? Intensified climate change not only implies more risks and actually reduces supply of land available for development. Increasing storm and flood frequency, for example, may make people more aware of these risks and may change their location preferences.
4. Surveys produce answers on a typical situation (under investigation) in the field of study and a set of socio-economic characteristics of each respondent. Would it mean that the whole population can be divided into groups on the basis of their socio-economic characteristics (e.g. age, income) and each of the groups will be associated with a particular type of behavior?
5. Micro calibration and macro validation: comparing results of simulations runs (when micro behavior is calibrated with survey data) with statistical macro measures.

We are interested in discussing these questions in general and in application to our case study in the Netherlands in particular. We are working on an ABM simulating urban dynamics in a coastal city (Filatova et al. 2007; Filatova and van der Veen 2007). In parallel we are performing a survey on risk of flood perception and location choices of households in the province of Zeeland in the Netherlands. We hope that this workshop will provide possibilities for sharing our experiences and a ground for a brainstorming session.

3.6 Example VI: Actors as factors for land use change: Effects of demographic change on land use across Europe

Intuitively, it seems to be evident that there is a close relationship between human society and natural environment. People change their environment through intensive utilisation: for agriculture, for living, for transport, for leisure activities, for resources, etc. Thus, it appears clear that there must be a close link between demographic and land use development. However, quantifying and modelling this relationship based on statistically significant correlations is a challenging task. Even if we focus the research question on one single land use type, namely settlement area, where a very close and direct connection to population as driving force is assumed, it is not easy to explain the relationship statistically by a formula fitting for different regions across Europe. In some European regions the development of settlement patterns and population numbers even diverges as on the one hand population stagnates or shrinks and on the other hand settlement areas grow. This phenomenon has socio-economic reasons. Empirical findings from Austrian and European studies proved that nowadays the growth of settlement area is not solely caused by growing population numbers but particularly in prosperous and urbanised regions by increasing demand for settlement area per person due to higher living standard and income (Loibl and Tötzer 2003, Tötzer et al. 2007). Thus, for modelling human actors as driving force for land use change, demand-related factors like settlement area/consumption per head, settlement density, household size, etc. have to be considered beside mere population numbers.

In this paper we will present first findings from our research within PLUREL, an Integrated Project funded within the 6th framework program of the EC. PLUREL deals with the relationships between urban, peri-urban and rural land use and aims to develop strategies for a sustainable development of these interlinked rural-urban regions (RURs). A key product will be the sustainability impact assessment tool for urban-rural linkages. PLUREL applies the DPSIR-concept (Driver-Pressure-State-Impact-Response) on different European scales: from NUTS0 to LAU2 in six European case study regions.

The research presented in this paper explores population as driving force for land use change focussing on settlement patterns and dynamics. We work on two different scales: on European scale and on micro-scale in six case study regions (among them e.g. Warsaw, Leipzig, Manchester). In this project we will examine if the findings from preceding research projects as well as from the PLUREL case studies could be confirmed on European scale, so that European-wide rules can be derived for certain region types (e.g. urban-monocentric, dispersed peri-urban, rural, urban-polycentric) across Europe. We will apply statistical analysis methods and carry out analyses on European NUTS3- level as well as on local scale for the case study regions.

Research on micro-scale allows in-depth analyses based on detailed data (e.g. LAU2) and gives insights into region-specific interdependencies between society, economy and environment. However, considering the macro-scale as well is particularly important for stakeholders and politicians in the EU. Thus, up-scaling the case study specific rules to the European scale will be an essential task within the project. With the help of pre-defined region types, results which correspond on local and on European scale will be proved and up scaled. Due to data constraints proxy-data will have to be used on European level.

The research will result in statistically based functions reflecting relationships between population and settlement areas in different region-types across Europe. These functions will be considered in many following work packages within the PLUREL project and will help to model the Sustainable Impact Assessment Tool for Rural-urban Relations – one of the key products of the PLUREL project.

3.7 Example VII: Land use policy impacts in the rural-urban region: a modelling framework

Because land is a fundamental input of anthropogenic (production, residence, recreation etc.) as well as non-anthropogenic (ecosystem functioning, refuge, habitat etc.) activities, modelling such impacts require a conceptual framework multi-sectoral and multi-zonal in scope. This framework should account for flows of people, commodities and services from one sector to the other and from one zone to the other. Because of the very nature of the problem at hand, an urban and rural context needs also be given to the conceptual framework. In this paper we propose an extension to the PACE model inspired by the modelling approach of metropolitan input-output models (see Jun, 1999 and 2005).

PACE is comparative-static multi-region, multi-sector CGE model. Primary factors of a region include labor, capital, and fossil-fuel resources. While in PACE regions are usually countries and cities in metropolitan input-output models, in our conceptual framework we refer to the following three regions: urban, peri-urban and rural. Each region can be divided in sub-region depending on the spatial disaggregation of available data. Capital is divided into two categories: manufactured capital (including infrastructure) and non-manufactured capital (including forests, mineral deposits, fisheries, biodiversity etc.). We also add land as a further resource representing land that is not used for capital. In PACE the energy sector is modelled explicitly to better account for impacts of changes in climate policy. In our framework we add the real estate sector and show how the decision to develop land can be modelled using a real option approach.

Nested constant elasticity of substitution (CES) cost functions are employed to specify the substitution possibilities in domestic production between capital, labour, land, energy and non-energy, intermediate inputs, i.e. material. Final demand in each region is determined by a representative agent, who maximizes utility subject to a budget constraint.

In PACE, furthermore, labour and capital are intersectorally mobile within a region but cannot move between regions. A discussion on data needs to make this conceptual framework operative follows.

3.8 Example VIII: Quantification of land use changes, modelling of processes and impacts of shrinkage and the question of scale

Following the purpose of understanding and analysis of interactions between society and landscape in urban areas this paper tries to give a methodological and practical insight into the assessment of socio-environmental impacts under conditions of uneven spatial development. In that context the paper draws special attention to the quantification and modelling of land use changes and shrinkage processes, in particular, based on empirical ascertainable and communal data and empirical research techniques. A second focus highlights a conceptual approach for the assessment of functionality of urban green spaces against the concepts of quality of Life (QoL) and associated Ecosystem Services (ESS) in urban areas dealing with both quantitative modelling and empirical qualitative research techniques. In a third focus the question of choosing the right scale for assessment and modelling of land-use changes will be dealt with as spatial dynamics and their socio-environmental effects seem to be very variable on a smaller scale and extreme within shrinking cities.

Interactions of society and landscape

Friction is the prerequisite for dynamism and interaction. Heterogeneous and uneven spatial development are that friction between landscape and society in shrinking cities. Regarding a surplus of open spaces resulting from enormous vacancies and demolition on the one side and a decreasing number of inhabitants on the other both domains appear to be under pressure. How do these citizens deal with their changed – sometimes blurred and unstructured- living surroundings, what kind of socio-environmental impacts derive from that dynamism and come to pass in post-shrinkage landscapes? In that context I will introduce into a recent study focussing on the quantification and assessment of socio-environmental impacts according to various demolition scenarios in the city of Leipzig, Eastern-Germany (Schetke & Haase 2007, in press). Main outcome of this study is a set of indicators focussing on both structural-ecological assessment (e.g. LSM) as well as on modified social spaces deriving from modified accessibilities of social infrastructure (green and technical ones). The emphasis of this set of indicators is the quantification and socio-environmental assessment of land use changes and shrinkage processes using empirical ascertainable (e.g. communal) quantitative and qualitative data.

Attractiveness of urban life. Concepts for assessment

After the introduction into a model of the assessment of socio-environmental impacts I want to expand these findings by going a bit deeper into the analysis of the attractiveness and quality of urban live by presenting a conceptual approach (see Schetke, Haase & Breuste 2008, in prep.) focussing on the functionality of green spaces accoording to the concepts of quality of life (see Burgess et al. 1988; Givoni 1991; Kawka & Sturm 2006) and associated ecosystem services (Bolund & Hunhammar 1999; Constanza 1997 et al.; de Groot et al. 2002).

Following the presentation of an indicator set quantifying and assessing socio-environmental impacts in shrinking this conceptual approach widens its view by focussing more clearly on the interactions between society and landscape in urban areas. To achieve this not only the area of research has been expanded by adjusting the model towards the analysis of the functionality of urban green under conditions of uneven – that means shrinkage and growth side by side- spatial development. But also the compilation of data implemented into the model has to be enlarged using not only administrative quantifiable land-use and social data but qualitative empirical data highlighting the perceptive side of land- use changes by clearly focussing on social-spatial interdependencies, as well.

Beside the scientific claim in analysing the socio-spatial interactions in urban landscapes the focus on specifically the functionality of urban green is founded on the fact that urban green and open spaces are among the driving factors of quality of life and of that attractiveness of urban life planners are in charge to provide.

Keeping in mind that this affects both planners and scientists the gap between the two domains can be bridged by the conscious implementation of valuable communal and empirical ascertainable data into such a model. Also planners are more and more in charge to estimate spatial and social dynamics in order to remain able to steer a sustainable spatial development and to promote the attractiveness of urban life. In that context a conceptual model not only dedicated to quantify land-use changes but also able to analyse and to depict socio-spatial interactions contribute to both side's gain of knowledge and progress.

Spatial and land use effects caused by demographic change. Choosing the right scale

In shrinking cites socio-environmental dynamics can be very heterogenous and diverse amongst different neighbourhoods and urban structure types. Both ecological and social affairs - each type of a single urban ecosystem, each social group of citizens- are affected in a different way with sometimes severe and sometime almost unnoticeable impact. The more, the process of shrinkage and the often accompanying demolition occurs in different spatial and temporal ways which make a general large-scale assessment and modeling (e.g. on city or regional scale) of land use changes and shrinkage processes difficult and redundant in meaning. The question of scale is long discussed in terms of land use assessment. Especially in terms of quantifying and modelling of both presented socio-environmental impacts of shrinkage and a more in-depth analysis of socio-spatial interactions and the functionality (see QoL and ESS) of urban green it is still a sensitive matter to discuss and to keep in mind.

3.9 Example IX: Integrated Modelling of Smallholder Land-use Decisions on the Availability of Rattan

The margins of national parks belong officially to the protected area of the parks. However, they are used for the livelihood of smallholders in the park's vicinity. Conflicts and continued poverty around protected areas suggest that existing approaches to conservation lack understanding of links between maintenance of diversity and human well-being [Bawa et al., 2004]. Regularly, the livelihood of the rural poor includes agricultural land-use. Large areas are converted by smallholder farmers, despite the fact that tropical rain forests play a major role in the provision of ecosystem services [Achard et al., 2002]. The interaction between human and natural systems at the rain forest margin play a key role in preserving and stabilising forested ecosystems [Maertens et al., 2006].

Ecosystem stability is a multi-dimensional concept requiring multi-disciplinary analysis because it concerns economic, ecological and social issues. This way we hope to identify more sustainable development options, such as mitigation of climate change effects and biodiversity loss, poverty alleviation and economic development for rural areas [Balmford et al., 2002].

One tool to address the livelihoods of the smallholders as well as impacts on ecosystem functioning are integrated assessment models. Mallawaarachchi and Quiggin [2001] e.g., present a model for the integrated assessment of sugar cane production in Queensland/ Australia. We will extend such an approach by a spatially explicit agent-based-modelling component. Recently the application of spatially explicit agent-based models have become a focus in the research on land-use and cover change [Bousquet and Le Page, 2004]. This modelling concept – originally from the field of problem solving in (distributed) artificial intelligence - provides an excellent frame to simulate the problem at hand. With the SIEHL-framework (Spatially and Institutionally Explit Household decision-making and Land use model) we apply this rationale to the margins of tropical rainforests, first to Indonesia (Lore

Lindu National Park); *In-SIEHL* and later to Ecuador (Podocarpus National Park; *Ec-SIEHL*).

The main component of this framework is an Agent-Based Model, which allows us to differentiate between the perception of individual agents and system response modelled with 'full' information. The land-use decision-making options will be the result of an economical optimized result of the production opportunities. We first apply this model to rattan collectors in Lore Lindu National Park in Central Sulawesi.

Multi-agent-model. The core element of the IN-SIEHL-framework is a Multi-Agent System (*M*AS). According to the Multi-Agent-Paradigm, agents are software representations ". . . that are situated in some environment and capable of autonomous actions in this environment in order to meet their design objectives" [Wooldridge, 2001]. MAS allow us to simulate the land-use decisions of smallholders on an individual level. Particularly, we can differentiate between how an individual agent perceives its environment (*'Merkwelt'*) and the 'full-information' system response (*'Wirkwelt'*). A common framework for the agent's rationale is the *Belief-Desire-Intention*-Architecture.

In our case, the framework can be explained as follows: Each agent has a certain *Desire* (*profitmaximisation*), which he tries to pursue. An ('Wirkwelt') stimulus triggers the revision of the *Belief* ('Merkwelt'). According to its beliefs, a set of options is generated, from which the agent choses one option which will – according to his belief – fit best to fulfill its desire (*Intention*).

For rattan collection this can be exemplified by the problem to actually design an optimal rattan harvesting strategy that maximises long-term rattan benefits for a poor household. The smallholders know about putative rattan sites (*Merkwelt*) and also roughly to which extent harvesting has taken place there. However, actual rattan harvesting decisions are not made from an omniscient position according to analyst knowledge on potentially optimal and sustainable harvesting strategies as obtained from an analysis of all *Wirkwelt* data available in the model.

Agents. In the Central Sulawesi In-SIEHL implementation. the agents in the model are aggregated entities, because they do not represent individual humans, but smallholder households as a decision-maker. Data of the availability of the capital were collected in social science surveys and fed into a database (Data from the STORMA-Project and Schwarze [2004]). These sources supply data on capital access and restrictions to economic activity of different classes of smallholder households. Off-farm work will be modelled as rattan extraction. Particularly for remote villages such as Au and Moa this is highly realistic. This decision-process will be optimised as a result of an analysis (Lingo) of single household production opportunities). Every agent has a plot of land he uses exclusively. The main activity of an agent is to decide on and implement the land use of their plot.

Bio-physical Environment. The original landscape data from the STORMA-project will be used. Based on LandSat-images on a 30 £ 30 m grid, we use the data on land-cover and altitude. Agents are located in the villages and rattan will be distributed according to a height gradient. Furthermore previous harvesting activities will be taken into account. With an GIS-Analysis and expert knowledge, the most probable entry points for rattan-harvesting will be located and supposed trails (e.g. a gradient with the smallest slope) used for modelling purposes. The abundance data of *Calamus zollingeri*, is used for initialisation Siebert [2004]. Since only two initial factors are known, which determine the abundance of rattan (distance to town and altitude), those will be used to simulate the distribution of rattan. After initialisation, the agent will decide – for example every "year" – on its land-use, which will be "implemented" subsequently. This will be the yield that corresponds to the harvesting rates that can be estimated using the Siebert [2004] data.

Model structure. The technical Framework structure is presented in figure 2. From a central Graphical-Users Interface (*JAVA-Application*), different background scenarios (price, climate variation) and evaluation components can be selected, and the simulation of the MAS is triggered. The MAS is modelled in Repast (http://repast.sourceforge.net), a toolkit with various built-in methods for data analysis and extension possibilities such as database connectivity or GIS-extension.

The economic and ecological data needed for simulation are loaded from an Entity-Relationshipdatabase. In this database, various data from different sources are stored, i.e. Land-Sat images on a 30£ 30m basis, information on vegetation cover and detailed household survey data including geo-referenced resource access. Depending on the research question, different ‘impact-modules’ can be included into the framework.

The ecological module ‘implements’ the land-use decision in ’*Wirkwelt*’,. . . its ecological consequences; e.g. on the hydrological cycle or on rattan stocks. The economic impact is a consequence of the implemented land-use decision, too. In this case exogenous factors (climate, . . .) influence crop yield, which might be very different from what the agent anticipated (’*Merkwelt*’). The profits are added to the financial capital. The results of the impacts are again fed back into the database and can be used for further analysis.

Calibration and validation. Data from work of Siebert [2000] and Siebert [2004] will be taken to estimate the spatial distribution of the rattan. However, both publications only offer rattan data in an aggregated form. In order to get a more realistic spatial distribution we apply the following steps. First, we calculate a weighted path raster. These paths are those, which are travelled most likely by the rattan collectors. We assign the weights, which stand for the movement costs. The values of the weights are chosen in accordance with expert knowledge. This means that travelling along rivers has the lowest movement cost and travelling within the forest has the highest costs. The cells of this raster contain the accumulated cost values. In the next step we combine the information of the rattan on the height gradient of Siebert [2000] with this raster.

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