Romero, H., Fuentes, C., Vásquez, A. 2009. Gated villages and natural hazards in Santiago de Chile. 5th International Conference of the Research Network Private Urban Governance & Gated Communities. Santiago, Chile - March 30th to April 2nd 2009.

Gated Villages and Natural Hazards in Santiago de Chile

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Abstract: Santiago's urbanization process has directly impacted the environmental balance of natural and urban spaces, mainly increasing built impervious surfaces, such as homes roof, roads, parking lots, etc., that have greatly changed the circulation of rain water in the city. In the Macul basin, a representative Andean piedmont basin, these impacts have been caused by the installation of gated condominiums where live mostly people of high socioeconomic level, increasing runoff that eventually reaches lower areas of the basin, where mainly live people of lower socioeconomic level, increasing their exposure to flooding and logging and creating a lack of environmental justice and demanding compensation measurements.

Keywords: Urban Sprawl, Environmental Justice, Environmental Hazards, GIS.

Resumen: El proceso de urbanización experimentado por Santiago ha impactado directamente en el equilibrio ambiental de los espacios naturales y artificiales, principalmente mediante el aumento de superficies construidas impermeables, tales como techos de viviendas, calles, estacionamientos, etc., que han modificado el comportamiento hídrico de las aguas de lluvia en la ciudad. En la cuenca de Macul, que es representativa de las quebradas que drenan el piedmont andino, estos impactos han sido producidos por la instalación de condominios cerrados, donde habita mayormente población de estratos socioeconómicos altos, que han aumentado la escorrentía que alcanza eventualmente a los sectores bajos de la cuenca, donde habita principalmente población de menores ingresos, aumentando su exposición a amenazas de inundaciones y anegamientos y creando una situación de injusticia ambiental que demanda medidas de compensación.

Palabras Clave: Expansión Urbana, Justicia Ambiental, Riesgo Ambiental, SIG.

Introduction

Latin American cities have strongly increased their surfaces during last decades (JANOSCHKA, 2002). In the case of Santiago, the city has doubled its spatial size between 1975 and 2005, passing from 30.000 to 60.000 Has., and mainly as a consequence of land liberalization and social housing programs. Urban sprawl has permanently expanded urban spaces beyond periphery zones, replacing natural covers and landscapes by built up surfaces that have, in turn, produced relevant environmental impacts (ROMERO Y VÁSQUEZ, 2005).

One of the most important environmental impacts caused by the unlimited sprawl process is related with hydrological changes that result from the systematic imperviousness of previous natural lands that have been covered by paved roads, building roofs and parking lots. Santiago is located in a closed Maipo-Mapocho rivers watershed, surrounded by the high Andean mountains at the Eastern border and by the Coastal range at the western side. Piedmonts are connecting these ranges with alluvial floodplains, throughout several streams and creeks such as De Ramón or Macul basins located in La Reina, Peñalolén and La Florida Eastern municipalities. These streams produce floods and water logging following rainfalls during winter season (May and August), threatening an important portion of city inhabitants. Santiago's climate is semiarid and annual rainfall average is 360 mm in an average number of only 20 rainy days.

Methodology

A multitemporal analyses for years 1975, 1989, 1998 and 2007 about land use and land cover changes, based on Pauleit (2005), WITHFORD *et al*, 2001, MIRIS (Michigan Resource Information System, 1998) and CORINE (Coordination of Information on the Environment, 1990) was prepared using satellite images.

Real runoff coefficients (Pe) –amount of water that down water discharges in a rain event- were calculated like **Pe = (P – 0,2*S)2 / (P + 0,8*S),** where P is the highest maximum rainfall average in 24 hour recorded in Santiago in 30 years (86.6 mm), S is the maximum water retention potential in the ground, according to the Curve Number (US Soil Conservation System, 1989), that estimates potential runoff for each land use and cover, based on natural and artificial soil characteristics.

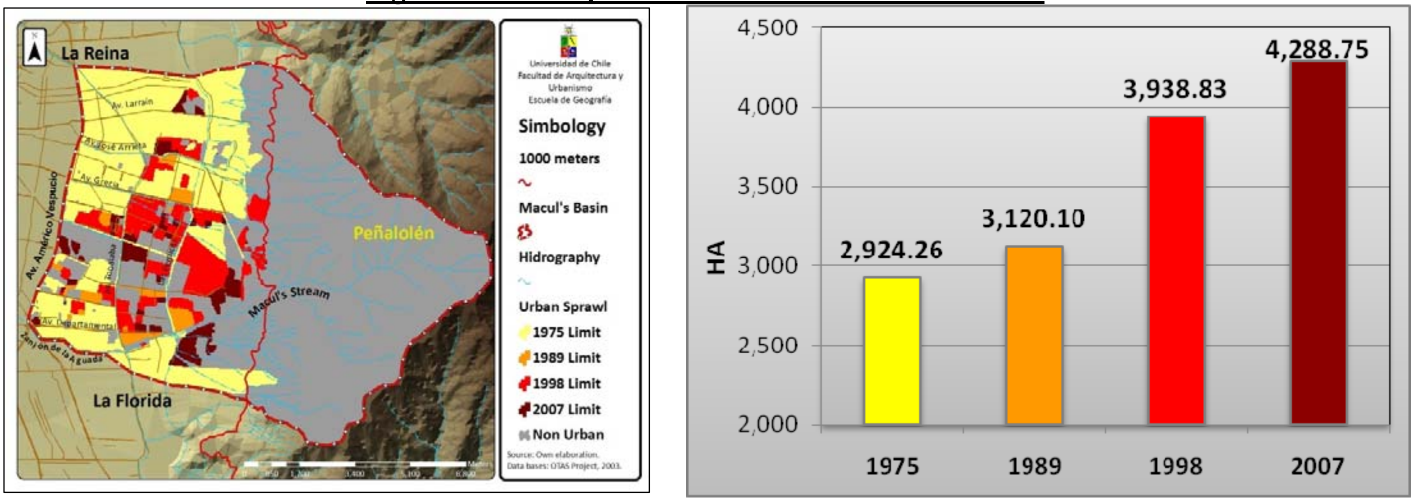
S = (25.400/CN) – 254
Where S is the maximum water retention potential in the ground in mm, and CN the Curve Number. Runoff coefficients (CE) estimate the rate between annual rainfall average (P) and water runoff.
CE = Pe / P
Where CE is the runoff coefficient, Pe the real runoff and P the maximum daily rainfall

Urbanization geographical patterns and runoff coefficients relationships were used to know urban water discharge, which was compared in turn with public works built up to avoid and mitigate the occurrence of floods and water logging, using a public work inventory prepared by DICTUC for Public Works Minister (MOP) (2006). To estimate local population threatened by floods and loggings, according to their socioeconomic level (FIELDING y BURNINGHAM, 2005), census data at squared blocks scale were analyzed. Socioeconomic classification was prepared by Adimark and divide people in highest income (ABC1), upper middle (C2), middle (C3), lower middle (D) and lowest income (E) classes.

Results

Urban areas located in piedmont watersheds have substantially growth between 1975 and 2007, specially those neighborhoods situated in the middle and surrounding the large Macul watershed, which has been severely affected by natural hazards, i.e, in May 1991. New urban development have occupied floodplains but also climb up slopes (figure 1), being mainly concentrated in middle and lower watershed sections, as a consequence of public regulation that is not allowing human settlements above 1000 m contour line. Between 1975 and 2007, 1.364,49 Has. of new urban development were added to the watershed. The total urban surface located inside the basin is currently estimated in 4.288,75 Has. which corresponds to 41% of the total area.

Figure 1: Urban Sprawl in Macul watershed 1975-2007.

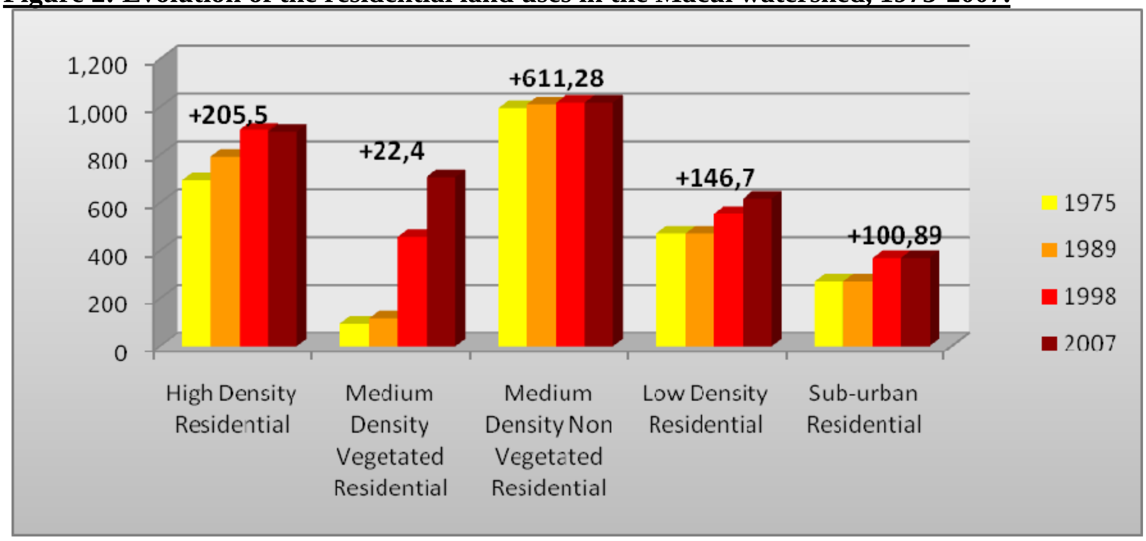


Source: Own elaboration.

Land use and cover changes are important variables in watershed urbanization. Residential land uses (Figure 2), have occupied 1.084 Has between 1975and 2007, covering agricultural and natural vegetation areas in the middle and upper watershed sections, respectively. Residential land uses vary according to their density: maximum sprawl (611 Ha or 56% of the total) corresponds to mean dense housing without vegetation, a series of middle and upper class condominiums that have been installed in steep slope areas that were previously covered by natural and agricultural lands with very low imperviousness rates (1-13%). Current imperviousness rates vary between 64 and 94%.
It is estimated that a Total Imperviousness Area of 10% separates good and impacted watershed environmental health (Whitford et al., 2001)

Lower middle class (D), very dense homes have occupied 205 Ha that represents 18% of total sprawl inside the watershed. Modest homes are, however located at the foothills, on discharge areas, and have very high imperviousness rates (above 93%). They are continuously affected by water logging and floods.

Figure 2: Evolution of the residential land uses in the Macul watershed, 1975-2007.



Source: Own elaboration.

Runoff coefficients have increased from 0,44 to near 1 or complete runoff, in most of the watershed, but particularly in its central zone, where urban developments have concentrated (table 1), specially between 1989 and 1998, when they reached 960 Ha.

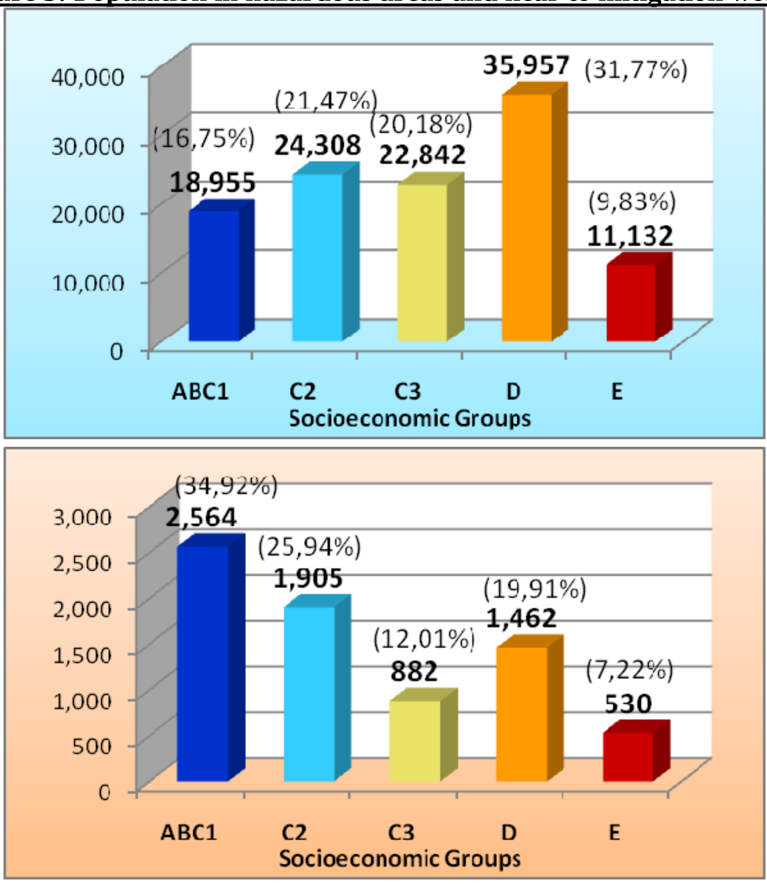
Table 1: Spatial variation of RC in Macul urban sprawl area.

RC change	1975-1989	1989-1998	1998-2007
Increase	337,86 ha.	958,67 ha.	271,39 ha.
Decrease	67,7 ha.	95,65 ha.	148,5 ha.

Source: Own elaboration.

Total population inside Macul watershed is 321.978 inhabitants. 113.194 of live in areas directly threatened by natural hazards. Only 7.343 inhabitants are protected against in some way against them. Socially, is the lower class which predominate in Macul, like in most of the city, since Group D formed 35,1% of the total population. **ABC1** (rich people) group is only 15,8%, and upper middle class (**C2)** is 18,7%. Figure 3 shows that the social distribution of the population threatened by natural hazards is almost similar to the general proportion. However, if the proportion of population that is protected by public work mitigations is selected, in this case, upper class and middle upper class increase their participation to 34,92% and 25,94%, respectively. Contradictory, lower class reduces their majority to be covered by mitigation practices in only around 20%.

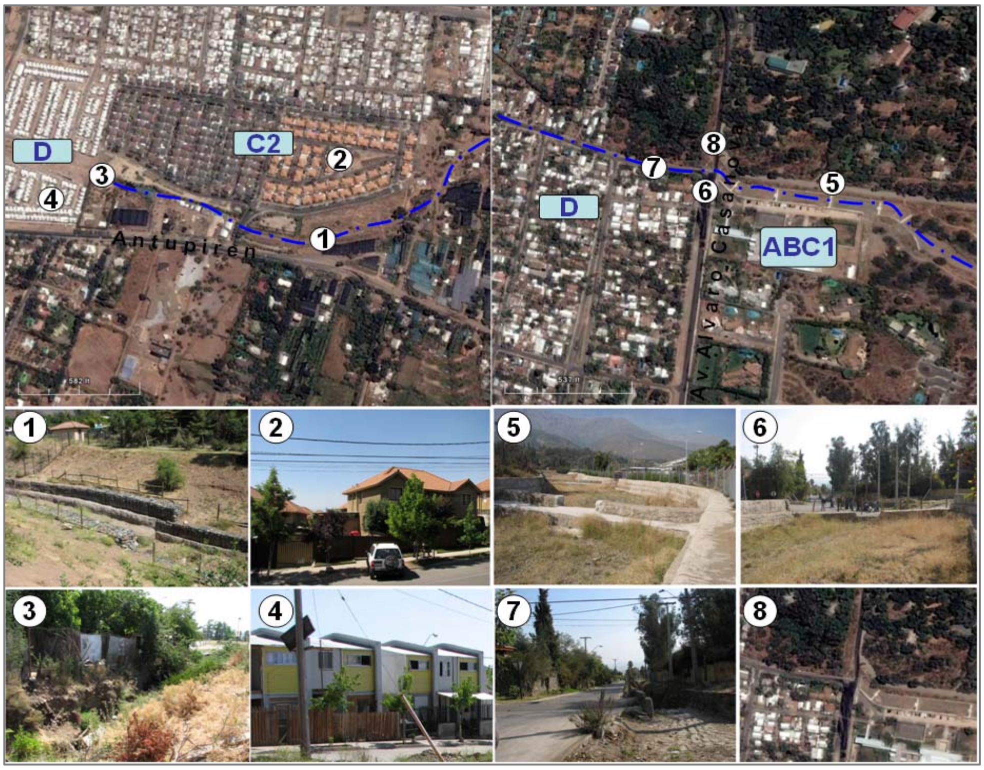
Figure 3: Population in hazardous areas and near to mitigation works.



Source: Own elaboration.

In short, different socio-economic groups can present a relatively similar exposure level when faced with naturally threats, like floods or landslides. However, their differentiate in terms of vulnerability since they can get large protection as a consequence of their greater social access to goods and services, appropriate infrastructures and political power. On the other hand, although homes of lower socio-economic population could be exposed to a reduced percentage of threats, their vulnerability is larger because weaker construction materials and deficient public infrastructure. This lack of environmental justice could be observed following urbanization patterns followed by one of the Macul watershed creeks (figure 4).

Figure 4: Natural hazard mitigation constructions along two Peñalolen creeks.



Source: Own Elaboration/Google Earth

Conclusions

The construction of gated villages in the upper section of Macul watershed, a representative of watershed located in the Santiago's Andean piedmont, has cooperated in the unlimited urban sprawl process that has characterized the growth of this city the last years. The urban occupation of Andean watershed has dramatically increased imperviousness rates and runoff coefficients, and these land uses and cover changes, have, in turn, influenced the occurrence of natural hazards, such as flooding and water logging.

Important socioenvironmental segregation could be observed between higher income residents that have occupied the uppermost part of the watershed and that are directly responsible from runoff and medium and lower income population that live in the lower section of the stream, where floods and water logging take place.

A strong process of environmental injustice result between upper and lower social groups, that are reinforced by public constructions aiming to avoid or mitigate natural threatens. Public Works are mostly located in the upper section and not where the most vulnerable socio and natural areas are situated. Special plans and programs to compensate these differences are required.

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