Spatial, Temporal and Social Scaling in Sparsely Populated Areas – Geospatial Mapping and Simulation Techniques to Investigate Social Diversity

Andreas KOCH and Dean CARSON

Abstract

Scale-dependence is a well-known phenomenon in geography with sophisticated theoretical approaches and techniques at hand to deal with the modifiable areal unit problem (MAUP). Geographical analyses are, however, predominantly focusing on urban spaces with a high level of small-scaled social diversity. While space is considered scale-sensitive less attention is paid to scale in a temporal and social context. The paper extends the MAUP discussion to time and social issues (modifiable temporal and social unit problems, respectively) and claims to take sparsely populated areas in investigations of diversity equally into account, since diversity in these regions in particular manifests more pronounced. This is illustrated by two empirical examples from Austria and Australia, applying raster maps and an agent-based modelling technique.

1 Introduction

Since the 1980s, there has been increasing attention paid to the techniques used to model diversity of demographic, economic and social conditions within geographic areas. SCHOLZ' (2004) theory of fragmented development alerted geographers to the need to understand ever more complex and fragmented social structuration that has arisen from the conflation of local and global activities ("glocalization") and the inter-relations of actual and virtual networked communities. Contests over boundaries and borders as limiters and delimiters of social and economic status occur ever more frequently. Interpretations of regional disparities and mechanisms to address them underpin new paradigms of spatial planning (GRAHAM & HEALEY 1999). Much of the research around fragmentation and new understandings of place has occurred in urban environments where the close proximity of relatively large numbers of people overlays with a diversity of experience in terms of access, social isolation, and economic opportunities. That urban spaces are heterogeneous is now beyond dispute, and a number of techniques have been developed to model their heterogeneity (e.g. BRUCH 2006, CROOKS 2008).

There tends to be much less attention paid to fragmentation and the social diversity of rural areas, particularly those that have sparse resident populations and are somewhat disconnected from the social and economic interdependencies between large urban 'cores' and their peripheries (CURRIE & KUBIN 2006). In sparsely populated areas, academicians and practitioners continue to imply homogeneity of social and economic conditions. This is illustrated, for example, in policy treatments of 'the north' in places like Canada, Australia and Arctic Europe (e.g. BONE 2003, INSTONE 2009) and 'the Alps' in central and western

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Europe (PERLIK et al. 2001). Paucity of demographic, social and economic data and their assumed poor quality are often cited as reasons for limited academic research into social diversity in more sparsely populated areas (CARSON et al. 2011).

The purpose of this paper is to investigate how social diversity may better be examined in the context of sparsely populated areas. We begin by arguing that diversity exists at spatial, temporal and social scales and that the tools used to examine diversity need to encompass these scales. For this purpose, we introduce extensions to the well-known Modifiable Areal Unit problem (MAUP) in the form of the MTUP (modifiable temporal unit problem) and MSUP (modifiable social unit problem). We illustrate these problems in the context of fragmentation studies in contrasting sparsely populated areas – Alpine valleys in the Salzburg region of Austria, and remote Indigenous communities in the Northern Territory of Australia. In the Austrian case, we examine how the use of raster maps may help particularly address MAUP and MSUP issues. In the Australian case, we propose the use of agent based spatio-temporal simulation modelling to address MTUP concerns. The conclusion urges awareness of the social (re-)constitution of scaling procedures that are so important to the comprehension of social fragmentation in differently populated areas.

2 The Theoretical Dimensions of Scale

A methodological and epistemological pluralism seems to be a logical and inevitable conclusion when scale-based investigations of social diversity are performed. Geocomputational approaches like spatio-temporal simulation of demographic changes (HARRIES et al. 2005) or settlement developments (BATTY 2005, KOHLER & GUMERMAN 2000) as well as (geo-)statistical analyses of e.g. real estate structures are largely dealing with concerns of a critical geography, because of their scale sensitivity and diversity awareness. According to KWAN & SCHWANEN (2009: 284) a critical epistemology in quantitative geography can be stated – “for instance, its emphasis on local context and local relationships instead of global generalizations about spatial processes, its increased sensitivity to multiple axes of difference […], and its attention to processes through which individual spatial knowledge is constituted and shapes spatial behavior […]”.

Moreover, scale and diversity or difference and context are core concepts used both in geocomputation and critical geography which allows for an explicit consideration of a plurality of attitudes – the indigenous population(s), the immigrants, the planners, or the scientists – and of advocating different ethical positions. Scale-awareness (due to its multi-perspectivism) provides at least a technique of circularity of reasoning and arguing, avoiding a unilateral causal chaining of supposed or actual facts which eventually become objective or real as ELLIS (2009: 305) points out with respect to racial classification: “The act of collecting data by […] fixed categories, of counting and estimating populations in them, reifies race and misleads with respect to the porosity of group boundaries and the variability of group experience”.

Accordingly, the next question is dedicated to the constitution of scales. The measure of scale, be it spatial, temporal, or social, is firstly not an apriori given fact, but a (re-) generated, (re-)constituted product of linking different activities of different social units in differently embedded spatial and temporal units (SHEPPARD & MCMASTER 2004: 15 and

19). Again, the circular process of tying together multi-scaled activities in space and time is crucial to approach an understanding of the Lebenswelt, change, and diversity.

In complexity theory this is conceptualized as the hybridity of local/micro motives or needs and global/macro behavior or structures which implies mutual relations instead of preferring one side of the distinction and which considers emergence as an independent force (see, for example, EPSTEIN 2006, JOHNSON 2001, or MITCHELL 2009 for computational social science and GIDDENS 1991 or LATOUR 2005 and 1993 for theoretical social science). A consecutive issue is the fluidity of scales. If "[s]patial scales are never fixed, but are perpetually redefined, contested and restructured in terms of their extent, content, relative importance and interrelations" (SWYNGEDOUW 2004: 133) then a conflated composition of geometrical and topological spatial relationships has to be taken into account.

Thus, the imagination of a socially constituted scale implies the inclusion of different concepts of spaces, times, and societies. Geometry (chorological space) and topology (relational space) are two of them at the spatial level (there are obviously more spatial concepts like the semantic or perceived ones, for our purpose, however, the two mentioned concepts are representative). At the temporal level it is appropriate to include concepts such as direct causal reaction, feed-back loops, adaptation, self-organization, and evolution (BOSSEL 2007). Social scales can be best described in a system theoretical context, differentiated as 'systems of interaction', 'organizations', and 'functionally specified social systems' like economy, politics, or science (other ideas of scaling the social, such as a distinction between community and society or between neighborhood, region, nation, and the global seem less appropriate due to their explicit size and/or space connotations). Scale, thus, is not only a technique to properly resolve geographical units (SIU-NGAM LAM 2004: 25f), but also a semantic concept to better comprehend power relations, exclusion mechanisms, and border meanings. As GOODCHILD (2004: 163f.) points out with respect to scaling effects of digital information and communications technologies, it is the spatial and functional organization of social phenomena that matters.

Spatial analysis is being aware of the manifold theoretical problems of scale-dependency and is well equipped with a set of techniques to solve or at least to approach these problems. In geo-statistics and geographic data mining investigation of spatial trends, spatial classification, spatial association, and spatial auto-correlation are considered main research fields (e.g. MILLER & HAN 2009). They all refer to the well-known modifiable areal unit problem (MAUP, see OPENSHAW 1984). Due to the above-mentioned temporal and social natures of scale it seems to be appropriate to extend the MAUP objective by introducing MTUP (modifiable temporal unit problem) and MSUP (modifiable social unit problem). One issue with respect to temporal units would be the *creeping processes* in demographic transitions; subtle and already 'in action' before being perceived, an invisible fact that needs to be explicitly uncovered (ZAHNEN 2008: 21). With respect to social units, one issue would be the political implementation of regional development plans in social networks which differ in size, shape, composition, hierarchy levels, and influential mechanisms of their participating social systems.

Geocomputation and related quantitative approaches in geography offer different techniques and models for dealing with MAUP, MTUP, and MSUP, i.e. with mutual relationships of diverse spatial, temporal, and social scales. In the following cases we examine two of these techniques – the use of raster maps to illustrate diversity of access to social infrastructure in the Salzburg region of Austria, and the use of agent based spatio-temporal simulation to model demographic diversity among remote Indigenous communities in Australia's Northern Territory.

3 Diversity of Access to Social Infrastructure in the Alpine Areas of Salzburg, Austria

With respect to all three modifiable unit problems we can conclude that diversity is an amalgam of scale-sensitive social, spatial, and temporal facts. They are interrelated and not necessarily equal in their relevance and meaning.

A simple approach is the use of raster maps (WONKA 2006). This approach highlights the ties between MAUP and MSUP, disregarding time by fixing it. In a European Union project context (see DEMOCHANGE.ORG) the Austrian project partner applied them to adequately illustrate the spatial correlation of regional population distribution and local concentration of social infrastructure. A 500×500m raster was used to represent accessibility on foot along the street network. Figure 1 shows for a section of the entire Salzburg pilot region the accessibility of basic infrastructure (retail, postal offices, drug stores, restaurants, etc.) in 2007, while Figure 2, for the same section and year, illustrates this for medical infrastructure (hospitals and doctors).

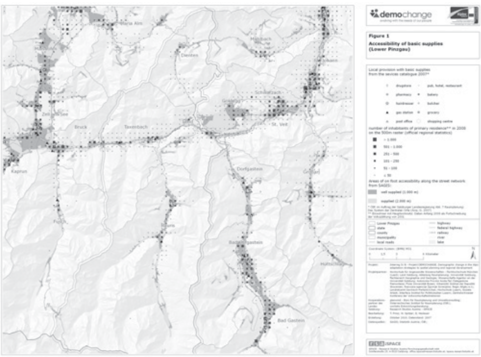

Fig. 1:
Accessibility on foot of basic infrastructure in one part of the Salzburg pilot region

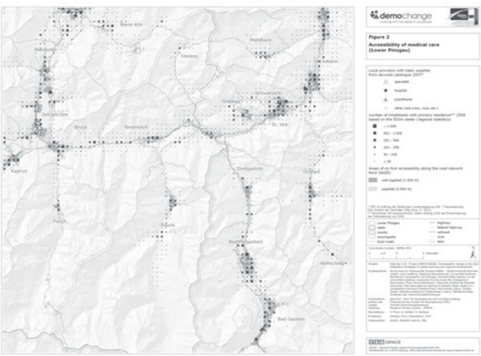

Fig. 2:
Accessibility on foot of medical infrastructure in one part of the Salzburg pilot region

A correlation of these phenomena at the administrative level of municipalities would result in erroneous interpretations, because population is not equally distributed across the territory, but along the Alpine valleys. Hence, accessibility here is more properly represented due to an explicit consideration of the distribution structure and network constraints (irrespective of the chosen threshold). Furthermore, a comparison of accessibilities between different infrastructures is feasible due to an adequate scalar reference.

The modifiable social-spatial diversity in these figures is first and foremost an attempt to imagine spatial diversity. Infrastructural points of interest – provision with basic supplies and medical care – indicate a specific point pattern which more or less ought to be equally distributed in the first case and which allows a certain degree of a clustered distribution in the second case. Based on these point patterns and the street network a zonal segmentation of on foot accessibility has been included. Accessibility, thus, is evaluable only from the spatial perspective which has been solved appropriately nonetheless, because the raster representation due to its large-scaled, equal-sized spatial focus takes population distribution more differentiated and more precisely into account than a vector representation with an arbitrary average value would do.

Raster cells are artificial, uniform, and scalable, notwithstanding aggregated units. However, by varying the cell size the MAUP problem can be handled properly. Accordingly, social units understood as artificially aggregated entities like for instance populations or social services, may be scaled differently. Spatial-cartographic uniformity enables a visual and analytical representation of social variability, because an exogenous spatial influence (correlation) is being excluded. If we think of social units as natural entities like individuals, households, communities or milieus, then a uniform understanding is misleading. In this case social variability correlates – at least partly – with specific spatial scales. This is surmountable with an integrated approach of raster space and agent based modelling techniques, an idea which has to be further investigated more intensely.

Both maps, however, failed to adequately represent social diversity. Its implicit message is that infrastructure refers to an assumed socially homogeneous population which seems to differ only in density values. What is missing is the range of social diversity in order to evaluate accessibility. The elderly and the youth, for example, differ in their mobility behaviour which feeds-back to a respective evaluation and usage of the available infrastructure. The same is true for gender-specific needs or for the diverse types of handicapped persons and their requirements.

Another influencing issue is household structure with its diverse spatial patterns of organizing activities such as labour, education, provision, or recreation. From the individual to households, associations, or other functional community affiliations: the modifiable social unit problem has not been solved in raster maps like the ones we used here as an example; neither per se by representing different social units nor in connection with different spatial units. A cellular automaton (CA) approach seems to be appropriate to overcome these bottlenecks, since CA are capable of embedding heterogeneous information – for example, multivariate statistical results, incorporating space- and scale-specific data – and taking neighborhood conditions into account. Even more advanced are agent-based approaches which will be discussed in the next chapter.

4 Demographic Diversity of Remote Indigenous Communities in Australia's Northern Territory

There are more than 70 discrete 'Indigenous communities' in Australia's Northern Territory with populations ranging from several dozens to several thousands of people. 'Indigenous communities' are those subject to special Northern Territory and Australian government legislation to control health and economic behaviour (TAYLOR & CARSON 2009). Related policy focuses on 'closing the gap' in indicators of health and economic status between Indigenous and non-Indigenous Australians (PHOLI et al. 2009). A variety of policy and research documents (see, for example, NEWMAN et al. 2008) imply that experience of 'the gaps' (in mortality, educational attainment, exposure to various health conditions etc.) is consistent among people living in remote Indigenous communities. Consequently, programs and policies have until exposed all Indigenous communities to the same treatment conditions. Assumptions have been made that Indigenous people will transition 'the gaps' in a uniform manner across space.

Recent research has questioned the validity of these assumptions. TAYLOR (2009), for example, argued that cultural diversity arising from the traditional organisation of Indigenous Australians into over 500 separate tribal/ cultural 'nations' has legacies in demographic diversity that is poorly understood.

We were interested in determining whether the organisation of Indigenous settlements across the Northern Territory reflected demographic diversity at the time of the 2006 Australian Census of Population and Housing, and how diversity might persist or diminish over time. In the first stage, we created thematic (vector) maps of various demographic (age and sex distributions, dependency ratios, family and household sizes) variables as measured in the Census and used spatial regression techniques to determine spatial patterns in these variables. In general, there were few identifiable spatial 'clusters' of settlements with similar characteristics, although a weak correlation did exist between sex ratio (number of men: number of women) and latitude (this is illustrated in Figure 3). Importantly, our analysis was conducted at the settlement level, and the spatial relationship was not apparent when populations were described at the regional level more commonly used in reporting Indigenous social and demographic statistics.

It is very difficult to investigate temporal scale effects in the context of remote Indigenous communities because data are only available about these settlements since Indigenous people were recognised as Australian citizens in 1967 (and so the first substantial data collection is the 1971 Census). Continuing difficulties in accessing Indigenous communities for the purposes of Census enumeration, high levels of mobility of Indigenous people living in remote areas, and poor translation of Census concepts (such as 'migration' and 'household') into Indigenous language has meant in practice that data of sufficient quality for demographic analysis has not been available until the late 1990s (TAYLOR et al. 2011). Even today, data about Indigenous deaths are available in only four of Australia's eight provinces, for example.

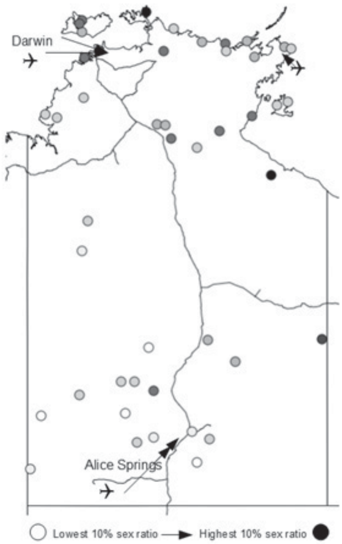

Fig. 3:
Diversity in Sex Ratio (number of males: number of females) among Indigenous communities in the Northern Territory

In this context, agent based spatio-temporal simulation facilitated an experimental approach to investigating MTUP. We constructed, in the NetLogo (WILENSKY 1999) simulation software, replicas of the 2006 populations (age, sex, number of children ever born to each adult woman, number of years each person had lived in the community) of two remote Indigenous communities and subjected agents to uniform probabilities relating to demographic events (births, deaths, in and out migration) in year one. We then allowed the populations to develop over a period of 15 years to assess the medium term impact of their different starting. Figure 4 illustrates how the demographic characteristics of the two communities (both with an initial population of approximately 2000 people) diverged over time. What was most important in terms of considering the MTUP problem was that divergence was not apparent within a five year timeframe (so would not be identified in consecutive quinquennial census, for example), but became dramatic after ten years of progression of the model. In short, the experiment illustrated that demographic diversity is likely to persist in remote Indigenous communities, but that sensitivity to the temporal scale effects is required to understand the nature and emergence of diversity. Policy makers and researchers should reconsider assumptions about homogeneity and convergence, and spatio-temporal simulation is a useful tool to investigate such assumptions when historical data are poor.

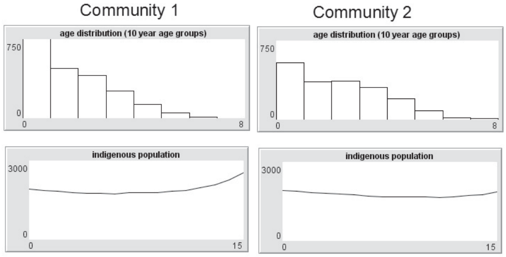

Fig. 4:
Projected demographic change in two Indigenous communities using agent based spatio-temporal modelling

5 Conclusion

We presented two techniques for examining social diversity in the context of sparsely populated areas. While spatial analysis using raster or vector maps are valuable for managing the MAUP and MSUP, they generally lack power to account for temporal differences. A more comprehensive approach in this regard is agent based spatio-temporal simulation modelling. Such models consider social-spatial interactions that occur over time (KOCH 2010). Short-term events impact medium-term developments through iterated feedback loops or creeping processes, leading to long-term transformations represented in adaptation or structural changes. As we demonstrated here, agent based spatio-temporal models can also be used as experimental research tools with time as an independent variable. While these techniques are not new, and both have been applied in urban contexts, there has been a seeming reluctance to adopt them in research into sparsely populated areas. Data quality and availability may be one explanation, but it may also be that researchers of such locations are not fully cognisant of the dimensions of scale – spatial, temporal, and social – which apply. Geo-political and statistical 'regions' are likely to be larger (in terms of land area) in sparsely populated areas, and disparate populations are more likely to be 'trapped' together in such regions. There are significant consequences for theory and practice in allowing such (re-)constructions of scale to underpin understandings of the people who live in and visit these places.

References

BATTY, M. (2007), Cities and Complexity: Understanding Cities with Cellular Automata, Agent-Based Models, and Fractals. MIT Press, 565 p.

BONE, R. (2003), The Geography of the Canadian North: Issues and Challenges (2nd ed.). Oxford University Press, 256 p.

BOSSEL, H. (2007), Systems and Models: Complexity, Dynamics, Evolution, Sustainability. Books on Demand Norderstedt, 372 p.

BRUCH, E. (2006), Residential Mobility, Income Inequality, and Race/Ethnic Segregation in Los Angeles. Population Association of America, 2006 annual meeting, available at: http://paa2006.princeton.edu/download.aspx?submissionId=60143 (23-01-2012).

CARSON, D., ENSIGN, P., RASMUSSEN, R., & TAYLOR, A. (2011), Perspectives on 'demography at the edge'. In: CARSON, D., RASMUSSEN, R., ENSIGN, P., HUSKEY, L. & TAYLOR, A. (Eds.), Demography at the Edge: Remote human populations in developed nations, 3-20.

CARSON, D., RASMUSSEN, R., ENSIGN, P., HUSKEY, L. & TAYLOR, A. (Eds.), Demography at the Edge: Remote human populations in developed nations. Ashgate Publishing Ltd, 344 p.

CROOKS, A. (2008), Constructing and Implementing an Agent-Based Model of Residential Segregation through Vector GIS. UCL Working Papers Series, Paper 133.

CURRIE, M., & KUBIN, I. (2006), Chaos in the Core-Periphery Model. Journal of Economic Behaviour and Organisation, 60 (2), 252-275.

DEMOCHANGE.ORG (2012), Demographic change in the Alps. Adaptation strategies to spatial planning and regional development, available at: http://www.demochange.org (28-01-2012).

ELLIS, M. (2009), Vital Statistics. The Professional Geographer, 61(3), 301-309.

EPSTEIN, J. (2006), Generative Social Science. Studies in Agent-Based Computational Modeling. University Press Group Princeton and Oxford, 356 p.

GIDDENS, A. (1991), Consequences of Modernity. Blackwell Publishers, 200 p.

GOODCHILD, M. F. (2004), Scales in Cybergeography. In: SHEPPARD, E. & MCMASTER, R. (Eds.), Scale and Geographic Inquiry: Nature, Society, and Method, 154-169.

GRAHAM, S. & HEALEY, P. (1999), Relational concepts of space and place – Issues for planning theory and practice. European Planning Studies, 7(5), 623-646.

HARRIES, R., SLEIGHT, P. & WEBBER, R. (2005), Geodemographics, GIS and Neighbourhood Targeting. John Wiley & Sons, 293 p.

INSTONE, L. (2009), Northern belongings: frontiers, fences, and identities in Australia's urban north. Environment and Planning A, 41, 827-841.

JOHNSON, S. (2001), Emergence: The Connected Lives of Ants, Brains, Cities, and Software. Scribner, 288 p.

KOCH, A. (2010), Geosimulation: theoretical and epistemological expeditions to the invisible relationships of space, time and social life. In: KOCH, A. & MANDL, P. (Eds.), Modeling and Simulating Urban Processes. LIT Verlag, 1-28.

KOHLER, T. & GUMERMAN, G. J. (2000), Dynamics in Human and Primate Societies: Agent-Based Modeling of Social and Spatial Processes. Oxford University Press, 416 p.

KWAN, M.-P. & SCHWANEN T. (2009), Quantitative Revolution 2: The Critical (Re)Turn. The Professional Geographer, 61(3), 283-291.

LATOUR, B. (2005), Reassembling the Social: An Introduction to Actor-Networ-Theory. Oxford University Press, 301 p.

LATOUR, B. (1993), We Have Never Been Modern. Harvard University Press, 168 p.

MILLER, H. J. & HAN, J. (2009), Geographic Data Mining and Knowledge Discovery. CRC Press, 458 p.

MITCHELL, M. (2009), Complexity: A Guided Tour. Oxford University Press, 384 p.

NEWMAN, P., MARINOVA, D., ARMSTRONG, R., RAVEN, M., MARLEY, J., MCGRATH, N. & SPRING, F. (2008), Desert Settlement Typology: Preliminary Literature. Desert Knowledge Cooperative Research Centre, 76 p.

OPENSHAW, S. (1984), The Modifiable Areal Unit Problem. Geo Books, 41 p.

PERLIK, M., MESSERLI P. & BÄTZING, W. (2001), Towns in the Alps: Urbanization processes, economic structure, and demarcation of European Functional Areas in the Alps. Mountain Research and Development, 21 (3), 243-252.

PHOLI, K., BLACK, D., & RICHARDS, C. (2009), Is 'close the gap' a useful approach to improving the health and wellbeing of Indigenous Australians? Australian Review of Public Affairs, 9 (2), 1-13.

SCHOLZ, F. (2004), Die Theorie der "fragmentierenden Entwicklung". Geographische Rundschau, 54 (10), 6-11.

SHEPPARD, E. & MCMASTER, R. (Eds.) (2004), Scale and Geographic Inquiry: Nature, Society, and Method. Blackwell Publisher, 288 p.

SIU-NGAM LAM, N. (2004), Fractals and Scale in Environmental Assessment and Monitoring. In: SHEPPARD, E. & MCMASTER, R. (Eds.), Scale and Geographic Inquiry: Nature, Society, and Method, 23-40.

SWYNGEDOUW, E. (2004), Scaled Geographies: Nature, Place, and the Politics of Scale. In: SHEPPARD, E. & MCMASTER, R. (Eds.), Scale and Geographic Inquiry: Nature, Society, and Method, 129-153.

TAYLOR, A., & CARSON, D. (2009), Indigenous mobility and the Northern Territory Emergency Response. People and Place, 17 (1), 29-38.

TAYLOR, A., BELL, L., AXELSSON, P. & BARNES, T. (2011), The Challenge of Enumeration and Population Estimation in Remote Areas. In: CARSON, D., RASMUSSEN, R., ENSIGN, P., HUSKEY, L. & TAYLOR, A. (Eds.), Demography at the Edge: Remote human populations in developed nations, 21-38.

TAYLOR, J. (2009), Indigenous demography and public policy in Australia: population or peoples? Journal of Population Research, 26, 115-130.

WILENSKY, U. (1999), NetLogo. http://ccl.northwestern.edu/netlogo/ (23-01-2012).

WONKA, E. (2006), Regionalstatistik in Österreich. Von der Tabelle zu räumlicher Analyse und Visualisierung. Salzburger Geographische Arbeiten, 39, 168 p.

ZAHNEN, B. (2008), Schleichende Naturrisiken als geographisches Problem der Zeit. geographische revue, 10 (8), 15-29.