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Recent changes in flood risk in the Gran La Plata, Buenos Aires province, Argentina: causes and management strategy

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Abstract The paper analyses the causes of flood occurrence in the Gran La Plata, Buenos Aires Province, Argentina, and the changes that have occurred since the 1970s. The area is characterized by serious deficiencies in the use and management of water resources. The main factors are: (1) flood risk information is not updated; (2) urban building organization does not consider the flood risk; (3) the topography and other physical features are not taken into account in urban development. This research considers some specific problems, especially in data availability, and suggests ways to solve them, including improved analytical methodology. One of the main objectives is to analyse flood risk in social terms, producing a map of flood risk from the "human social vulnerability" point of view. The results suggest that flood risk has increased since the 1980s and that this is associated with changes in precipitation patterns that have also been aggravated by lack of controls on urban development. The poorer areas with the lowest level of infrastructure and public services, many of them developed over the last quarter-century, are especially vulnerable.

Keywords Flood · Human social vulnerability · Precipitation · Topography and urban building

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Introduction

The principal thesis of this research is that flood studies need to be undertaken in terms of social risk, rather than solely in terms of the physical environment (Funtowicz and Ravetz 1991, 1992, 1993). Social vulnerability and environmental damage should not be considered as separate entities and this needs to be borne in mind in developing methodological approaches and in the search for solutions (Andrade 2004; Andrade et al. 2003a, b; Ackers and Ruxton 1975; Morley 1995; World Bank 2004; Birdsall and Londoño 1997; Funtowicz and Leinfellner 2002).

This is needed particularly at government level, both locally and nationally, since government should be responsible for protecting people's homes and livelihoods and it is the only body that can effectively carry out the necessary measures (Coleman 1995; Butler et al. 2006).

Figure 1 shows the general location of the study area, Gran La Plata in Argentina. Figure 2 shows the area studied, which covers 1,160 km^2 and has

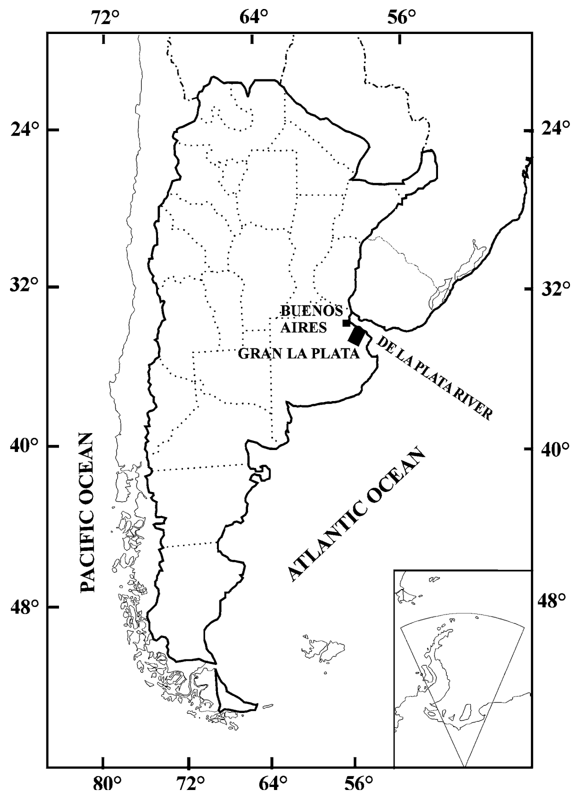

Fig. 1 Location of the study area in Argentina

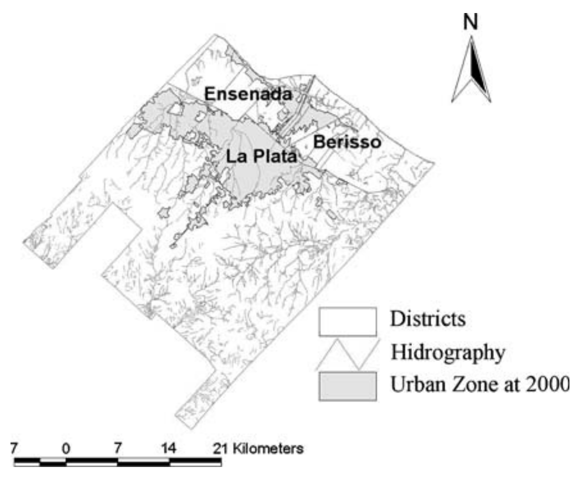

Fig. 2 Study area

640,000 inhabitants. It includes three districts: La Plata (924 km^2)—capital of Buenos Aires province, Berisso (135 km^2) and Ensenada (101 km^2). The specific objectives of the study are: (1) to show the spatial pattern of vulnerability to flooding and the changes that have occurred over recent decades; (2) to relate this to physical and human factors; (3) to develop an analytical approach in an environment where standard data are very limited; (4) to find methods of identifying flood areas, including remote sensing; (5) to identify the areas of greatest social vulnerability.

Methods

The study was carried out using daily precipitation data from La Plata Airport meteorological station (34°58′ S, 57°54′ W, 23 m) courtesy of the National Meteorological Service for the period 1971–2000 and flood data obtained from “El día”, a local distribution newspaper (Natenzon 2003a and b). Temporal variability was studied at annual and monthly scales, covering changes in both quantity and intensity. A map of flood occurrence has been drawn from this information. A Geographic Information System (Map/Info version 6.0 and ARC/View version 3.1) was used to relate hydrographic data, altitude levels, flooded areas, wetlands and land uses. GIS technology and remote sensing analyses were undertaken using two satellite images from the years 1986 and 2000 (ER-Mapper version 6.1). These proved to be very useful for the required purposes: to identify areas exposed to flood risk and to infer population density. The methodology is based in a Flood Risk Analysis Model (Social Risk Theory) (Natenzon et al. 2003) with these following basic components.

Danger: the potential capacity for flooding. Danger was identified using the following variates: spatial and temporal patterns of precipitation, evaluation of surface hydrography, analysis of flood occurrence records, identification of low-lying areas, identification of land uses that modify runoff, identification of human constructions and their influence on natural runoff.

Exposure: refers to the spatial materialization of danger or menace. All that may be affected by flooding constituted “the exposed”: human beings, goods and activities. Exposure was determined using cartography, aerial photos and satellite image interpretation. These were used to identify the affected geographic area, to evaluate the affected land uses, and in the identification of the affected population and critical areas (Moser and Holland 1996).

Uncertainty: as limits in the current knowledge and in jurisdictional and administrative issues. Uncertainty was identified for: national, provincial and local projects related to flood management and evaluation of the emergency system.

Vulnerability: as the differential capability to face the catastrophic event. It is conditioned for previous socioeconomic features. Preparing, preventing and recovery strategies are the main components in vulnerability mitigation. Social vulnerability analysis will allow the identification of different reactions to the same phenomena (Minujín 1999; Moser 1998).

In this paper, danger and exposure are the two components analyzed; the other two—uncertainty and vulnerability—will be examined in other studies.

Results and discussion

Figure 3 shows the precipitation events that have caused flooding in Gran La Plata over recent decades. The Gran La Plata experienced a significant change in the number of floods between the decade 1971–1980 and the decade 1991–2000 (Scarpati and Benitez 2005). Floods have increased from 25 events during the decade 1971–1980 to 77 events during the decade 1991–2000. Table 1 shows the statistical analyses of the three decades studied and Fig. 4 shows the Box plots.

Table 1 shows that the data do not follow a Normal distribution: the extreme values have decreased and the variance coefficient increased slightly.

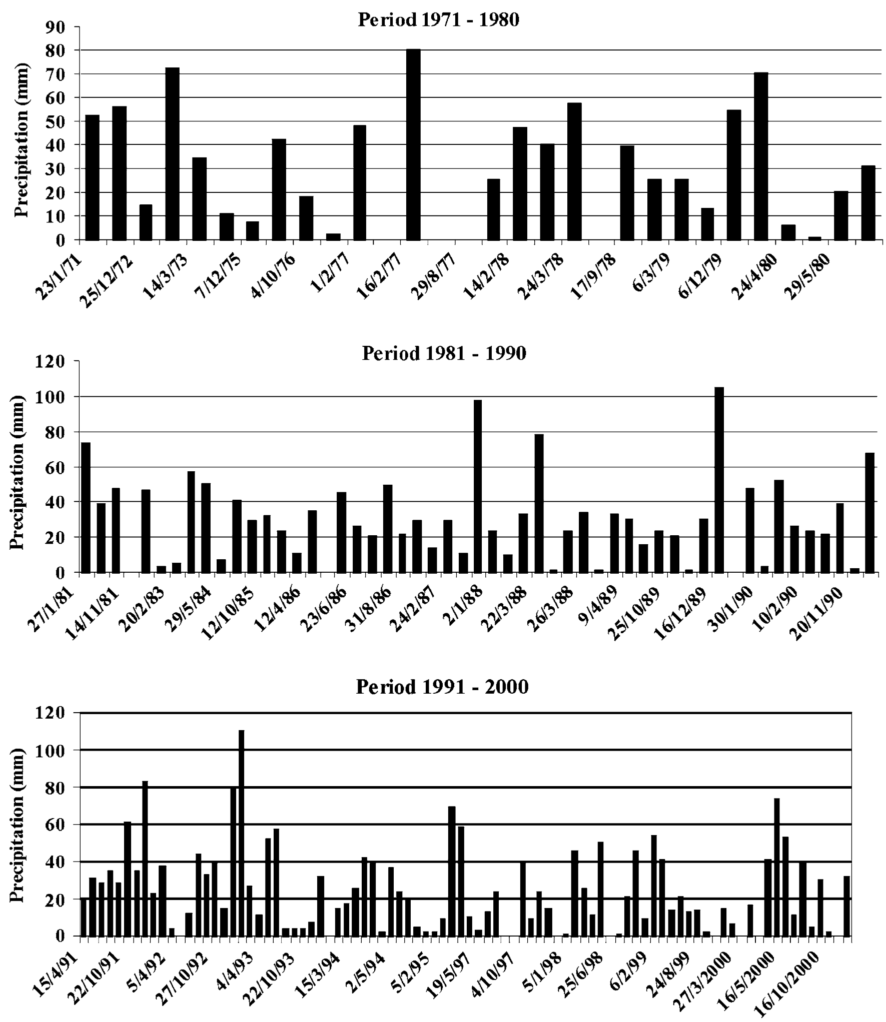

Fig. 3 Floods in La Plata city and the corresponding values of precipitation

Table 1 Statistical analyses of the precipitation events causing floods

Decade	1971–1980	1981–1990	1991–2000
n	25	50	77
Mean	35.5	31.5	27.3
Variance ($n-1$)	485.2	552.2	490.4
Coefficient of variation	62	74.6	81
Minimum	2.5	1	1
Maximum	80	105	110
Median	34	29	24
Q1	18	15	11
Q3	52	45	40
P (0.5%)	5.5	1.3	2
P (10%)	6.8	2.9	3.2
P (25%)	18	15	11
P (50%)	34	29	24
P (75%)	52	45	40
P (90%)	70	62	57
P (95%)	72	78	74
Percentile 50	34	29	24

Abbreviation: P—Occurrence probability

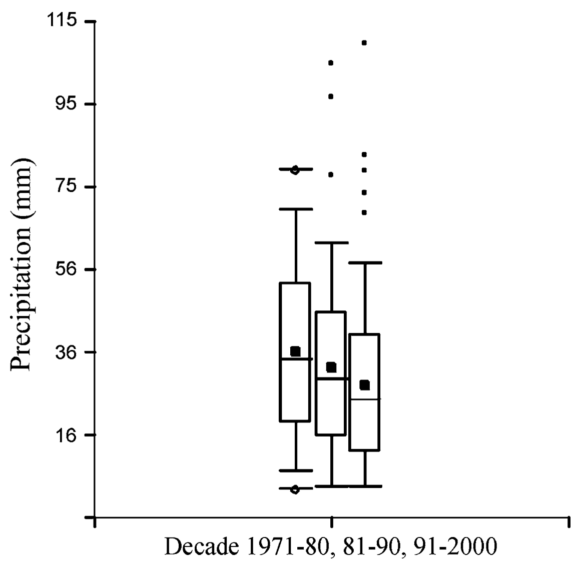

Fig. 4 Statistical analysis of the floods

A map of flood occurrence in the Gran La Plata is presented in Fig. 5 and one specifying the most vulnerable areas in Fig. 6. The areas most affected have been those which have experienced a strong urban growth, like Olmos, Abasto, Melchor Romero, Villa Elvira, Gonnet and City Bell. They have also

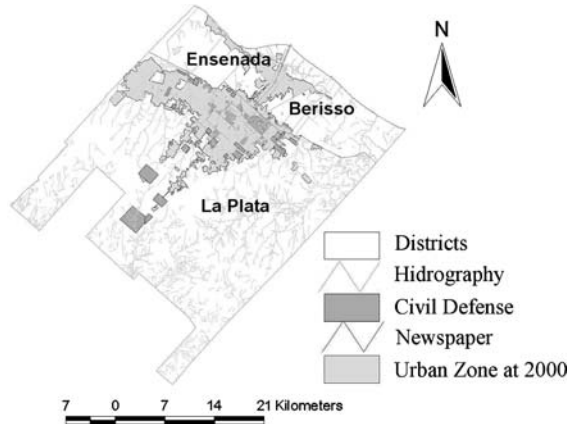

Fig. 5 Flood occurrence in Gran La Plata

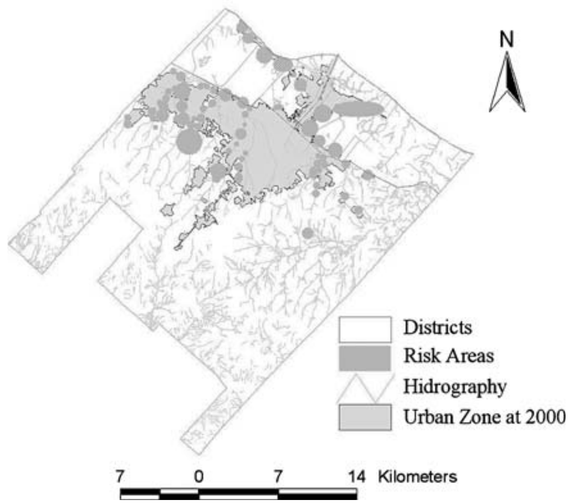

Fig. 6 Vulnerable areas in the Gran La Plata

developed a high percentage of poorly constructed housing and a lack of basic infrastructure, especially during the last decade. The flooded areas of the urban zones do not necessarily coincide with areas of low income population, except in the northwestern zone, which is the sector with the highest level of unsatisfied basic needs.The Indicators of this last property, according the INDEC (National Institute of Census) (1991, 2001), are:

- Occupancy: homes with more than three people per room.
- Living conditions: inadequate housing (rented room, delapidated house).
- Sanitary conditions: homes without bathroom or toilet.

– Non-attending school children: homes where some children of school age do not go to school.
– Subsistence capacity: homes with four or more people for each one who has work, and where the head of the family is poorly educated.

There are areas with flood risk that are associated with or close to small rivers that have been piped underground. There is a large concentration of public buildings (schools, social housing, etc.) in the flood risk areas. The area surrounding the La Plata—Buenos Aires highway is affected because the direction of the highway is perpendicular to the natural direction of drainage for local runoff.

The current planning legislation is inadequate because it does not consider all situations. In particular, there are no restrictions on the location of new human settlements.

Conclusions

Floods in Gran La Plata are caused mainly for climatic and topographic factors. Recent increases in flood frequency seem to be partly the result the rainfall increasing in the pampean flatland during the last two decades. However, analyses of the growth of the urban area and changes in land uses which modify the natural runoff, suggest that flood frequency has also been markedly increased by social activity. Consequently, the aggravating effects of land use change need to be considered in future urban development and the management of extreme hydrological events.

The lack of reliable information about flood risk and the lack of an urban planning procedure that considers the physical characteristics of the environment are additional factors that need urgent consideration.

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