Editors: Biljana Abolmasov, Miloš Marjanović, Uroš Đurić

Proceedings of the 2nd Regional Symposium on

LANDSLIDES

in the Adriatic - Balkan Region

14-16th May 2015 Belgrade - Serbia

Editors:
Dr Biljana Abolmasov, University of Belgrade, Faculty of Mining and Geology
Dr Miloš Marjanović, University of Belgrade, Faculty of Mining and Geology
Uroš Đurić, MSc, University of Belgrade, Faculty of Civil Engineering

Proceedings of the 2nd Regional Symposium on

LANDSLIDES

in the Adriatic-Balkan Region, ReSyLAB, Belgrade 14-16 May 2015

University of Belgrade, Faculty of Mining and Geology
May 2017

EDITORS

- Dr Biljana Abolmasov
- Dr Miloš Marjanović
- Uroš Đurić, MSc

ORGANIZING COMMITTEE

University of Belgrade, Faculty of Mining and Geology

Members

- Dr Ivan Obradović (Dean)
- Dr Biljana Abolmasov (Vice Dean)
- Dr Gordana Hadži-Niković
- Dr Dragoslav Rakić
- Dr Dragutin Jevremović
- Dr Radojica Lapčević
- Dr Čaki Laslo
- Dr Miloš Marjanović
- Snežana Bogdanović, MSc
- Irena Basarić, MSc
- Jelka Krušić, MSc
- Katarina Andrejev, MSc

University of Belgrade, Faculty of Civil Engineering

- Dr Zoran Radić
- Uroš Đurić, MSc

University of Novi Sad, Faculty of Technical Sciences

- Dr Milinko Vasić

Honorary Members

- Dr Petar Lokin
- Dr Duško Sunarić
- Dr Slobodan Ćorić

INTERNATIONAL SCIENTIFIC COMMITTEE

Members

- Dr Snježana Mihalić Arbanas, Croatia (ICL ABN)
- Dr Željko Arbanas, Croatia (ICL ABN)
- Dr Matjaž Mikoš, Slovenia (ICL ABN)
- Dr Marko Komac, Slovenia (ICL ABN)
- Dr Sabid Zekan, Bosnia and Herzegovina (ICL ABN)
- Dr Milorad Jovanovski, FYROM
- Dr Vlatko Šešov, FYROM
- Dr Zvonko Tomanović, Montenegro
- Dr Cristian Marunteanu, Romania
- Dr Marinos Skempas, Greece
- Dr Kyoji Sassa, Japan
- Dr Janusz Wasowski, Italy
- Dr Leonardo Cascini, Italy
- Dr Michael Krautblatter, Germany

PUBLISHER:
University of Belgrade, Faculty of Mining and Geology

FOR PUBLISHER:
Prof. Dušan Polomčić, Dean

COVER DESIGN:
Srđan Krstić

PRINTED BY:
Sapient Graphics

ISSUED:
250 Copies

FRONT COVER PHOTO:
Landslide Leva Reka, Kraljevo, Serbia (by Biljana Abolmasov)

BACK COVER PHOTO:
Landslide Leva Reka, Kraljevo, Serbia, UAV photo (by Dragan Milovanović and Stefan Miljković)

Disclaimer
The content of this proceedings does not reflect the opinion of the editors or publisher. Responsibility for the information and views expressed in the papers lies entirely with the author(s).

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

551.4.037(082)
624.131.53(082)
624.138(082)

REGIONAL Symposium on Landslides in the Adriatic-Balkan Region (2 ; 2015 ; Beograd)
Proceedings of the 2nd Regional Symposium on Landslides in the Adriatic-Balkan Region, RESYLAB, Belgrade 14-16 May 2015 [Elektronski izvor] ; editors Biljana Abolmasov, Miloš Marjanović, Uroš Đurić / editors Biljana Abolmasov, Miloš Marjanović, Uroš Đurić. - Belgrade : University of Belgrade, Faculty of Mining and Geology, 2017 (Belgrade : Sapient Graphics). - 1 elektronski optički disk (CD-ROM) ; 12 cm

Sistemski zahtevi: Nisu navedeni. - Tiraž 250. - Invited lecturer: str. 256-261. - Nasl. sa naslovnog ekrana. - Bibliografija uz svaki rad. - Registar.

ISBN 978-86-7352-296-8

a) Клизишта - Зборници b) Косине - Зборници
COBISS.SR-ID 234417420

Assessment of population vulnerability in risk analysis using dasymetric database of Serbia

Branislav Bajat[(1)], Nikola Krunić[(2)] Milan Kilibarda[(1)], Aleksandar Sekulić[(1)]

1) University of Belgrade, Faculty of Civil Engineering, Department of Geodesy and Geoinformatics, Bulevar kralja Aleksandra 73, 11000 Belgrade Serbia

2) Institute of Architecture and Urban & Spatial Planning of Serbia, Bulevar kralja Aleksandra 73, 11000 Belgrade Serbia

Abstract This study reveals the importance of disaggregating population data that has previously been aggregated by census tracts or municipality polygons in order to achieve more accurate population distribution/location. Demographic census data are mapped as statistical surfaces and are often presented on choropleth maps. The major drawback of such maps is that population distributions are often misrepresented as homogeneous cartographic units when in fact this may not be the case. These misrepresentations of data can falsely omit uninhabited areas from within the cartographic units. A newly-developed dasymetric mapping method that is suitable for modelling population distribution on the regional or country scale is presented in this paper. This paper outlines an original solution for dasymetric mapping that is based on previous results concerning the experiences of European and worldwide projects related to dasymetric population density grid production. The region of interest in this study is Serbia, for which a database of the entire territory's spatial distribution of population and population density has been constructed and is based on proposed methodology herein. The constructed database provides a population statistical surface of 100 x 100 m resolution, and it is already available for free online to all experts dealing with hazard risk management.

A case study is presented here that compares the official aggregated estimates of Serbian population that are potentially impacted by landslide hazard prone areas in the City of Belgrade with estimates obtained by disaggregated dasymetric mapping. The obtained results indicate severe differences in population counts obtained by these two different data sources.

Keywords dasymetric modelling, land use suitability, cartographic web service

Introduction

The importance of disaggregating population data that has been previously aggregated by census tracts or other units has previously been highlighted in many hazard risk analysis studies that aim towards achieving more realistic population distributions (Chen et al.,2004; Maantay and Maroko, 2009; Freire, 2010; Giordano and Cheever, 2010).

Cartographic presentation of heterogeneity /homogeneity in the spatial distribution of population is still a major problem in modern geography and other geo-sciences as well. The traditional method of thematic or choropleth mapping rarely gives satisfactory results. The traditional choropleth map creates a misleading impression of a uniform distribution of a phenomenon in space, although it most often varies in the specific geographic area. In the Republic of Serbia, the population data are usually presented on the level of census designation places by the aggregation of census and statistical districts data.

In this study, Geographic Information Systems (GIS) technology constitutes the basis for the methodology developed to identify a vulnerable population for any possible hazard. GIS technology has led to the development of risk information systems that can be used to analyse risk and evaluate the consequences of decisions made that mitigate or reduce risk (van Westen, 2004).

World gridded demographic databases

One of the examples for mapping the spatial population distribution at a global level is the LandScan Global Population Database (LSGPD), which has been developed by the Oak Ridge National Laboratory (ORNL) within the Global Population Project for the needs of assessing the population vulnerability after disastrous events (Dobson et al., 2000). The LandScan database is a dasymetric model of a population distribution in a grid format and is based on accumulated census data obtained from countries that provide a 24-hour ambient population estimate. The resolution of the LandScan database is of 30 arc seconds by 30 arc seconds (grid size 1×1 km).

There are also other public available databases for different purposes on the global level (Bengtsson et al., 2006, Balk and Yetman, 2004, CIESIN and CIAT, 2005) that depict population density over the entire world, However, all of these publicly available population densities are inappropriate for smaller scale demographic studies that include analyses for microlocations and for large scale social, economic and environmental applications such as hazard mapping.

Existing desymetric databases in Serbia

There are already a number of studies related to the dasymetric mapping in Serbia. They are mainly related to regional or local spatial levels. The possibility of using a dasymetric method for the purpose of assessing "daily" or "ambient population" and "night" population in the territory of Vojvodina has been presented in the paper written by a group of authors (Krunić et al., 2011). Bajat et al. (2013) recently presented a methodology for rescaling soil imperviousness data by using a spatial database of building height typology of the City of Belgrade in order to develop a dasymetric model that might be used for estimating population distributions in urban areas.

Materials and methods

Population data of Serbia

The Republic of Serbia covers an area of 88,361 km² and, in accordance to the 2011 census, has a population of 7,120,666 (no data for the Autonomous Province of Kosovo and Metohija) with a population density of about 92 inhabitants per km². The estimated population of Serbia in 2006 (SORS, 2012) was used in this study. A total of 160 municipalities of which 16 belonged to the City of Belgrade, were encompassed within this study. The total estimated population in the year 2006 was 7,411,982 inhabitants. The distribution of population density in a form of choropleth map is given in Fig.1 (left).

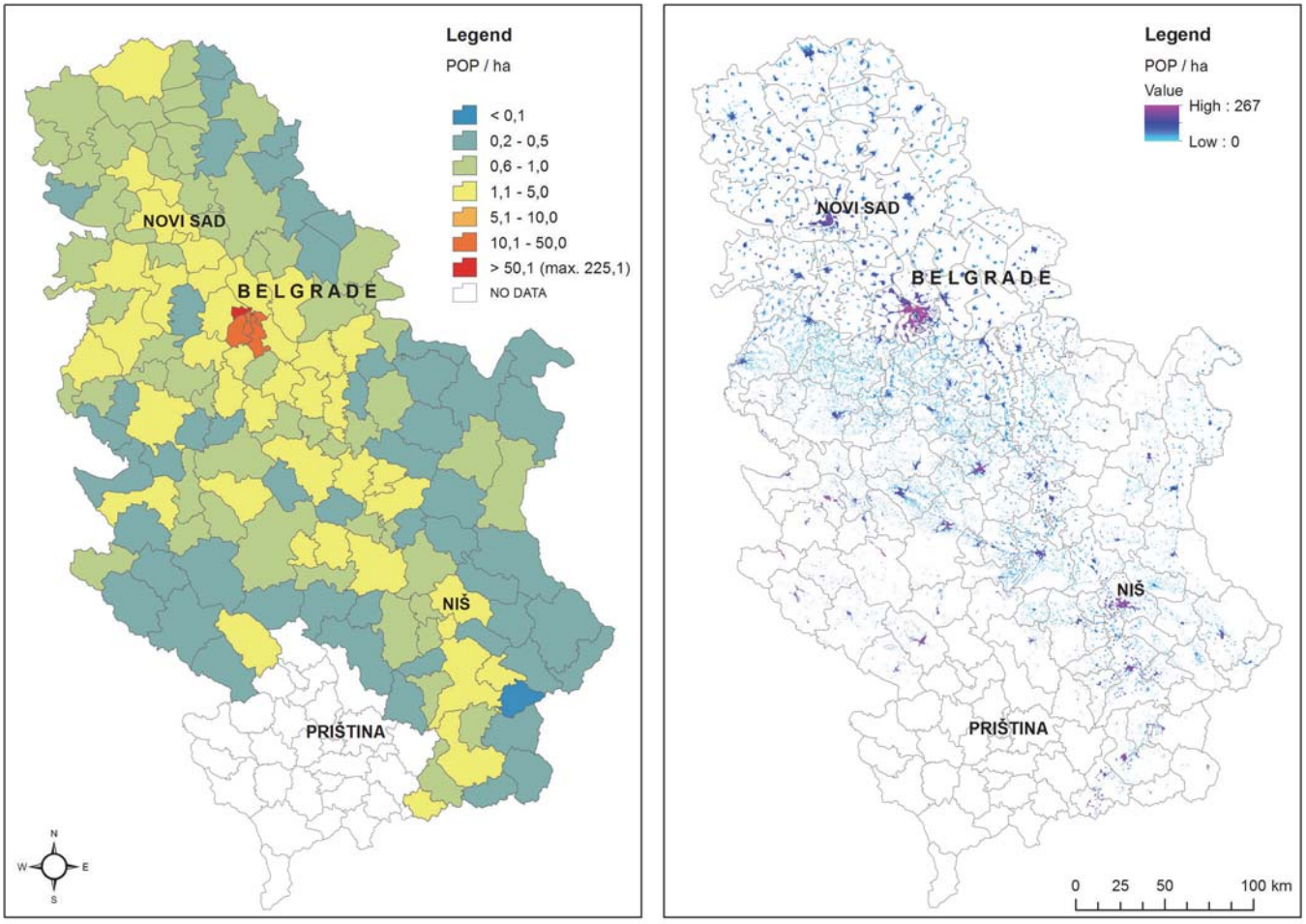

Figure 1 Choroplet (left) and dasymetric (right) maps of population denisty in Serbia for the year 2006.

Applied Dasymetric Model

A dasymetric database of Serbia referring to the year 2006 was produced and is based on an adapted degree of soil sealing raster layer and terrain altitude:

$$G_D \int SS, A \qquad [1]$$

where G_D represents dasymetric density, SS represents soil sealing and A represents altitude of terrain. The soil sealing database represents the land surface that has become imperviousdue to anthropogenic impact (Burghardt, 2006.) This database is available in two spatial resolutions 20 m and 100 m, and for this purpose we used the coarser one. The ASTER GDEM digital terrain model with a spatial resolution of 30 m (for this study resampled to 100 m resoultion) was used for terrain altitudes.

More details about the methodology used for generating a dasymetric database of Serbia are available in the paper presented by Krunić et al. (2015).

The result of dasymetric modeling is presented as thematic map in Figure 1 (right). The dasymetric map indicates a more realistic presentation of a spatial population distribution in comparison to a classical choropleth map that reveals official publically available census data.

The final results of the dasymetric database of Serbia are portrayed as a thematic map that can be communicated and shared easily through the cartographic web map-based service. The web map was achieved using recently developed packages in the R language environment including the newly developed package *plotGoogleMaps* (Kilibarda & Bajat, 2012), which is based on Asynchronous JavaScript and XML technology (AJAX) and Google Maps Application Programming Interface (API) service that produces HTML file map mashups. The web map is available at URL: http://osgl.grf.bg.ac.rs/PopDensSerbia2006.html.

Moreover, the data of the dasymetric database are also available to download for each municipality in GeoTiff format (by clicking on municipality polygon).

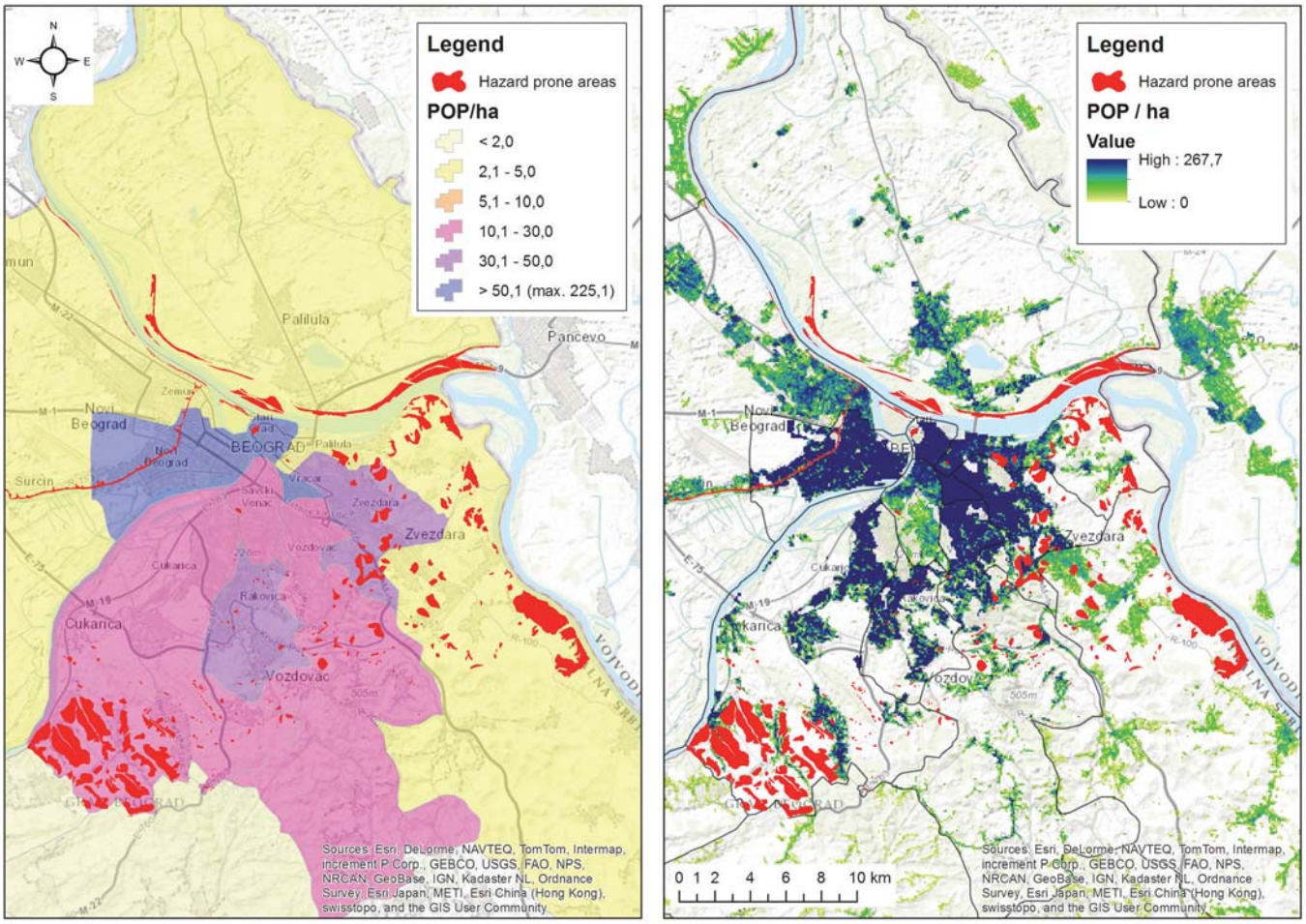

Figure 2 Hazard prone delineated areas over the choroplet (left) and dasymetric (right) population density maps of Belgrade city area.

Data processing and results

The land-use suitability (LUS) data layer (Djurić et al. 2013) is readily usable in the GIS environment. The Master Plan of the City of Belgrade was used to delineate areas that are susceptible to landslide and ground subsidence hazard. The other class of input data concerns spatial population distribution.

The hazard-prone areas were delineated by overlaying the official data of population distribution aggregated on municipality level with LUS layer polygons that refer to unsuitable and very unsuitable land classes (Fig 2 left). The total count of vulnerable population was calculated by multiplying the areas of hazard prone polygon areas with the average population density related to particular municipality. The total number of vulnerable population obtained in such way is 48,418 for the entire case study area. On the other hand, by applying the same procedure with the dasymetric raster data, the total number of vulnerable inhabitants is 23,119. The difference between those two estimated amounts is a consequence of the fact that most of the hazard prone areas actually cover uninhabited space.

One can get the opposite results if we focus on a particular hazard-prone polygon covering a populated area. For example, the polygons depicted in Figure 3 indicate 2527 people in accordance to the daymetric database (Fig 3 right) are at risk whereas official data of

population distribution indicates 578 people are at risk (Fig 3 left).

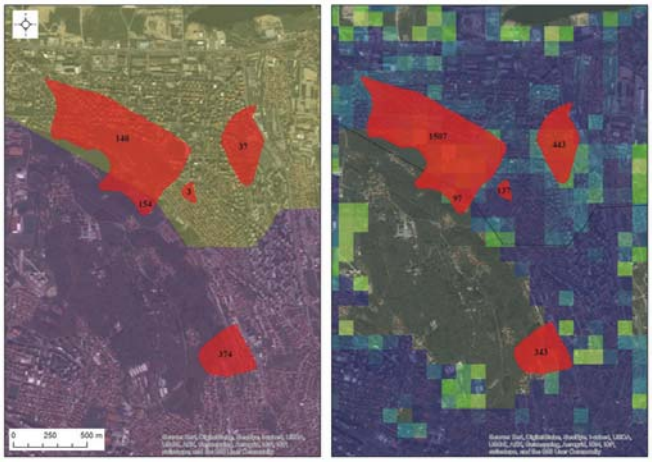

Figure 3 Hazard prone delineated polygons over official data of population distribution (left) and dasymetric database (right) of Belgrade city area.

Conclusion

Official census data that is usually aggregated on census tracts or even on the municipality level are not suitable for population vulnerability assessment with regard to the biased estimate of people under risk. Undercounting or overcounting of an impacted population could have serious implications for risk management and mitigation.

The dasymetric mapping method could solve this problem by dividing the modelled space into zones with a higher degree of homogeneity; thereby reflecting more truthfully the variations in a statistical population layer, with support of additional variables and their correlations. The production of population surface models suitable for risk analysis applications can be achieved by coupling this methodology with the GIS environment and free open access database of soil sealing (soil imperviousness)..

The obtained database can be an instrument to assess cost-benefit ratios when local and government authorities analyze the effect of certain mitigation measures. Moreover, the database could serve as an important tool that can be implemented in the disaster awareness phase of disaster risk management at the municipal level.

Acknowledgments

This work was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (Contracts No. III 47014 and TR36035).

References

Bajat B, Krunić N, Petrović MS, Kilibarda M (2013) Dasymetric modelling of population dynamics in urban areas. Geodetski Vestnik. 57(4): 777-792.

Balk D, Yetman G (2004) The global distribution of population: Evaluating the gains in resolution refinement, documentation for GPWv3. GPWv3 working paper. CIESIN. (available at http://sedac.ciesin.org/gpw/docs/gpw3_documentation_final.pdf)

Bengtsson M, Shen Y, Oki T (2006) A SRES-based gridded global population dataset for 1990–2100. Population and Environment. 28(2): 113-131.

Burghardt W (2006) Soil sealing and soil properties related to sealing. Geological Society, London, Special Publications. 266: 117-124.

Chen K, McAneney J, Blong R, Leigh R, Hunter L., Magill C (2004) Defining area at risk and its effect in catastrophe loss estimation: a dasymetric mapping approach. Applied Geography. 24(2): 97-117.

CIESIN and CIAT (2005) Gridded Population of the World, Version 3 (GPWv3). Palisades, NY: Socioeconomic Data and Applications Center (SEDAC), Columbia University. available at http://sedac.ciesin.columbia.edu/gpw

Dobson JE, Bright EA, Coleman PR, Durfee R, and Worley BA (2000) Landscan: A global population database for estimating populations at risk. Photogrammetric Engineering and Remote Sensing. 66: 849-857.

Djurić U, Marjanović M, Šušić V, Petrović R, Abolmasov B, Zečević S, Basarić I (2013) Land-use suitability analysis of Belgrade city suburbs using machine learning algorithm, Symposium GIS Ostrava 2013, CD Proceedings, 21th - 23th January 2013, Ostrava, Czech Republic. ISBN 978-80-248-2944-9.

Freire S (2010) Modeling of spatiotemporal distribution of urban population at high resolution–value for risk assessment and emergency management. In Geographic information and cartography for risk and crisis management Konecny M, Zlatanova S, Bandrova TL.(ed.) Springer Berlin Heidelberg. (ISBN: 978-3-642-03441-1). p.429.

Giordano A, and Cheever L (2010) Using dasymetric mapping to identify communities at risk from hazardous waste generation in San Antonio, Texas. Urban Geography. 31(5): 623-647.

Kilibarda M, Bajat B (2012) plotGoogleMaps: The R-based web-mapping tool for thematic spatial data. Geomatica 66(1): 37-49.

Krunić N, Bajat B, Kilibarda M (2015) Dasymetric mapping of population distribution in Serbia based on soil sealing degrees layer. In Ruzickova K, Inspektor T (ed.). Surface Models for Geosciences. Lecture Notes in Geoinformation and Cartography. Springer. (*in press*).

Maantay J, and Maroko A (2009) Mapping urban risk: Flood hazards, race, & environmental justice in New York. Applied Geography. 29(1): 111-124.

Statistical Office of the Republic of Serbia (SORS) (2012) Natural changes of population in the Republic of Serbia, Statistical Office of the Republic of Serbia, Belgrade.

van Westen C J (2004) Geo - information tools for landslide risk assessment : an overview of recent developments. Proceedings of the 9th international symposium on landslides, June 28 -July 2, 2004 Rio de Janeiro, Brazil. pp. 39-56.