An exploratory study on building, land change use, traffic and temperatures rising in Porto Alegre city - Brazil

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Summary

1 Introduction

In this paper we analyze evolution of land change patterns, building, transportation, mobility and temperatures shifts, gathered for the case of Porto Alegre, the Southernmost Brazilian metropolis of the country.

Using Landsat satellite images captured in 1986, 1997 and 2011, geo-referentiated and processed, we show that the city underwent an intensive process of urbanization that resulted in an entire neighborhood resized in Southeast direction, whose growth turned from radial sprawl, up to 1997, to a more scattered expansion that is nowadays featured as a new area of conurbation towards South.

Northeast neighborhoods experimented an expected advance in vertical building, already provided by the Master Plan for Urban and Environmental Development.

2 Climate change and urbanization

Urbanization is perhaps the most remarkable process over daily people lives.

Since 2008 global population crossed the 50% mark as urban, and up to 2030, this average will reach 60% [1].

There are controversial studies about the precise results of the relationships between urbanization and long term temperatures modifying.

Does urban density increase or decrease greenhouse gases emission? Is urban heating improving or dropping?

Studies on urbanization and heating are focused on are focused on health effects and strategies for adaption to climate change [1, 16, 17], and on general issues about urbanization, population density, heating and climate change [4, 8, 9, 11, 12, 15, 18, 20, 21, 22].

2.1 Scale issues

While there are certainties about unfair harm effects of climate change – with underdeveloped regions and poor people being the most affected – there are also uncertainties on how to assess local level climate change [5].

Global climate change models do not work in small scales, so it is very difficult to link urbanization with climate change and vice-versa [27].

Emerging regional studies [29] are trying to fill this gap.

2.2 Urbanization and heating: a review

Studies on Urban Heat Island (UHI) – about differences in air and surface temperatures in different sites of the same city.

78% of the carbon emissions are attributed t cities [4,8].

Some studies on UHI: Porto Alegre, Brazil 1989 [3], Istanbul and Ankara, Turkey, 1995 [36], Göteborg, Sweeden, 2003 [35], New Jersey, USA, 2004 [18], Jakarta, Indonesia, 2010 [31], South Korea cities, 2011 [6].

3 Objectives and methods

We performed this research as an exploratory case study [41], intended to understand the complex phenomenon of linkages among urbanization – land change use, building, vehicles fleet, mobility – and temperature rising in Porto Alegre city, Brazil.

We have gathered and analyzed data on population growth, civil building, land use change, vehicles fleet and average monthly temperatures from 1931 to 2010, taken in the following ranges: 1931-1960, 1961-1990, 1991-2000, 2001-2010.

We geo-processed and analyzed Landsat satellite images of June 1st 1986, July 1st 1997, May 5th 2011 using Envi software. Urbanized areas were identified and accounted for each image with AutoCAD software.

4 Exploratory study: Porto Alegre

4.1 General aspects

The Southernmost Brazilian metropolis, Porto Alegre is the capital of Rio Grande do Sul, placed at Central Depression of the State. It has as geographical coordinates 30°02'0" South and 51°12'00" West.

The city occupies 496.82 Km^2, and has a population of 1,409,351 inhabitants, with a density of 2,836 indwellers/km^2. It has averages temperatures ranging from 20°C to 23°C. It keeps 24.1% of the original vegetation – of this amount, 13.9% are forest coverage and 10.2% are underbrush.

From 1900 to 1960, city's population grew from 73,000 indwellers to 635,000 indwellers. From 1990 to 2000, Porto Alegre had a population growth of 9% and this percentage is getting more or less stable in the last 10 years.

More than 23% of the city's habitants lived in slums up to 2007.

4.2 Building and land change use

The offering of building unities in Porto Alegre increased 40% from 1998 to 2010.

The city underwent dramatic vegetation supression in the last decade, especially at South and Southeast areas. Some South neighborhoods underwent vegetation losses up to 69% in the last 40 years.

The city is experiencing a change in behavior regarding housing: while low income people keep on pressuring hill slope, high income people is moving far away from central areas, contributing for horizontal sprawl.

Urbanized areas corresponded to 145,99 Km^2 in 1986, to 160,71 Km^2 in 1997 and to 174,68 Km^2 in 2011. It represents an increase of 10.08% from 1986 to 1997 and of 8.69% from 1997 to 2011.

4.2 Building and land use change

Satellite images show a significative horizontal sprawl until up to 2011, especially in South and Southeast areas, despite the little decreasing of 1.39 percentual point in urbanized area from 1997 to 2011 if compared with 1986 to 1997.

We can consider that horizontal sprawl took place mainly in South and Southeast, while Northeast areas likely have passed intensive densification, what can be testified by building offering growth.

Northeast followed what was planned in Urban Master Plan (densification targets), but Southern areas were no supported by urban planning – it has no support for underpinning disorderly land change use.

4.2 Building and land use change

Landsat image of June 1st 1986 shows scattered urbanized area at Southeast (1) and a dense spot area at South (2)

4.2 Building and land use change

Landsat image of July 1st 1997 shows that Southeast area (1) has became more dense (limit between Porto Alegre and Viamao city) and South area has grown (2) radially

4.2 Building and land use change

Landsat image of May 5th 2011 shows that South area (2) has sprawled even more and underwent conurbation with other South areas (3)

4.3 Traffic and mobility

On road emissions contributes for 23% of the total emissions around the world. Traffic injuries are the second cause of death in young people all over the world (ages from 5 to 29) [10].

Porto Alegre has one car by 2.7 indwellers, 2,761 kilometers of roads for collective and individual transportation vehicles, and 722,078 vehicles in circulation. Bicycle paths comprise just 3.2 kilometers all over the city, and this extent is not continuous.

Considering the costs of public transportation to people, deaths in traffic by 100 indwellers, bike pathways extension, and the ratio between individual car travels and public (bus) travels, Porto Alegre is almost at the bottom of the list among 9 Brazilian capitals – it occupies the 7^{th} place.

Vehicle fleet of the city is increasing at 6% by year.

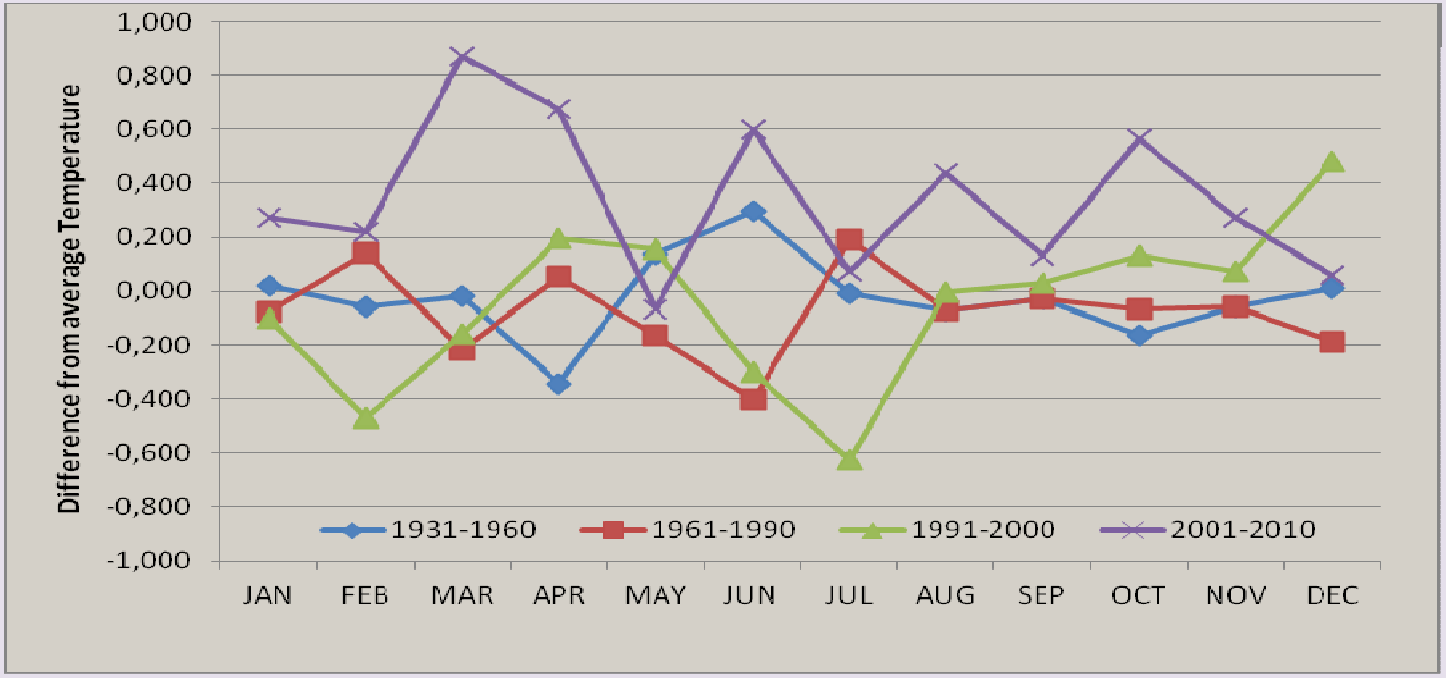
4.4 Average temperatures rising

Mininum average temperatures have grown and maximum average temperatures have risen all over Rio Grande do Sul State between 1930 and 2007 [47].

Taking in account the temperatures observed in the four time ranges (1931-1960, 1961-1990, 1991-2000 and 2001-2010), we applied the ANOVA and a multiple comparison procedure to determine which periods have shown significant differences compared with the others. Using a 0.05 significance level, statistical results show that 2001-2010 temperatures are significantly higher than those observed for 1931-1960, 1961-1990, and 1991-2010.

4.4 Average temperatures rising

The differences registered for the last decade are of 0.367ºC (compared with 1931-1960), of 0.417ºC (compared with 1961-1990) and of 0.392ºC (compared with 1991-2000). We can state that the last 10 years has been hotter than the 30 years comprised between 1961 and 1990.



5 Discussion and conclusion

Although there are not conclusive research about the direct linkage between urbanization and climate change, mainly due the difficult for translating global change models into smaller scales, several studies on urban climate change have revealed positive relations between urban land change and heating [4, 6, 17, 22, 31, 32, 33, 35, 36, 37, 38, 39, 40].

In Porto Alegre city, the Southernmost Brazilian metropolis, focus of our research, [3] found positive co-relationships between building density and temperatures rising.

5 Discussion and conclusion

Analyzing side by side land change use with the aid of real estate data and satellite images across a range of 25 years (from 1986 to 2011), as well as traffic variation and average temperatures of Porto Alegre, taken from 1931 to 2010, we conclude that the pace of changing in land that underwent sprawl process kept itself almost constant since the middle of the 80's, but South areas has grown under a disorderly pattern if compared with overall.

We also registered an average increase temperature of almost 0.4ºC in the last decade, compared with the ten years immediately before. Although we cannot surely state that the temperature growth is a direct outcome of urbanization phenomenon, we deem relevant to warn public authorities to take a better look at this whole set of gathered data in order to rethink the way urban Master Plan has been implemented.

Thank you!

Main references – as quoted in original paper

1. Harlan, S.L., Ruddell, D.M. Climate change and health in cities: impacts of heat and air pollution and potential co-benefits from mitigation and adaptation. *Current Opinion in Environmental Sustainability* **2011**, 3:126–134.

3. Hasenack, H. Influência de variáveis ambientais sobre a temperatura do ar na área urbana de Porto Alegre. Master thesis, 1989. Geosciences Institute, Federal University of Rio Grande do Sul.

4. Gu, C., Hua, L., Zhang, X.,Wang, X., Guo, J. Climate change and urbanization in the Yangtze River Delta. Habitat International 35, 2011: 544-552.

5. Bentley, M. Healthy Cities, local environmental action and climate change. Health Promotion International 2007, Vol. 22 No. 3, 246-253.

6. Kim, M., Kim, S. Quantitative estimates of warming by urbanization in South Korea over the past 55 years (1954-2008). Atmospheric Environment 45, 2011: 5778-5783.

8. Grimm, N.B., Faeth, S.H., Golubiewski, N.E., Redman, C.L., Wu, J., Bai, X., Briggs, J.M. Global Change and the Ecology of Cities. Science, Feb 8th 2008 Vol. 319: 756-760.

9. Seto, K.C., Sánchez-Rodríguez, R., Fragkias, M. The New Geography of Contemporary Urbanization

and the Environment. Annual Review of Environment and Resources 2010. 35:167–94.

10. De Nazelle, A., Nieuwenhuijsen, M.J., Antó, J.M., Brauer, M., Briggs D., Braun-Fahrlander, C., Cavill, N., Cooper, A.R., Desqueyrouxi, H.,Fruin, S., Hoek, G., Panis, L.I., Janssen, N., Jerrett, M., Joffe, M., Andersen, Z.J., van Kempen, E., Kingham, S., Kubesch, N., Leyden, K.M., Marshall, J.D., Matamala, J., Mellios, G., Mendez, M., Nassif, H., Ogilvie, D., Peiró, R., Pérez, K., Rabl, A., Ragettli, M., Rodríguez, D., Rojas, D., Ruiz, P., Sallis, J.F., Terwoert, J., Toussaint, J.F., Tuomisto, J., Zuurbier, M., Lebret, E. Improving health through policies that promote active travel: A review of evidence to support integrated health impact assessment. Environment International 37, 2011: 766–777.

11. McDonald, R.I., Green, P., Balk, D., Fekete, B.M., Revenga, C., Todd, M., Montgomery, M. Urban growth, climate change, and freshwater availability 2011:1-6. Proceedings of the National Academy of Sciences of the United States of America. April 12nd 2001, Vol 108, N 15: 6312-6317. Available at: http://www.pnas.org/content/suppl/2011/03/22/1011615108.DCSupplemental. Last access: August 15th 2011.

12. Dodman, D. Urban density and cimate change. Report. United Nations Population Fund (UNFPA)

Analytical Review of the Interaction between Urban Growth Trends and Environmental Changes. April 2nd 2009, 23p.

Main references

15. Satterthwaite, D. Climate change and urbanization: effects and implications for urban governance. Report. United Nations Expert Group Meeting on Population Distribution, Urbanization, Internal Migration and Development. Population Division. Department of Economic and Social Affairs United Nations Secretariat, 2007, p.1-29.

16. Aalst, M.K., Cannon, T., Burton, I. Community level adaptation to climate change: The potential role of participatory community risk assessment. Global Environmental Change 18, 2008: 165–179.

17. Moser, C., Norton, A., Stein, A., Georgieva, S. Pro-Poor Adaptation to Climate Change in Urban Centers: Case Studies of Vulnerability and Resilience in Kenya and Nicaragua. The World Bank Sustainable Development Network Social Development Department, June 2010, p. 1-96.

18. Solecki, W. D., Rosenzweig, C., Pope1, G., Chopping, M., Goldberg, R., Polissar, A. Urban Heat Island and Climate Change: An Assessment of Interacting and Possible Adaptations in the Camden, New Jersey Region. Environmental Assessment and Risk Analysis Element. Research Project Summary> State of New Jersey, Department of Environmental Protection, Division of Science, Research and Technology, 2004:1-5.

20. Lankao, P.R. Urban Areas and Climate Change: Review of Current Issues and Trends- Issues Paper for the 2011 Global Report on Human Settlements, 2008, 101p.

21. Patz, J., Campbell-Lendrum, D., Gibbs, H., Woodruff, R. Health Impact Assessment of Global Climate Change: Expanding on Comparative Risk Assessment Approaches for Policy Making. Annu. Rev. Public Health 2008. 29:27–39.

22. Stephenson, J., Newman, K., Mayhew, S. Population dynamics and climate change: what are the links? Journal of Public Health, 2010, Vol. 32, No. 2, pp. 150–156.

31. Tokairin, T., Sofyanb, A., Kitada, T. Effect of land use changes on local meteorological conditions

in Jakarta, Indonesia: toward the evaluation of the thermal environment of megacities in Asia. International Journal of Climatology 30, 2010: 1931–1941.

32. Huang, G., Zhou, W., Cadenasso, M.L. Is everyone hot in the city? Spatial pattern of land surface temperatures, land cover and neighborhood socioeconomic characteristics in Baltimore, MD. Journal of Environmental Management 92, 2011: 1753-1759.

33. Hu, Y., Jia, G. Influence of land use change on urban heat island derived from multi-sensor data. International Journal of Climatology 30, 2010: 1382–1395.

Main references

35. Eliasson, I., Svensson, M.K. Spatial air temperature variations and urban land use – a statistical approach. Meteorol. Appl. 10, 2003: 135–149.

36. Karaca, M., Tayanç, M., Toros, H. Effects of urbanization on climate of Istanbul and Ankara. Atmospheric Environment Vol 29, N 23, 1995: 3411-3421.

37. Song, L., Cannon, A.J., Whitfield, P.H. Changes in Seasonal Patterns of Temperature and Precipitation in China During 1971–2000. Advances in Atmospheric Sciences, Vol 24, N 3, 2007: 459-473.

38. Fischer, T., Gemmer, M., Lüliu, L., Buda, S. Temperature and precipitation trends and dryness/wetness pattern in the Zhujiang River Basin, South China, 1961-2007. Quaternary International, 2011, 244: 138-148.

39. Elagib, N.A., Abdu, A.S.A. Development of temperatures in the Kingdom of Bahrain from 1947 to 2005. Theor Appl Climatol 2010, 101:269–279.

40. Wilson, S.M., Richard, R., Joseph, L., Williams, E. Climate Change, Environmental Justice, and Vulnerability: An Exploratory Spatial Analysis. Environmental Justice, Volume 3, Number 1, 2010: 13-18.

41. Yin, R.K. Case study research. Design and methods. Fourth Edition. Sage Publications, 2009.

47. Rossatto, M.S. Os climas do Rio Grande do Sul: variabilidades, tendências, tipologias. Doctorat dissertation, 2011. Institute of Geosciences. Federal University of Rio Grande do Sul, Brazil.